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Survey Paper

The Impact of Game-Based Learning on the Achievement of Learning Goals and Motivation for Learning Mathematics - Literature Review

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Abstract

Information technologies are an integral part of a contemporary society which bases its progress on knowledge being one goal of education. Beside acquiring knowledge, skills and routines, the goal of education is to create a complete individual who can rationally and timely make decisions, purposefully react in new situations and be trained for life-long learning. In order to accomplish all this, it is necessary to make educational process more creative, contemporary and adjusted to new generations of computer literate pupils who demand quicker and more frequent interactions, a lot of information at the same time, generations who quickly acquire rules of computer games. Computer games meeting pedagogical criteria should become an integral part of learning. Teaching with mathematical computer games, which fulfil pedagogical criteria, influences pupils' motivation, learning, retention and forgetting. This paper provides a review of literature in this field and determines whether the use of mathematical computer games contributes to more efficient realisation of educational goals at all level of education. Furthermore, considering prior research we have attempted to establish whether the use of mathematical games for teaching has an impact on the formation of a positive attitude of pupils of different ages toward the subject of mathematics, their motivation and knowledge acquisition when compared to learning without computer games. Finally, we have analysed different research methods concerning this issue and assessed the impact of pedagogically designed mathematical computer games on the realisation of educational goals and quality improvement of teaching and learning.
Keywords: game based learning, math, computer games

1. Introduction

Teaching and learning in contemporary schools has been under a great influence of IT following a trend in contemporary societies which base their progress on the knowledge of information. One of educational goals is to create a competent individual who can, at any time, access source of information, use it and apply it in new situations. The goal of contemporary education is to train pupils for life-long learning and decision making. Learning, as a process of acquiring knowledge, skills and routines, is more effective if new knowledge is gained by multiple perceptive experiences during teaching facilitated by multimedia teaching (Steinkuehler, 2010). He emphasises that, when playing computer games, pupils develop different skills, which otherwise would not be so apparent in traditional teaching. Robertson and Howells (2007) focus their result analysis on the aspects of successful learning indicating that computer games increase pupils' enthusiasm and motivation, transferring this positive attitude on learning. They also observed better knowledge interrelationship and implementation in new situations due to playing computer games. Also, while playing games and having fun, pupils come across new words, which later on they use with ease in everyday situations. Computer games intended for increasing quality

of education should become an integral part of contemporary teaching strategies. We encounter new generations of computer literate pupils who demand quick and more frequent interactions and inductive reasoning, pupils using different information at the same time, generations who quickly acquire the rules of a computer game, solve problems using computers and who reluctantly, either at school or home, spend a lot of time doing exercises in workbooks. Prensky (2001) explains how the socialisation of today's children is different from their parents': "The numbers are stunning: more than 10,000 hours of video game playing, more than 200,000 received and sent e-mails and instant messages on line, more than 10,000 hours of talking on mobile phones, more than 20,000 hours of watching TV (which MTV has greatly contributed to), more than 500,000 seen commercials – and that is before they graduate, and, at best, 5,000 hours of reading books." These "digital natives" are the students of the present. It is essential to cater for pupils' needs and to make educational process more creative and contemporary. Therefore it is important to integrate computer games into learning. Computer games directly support learning by giving pupils an opportunity to develop knowledge and cognitive skills in an emotional way, to make decisions in critical situations by solving problems, to learn by researching and to experience situational learning (Holzinger, Nischelwitzer and Meisenberger, 2005). By playing computer games pupils discover and develop their abilities and skills, gain experience, learn and create. Games develop imagination and creativity. Computer games have their meaningful context (Lee, Hoadley, 2007), learning becomes a situation contributing to the formation of a competent and confident individual. Games are the best motivation for learning and activities. For each subject there are computer games which can be integrated into the teaching process. Pupils traditionally find some subject harder and some easier. We know from experience that they have the weakest results in mathematics. In all evaluated domains in PISA 2009 project (http://www.pisa.hr/knjige/2009-rezultati-4-matematicka-pismenost/Default.html), Croatian pupils had the worst results in mathematical literacy. According to this research, more than 33% of Croatian students did not acquire the starting level of mathematical literacy at which they should begin to show competences needed for productive participation in everyday situation requiring mathematical literacy. The 2006 Curriculum for primary school published on the Ministry of science, education and sport's website states: "Mathematics is one of the core subjects in primary schools because of the knowledge necessary for participation in work, economy, contemporary technologies and society", but it is also emphasised that "mathematics is the most difficult subject for a great number of pupils" (238). This is the reason for researching the role of mathematical computer games in education. Their accessibility on the Internet is great. It is necessary to determine the impact of these games, taking into account learning theories, on different age groups, on the development of their logic skills being expressed by the goals of mathematics and the ability to solve math problems and by the mathematical goals which train pupils for abstract thinking, logical reasoning and precise formulation. At the same time we should establish the impact of math computer games on motivation end assess differences in acquiring knowledge by using computer games in comparison to traditional teaching.

2. Methodology and research issues

2.1. Preliminary review of previous research on computer games

In order to introduce the problems connected to computer games usage in education, in this part we presents a review of relevant previous research in the field of teaching with computer games. Van Eck (2006) mentions that in the last 40 years many studies have discovered that games promote learning and decrease the time of teaching for a large number of subjects and with pupils of different age. He reminds us of the studies which determined positive impacts of digital games on learning, also in different subjects and with different ages. Papastergiou (2009) conducted a research in a secondary school on a sample of 88 pupils, 47 in group A who used computer games in learning, and 41 in control group B without computer games. The research analysis indicated that teaching with computer games was more efficient in

promoting pupils' knowledge, i.e. these pupils were more motivated for work when compared to teaching without computer games. In their study Kebritcki and Hirumi (2010) looked into the effects of computer games on pupils' mathematical achievements and motivation for learning. They also examined the effects of prior math knowledge, computer skills and knowledge of English on achievements and motivation. The results indicated a significant improvement of achievements of pupils who played computer games. The pupils who played games both in ordinary classrooms and computer labs had better motivation when compared to the pupils who played games only in computer labs. Prior knowledge, skills and knowledge of English did not have a significant role in achievements or motivation. During an eight-week research in which 10-year-olds created their own games, Robertson and Howells (2007) emphasised the importance of the teacher's role. A teacher has to be a god organiser and leader, while providing help and support and directing pupils in their active work. Since the process of game design also involved game playing (because of testing), pupils developed better meta-cognitive skills and decision-making skills which is a result identical to results of researches dealing with positive impacts of games on learning. A similar research (Vos, Van der Meijden, and Denessen, 2010) was conducted in a primary school on a sample of 235 pupils, 128 of which designed their own game (a version of Memory), and a control group of 107 pupils played the existing version of Memory game. The research showed that designing a game is a better way to improve motivation and to learn easier than a simple playing of the game. The results analysis of a geography lesson in which computer games were used (Tüzün, Yılmaz-Soylu, Yavuz, and Kızılkaya, 2009) indicated a significant difference in easier learning and increased motivation as well as greater independence of pupils who played computer games during learning. In his research Burguillo (2010) observed that a combination of game playing and friendly competition resulted in pupils' strong motivation and helped increase learning effectiveness. Furthermore, the research by Yang and Chen (2010) determined that spatial skills were significantly improved after playing a digital mathematical computer game (pentomino). The results also indicated that playing digital games reduced the difference in spatial skills between boys and girls. Bokyeong, Hyungsung and Youngkyun (2009) suggested that using meta-cognitive strategy in learning based on computer games had a great influence on better achievements in games, learning and improving skills for social problems solving and new situations. Research analysis (Kebritchi, Hirumi, 2008) of pedagogical foundations of the existing computer games came up with a few patterns which can be used for future research of educational games. According to this research, 40% of computer games are based on theories of learning or teaching strategies, and the others do not have any educational foundations. Contemporary computer games do not have any hardware or software restrictions. A good computer game must meet pedagogical criteria, be educational and interesting in order to have a positive impact on pupils. Roach (2003) claims that the main pedagogical criterion qualifying a computer game should be content understood by a child. Furthermore, a game has to have a social, cultural and educational potential in accordance with the existing educational frames within the society directed at technology.

With time the role of technology in education has changed following the development of educational packages (educational programmes and games). Evaluating computer games in this context, especially mathematical games, without considering development of the Internet and accessibility to computers in education, would be one-sided. Since the 1990s accessibility to computers has been much better. Due to this fact, we have decided to review the last 15 years of research on the role of mathematical computer games.

2.2. Research methodology

The aim of the review is to find the papers addressing the key questions of our research. It was carried out December 2010 in Web of Science and ScienceDirect databases. The study followed these key concepts: (mathematical computer games, mathematics, education, multimedia, web-based instruction, the Interned, blended learning) AND (achievements, motivation, satisfaction, perception). These concepts were connected with logical

conjunctions AND and OR in pairs. Due to a rapid development of computer games technology in the last 15 years, papers published from 1995 – 2010 were taken into consideration.

Researching Web of Science and ScienceDirect we identified 32 papers classified in *Table 1*.

The aim of this paper is to synthesise all available research which can answer the following questions:

Q1: What is the impact of mathematical computer games on realising educational goals at all levels of education in learning mathematics?

Q2: How does the usage of mathematical computer games influence pupils' motivation and attitude to mathematics as the most difficult subject?

Q3: How does an educational mathematical computer game (in comparison to the one not based on pedagogical standards) influence the realisation of educational goals?

Table 1 presents a review of all analysed empirical research with the key data about the papers. The table shows examinees' age, their number, and the country where the research was conducted. Following are the data about the key research questions and the answers to them (positive, negative, the impact cannot be determined). It is also indicated if one of the questions was not considered in the paper.

No	Paper	Age	number (N) of examinees	Country where the research was conducted	Q1	Q2	Q3
1	Bokyeong, K., Hyungsung P., Youngkyun, B., Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learning, Computers & Education, Volume 52, Issue 4, May 2009, Pages 800-810	Grade 9	N= 123	Korea	positive (+)	positive (+)	Not considered
2	Burguillo, C., J., Using game theory and Competition-based Learning to stimulate student motivation and performance, Computers & Education, Volume 55, Issue 2, September 2010, Pages 566-575	Primary school	N= 246	Spain	positive (+)	positive (+)	Not considered
3	Cameron, B., Dwyer, F., The effects of online gaming, cognition and feedback type in facilitating delayed achievement of different learning objectives. Journal of Interactive Learning Research, 16(3), (2005) 243-258.	Grades 7 and 8, primary school	N= 422	USA	positive (+)	Not considered	Not considered
4	Çankaya S., Karamete A., The effects of educational computer games on students' attitudes towards mathematics course and educational computer games, Procedia Social and Behavioral Sciences 1 (2009) 145–149	Grades 7 and 8, primary school	N= 176	Turkey	No impact	No impact	Not considered
5	Chun-Yi, L., Ming-Puu, C., A computer game as a context for non-routine mathematical problem solving: The effects of type of question prompt and level of prior knowledge, Computers & Education 52 (2009) 530–542	Grade 9	N= 78	Taiwan	Positive (+)	Not considered	Not considered
6	Costu S., Aydınb S., Filiza M., Students' conceptions about browser-game-based learning in mathematics education: TTNetvitamin case, Procedia Social and Behavioral Sciences 1 (2009) 1848–1852	Grades 6 – 8, primary school	N= 16	Turkey	positive (+)	Not considered	Not considered

7	Din, F. S., Calao, J., Playing computer games versus better learning. Paper presented at the Eastern Educational Research Association. Clearwater, Florida. (2000)	Pre-school age	N= 47	USA	No impact	Not considered	positive (+)
8	Harter C. A., Heng-Yu, K., The effects of spatial contiguity within computer-based instruction of group personalized two-step mathematics word problems, Computers in Human Behavior 24 (2008) 1668–1685	Grade 6, primary school	N= 98	USA	positive (+)	positive (+)	Not considered
9	Huang Wen-Hao, Huang Wen-Yeh, Tschopp J., Sustaining iterative game playing processes in DGBL: The relationship between motivational processing and outcome processing, Computers & Education 55 (2010) 789-797	Students	N= 264	USA, Taiwan	Not considered	positive (+)	Not considered
10	Karakus T., Inal Y., Cagiltay K., A descriptive study of Turkish high school students' game-playing characteristics and their considerations concerning the effects of games, Computers in Human Behavior 24 (2008) 2520–2529	Secondary school	N= 1223	Turkey	No impact	No impact	Not considered
11	Ke, F., Grabowski, B., Game playing for mathematics learning: cooperative or not? British Journal of Educational Technology, 38(2), (2007) 249-259.	Grade 5, primary school	N= 125	USA	positive (+)	Not considered	Not considered
12	Kebritchi M., Hirumi A., Bai H., The effects of modern mathematics computer games on mathematics achievement and class motivation, Computers & Education 55 (2010) 427-443	Secondary school	N= 293	USA	positive (+)	positive (+)	positive (+)
13	Kebritchi M., Hirumi A., Examining the pedagogical foundations of modern educational computer games, Computers & Education 51 (2008) 1729–1743		theoretically	USA	Not considered	Not considered	positive (+)
14	Klawe, M. M., When does the use of computer games and other interactive multimedia software help students learn Mathematics?. Unpublished manuscript. Retrieved 11.12.10 from. http://www.cs.ubc.ca/nest/egems/reports/NCTM.doc. (1998)	Grades 4 – 8, primary school	N= 64	Canada	positive (+)	positive (+)	positive (+)
15	Laffey, J. M., Espinosa, L., Moore, J., Lodree, A., Supporting learning and behavior of at-risk young children: computers in urban education. Journal of Research on Technology in Education, 35(4), (2003) 423-440.	Pre-school and grade 1	N= 187	USA	No impact	Not considered	Not considered
16	Lim, C. P., Nonis, D., Hedberg, J., Gaming in a 3-D multiuser virtual environment: engaging students in science lessons. British Journal of Educational Technology, 37(2), (2006) 211-231.	Grades 1 – 6, primary school	N= 1200	Australia	No impact	Not considered	Not considered
17	Lopez-Morteo G., Lopez G., Computer support for learning mathematics: A learning environment based on recreational learning objects, Computers & Education 48 (2007) 618–641	Secondary school	N= 47	Mexico	Not considered	positive (+)	Not considered

18	Moreno, R., Who learns best with multiple representations? Cognitive theory implications for individual differences in multimedia learning. Paper presented at World Conference on Educational Multimedia, Hypermedia, Telecommunications. Denver, CO. (2002)	Grades 5 and 6, primary school	N= 61	USA	positive (+)	Not considered	Not considered
19	Papastergiou M., Digital Game-Based Learning in high school Computer Science education: Impact on educational effectiveness and student motivation, Computers & Education 52 (2009) 1–12	Students	N= 88	Greece	positive (+)	positive (+)	Not considered
20	Ping Lim C., Global citizenship education, school curriculum and games: Learning Mathematics, English and Science as a global citizen, Computers & Education 51 (2008) 1073–1093	Primary school	N= 80	Australia	positive (+)	positive (+)	Not considered
21	Roach, R., Research schools work to improve classroom use of computer games, Black Issues in Higher Education, Issue 21., vol.20, p.42., 2003.		theoretically	USA	Not considered	Not considered	positive (+)
22	Robertson, J., Howells, C., Computer game design: Opportunities for successful learning, Computers & Education, Volume 50, Issue 2, February 2008, Pages 559-578	Grade 3, primary school	N= 30	USA	positive (+)	Not considered	positive (+)
23	Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., Beyond nintendo: design and assessment of educational video games for first and second grade students. Computers & Education, 40(1), (2003) 71-94.	Grades 1 and 2, primary school	N= 1274	Chile	positive (+)	positive (+)	positive (+)
24	Sedig K., Toward operationalization of ‘flow’ in mathematics learnware, Computers in Human Behavior 23 (2007) 2064–2092	Grade 7, primary school	N= 40	Canada	positive (+)	Not considered	Not considered
25	Sedighian, K., Sedighian, A. S., Can Educational computer games help educators learn about the psychology of learning mathematics in children? Paper presented at 18th Annual Meeting of the International Group for the Psychology of Mathematics Education, the North American Chapter, Florida, USA, (1996)	Grades 6 and 7, primary school	N= 1250	Canada	Not considered	positive (+)	Not considered
26	Shaffer D. W., Epistemic frames for epistemic games, Computers & Education 46 (2006) 223–234	Grades 3 and 4 secondary school	N= 14	USA	positive (+)	positive(+)	Not considered
27	Tüzün, H., Yılmaz-Soylu, M., Yavuz, I., Kızılkaya, G, ., The effects of computer games on primary school students’ achievement and motivation in geography learning, Computers & Education, Volume 52, Issue 1, January 2009, Pages 68-77	Grades 5 and 6, primary school	N= 128	Turkey	positive (+)	positive (+)	Not considered
28	Van Eck, R., Digital Game-Based Learning: It's Not Just the Digital Natives Who Are Restless, EDUCAUSE Review, vol. 41, no. 2 (March/April 2006): Pages 16–30		theoretically	USA	positive (+)	positive (+)	positive (+)

29	Vos N., Van der Meijden H., Denessen E., Effects of constructing versus playing an educational game on student motivation and deep learning strategy use, Computers & Education 56 (2011) 127–137	Primary school	N= 235	Netherlands	No impact	No impact	Not considered
30	Yang J. C., Chen S. Y., Effects of gender differences and spatial abilities within a digital pentominoes game, Computers & Education 55 (2010) 1220–1233	Grade 5, primary school	N= 34	Taiwan	positive (+)	Not considered	Not considered
31	Yip, F. W. M., Kwan, A. C. M., Online vocabulary games as a tool for teaching and learning English vocabulary. Educational Media International, 43(3), (2006) 233-249	Secondary school	N= 100	Taiwan	positive (+)	Not considered	Not considered
32	Young-Loveridge J. M., Effects on early numeracy of a program using number books and games, Early Childhood Research Quarterly 19 (2004) 82–98	5-year olds	N= 106	New Zealand	positive (+)	Not considered	Not considered

Table 1. Review of analysed research and their characteristics

3. Review of research on mathematical computer games – analysis of results

Do mathematical computer games contribute to more efficient and quicker realisation of educational goals at all levels of education, do they boost motivation, do they influence quicker and better knowledge acquisition, do they create pupils' positive attitude toward learning mathematic and toward mathematic as the most difficult subject – these are the question that attract attention even today. We can look for the answers in previous research in this field.

Cameron and Dwyer (2005) considered the relationship between playing computer games and realising educational goals. Trying to determine how computer games influence the realisation of educational goals, they carried out a research on a sample of 422 pupils and proved that playing computer games is an important learning strategy in realising educational aims at all levels and with children of different ages (from pre-schoolers to students). Young and Loverdige (2004) looked into learning mathematical concepts in early childhood. Their task was to establish how computer games affect basic mathematical skills of five-year-olds. 106 children participated in the research. The obtained results showed that mathematical knowledge of children who played computer games was a lot better when compared to the knowledge of children who did not play computer games. Even after a year the knowledge of this group was still statistically better. As a matter of fact, five-year-olds learned mathematics easier and quicker by playing computer games. For them the first encounter with mathematical concepts was a game, a fun activity, so it can be assumed that dealing with mathematical concepts from that time on evoked positive feelings increasing their motivation for learning mathematics. In fact, if children have a positive attitude toward mathematics from an early age, which computer games also greatly contribute to, acquiring mathematical concepts in primary school will not be a problem and in that way mathematics will not be one of the most difficult subjects. However, even from a child's early age a computer game has to fulfil pedagogical criteria. This idea is supported by the research conducted by Din and Calao (2000) on a sample of 47 pre-school children divided into two groups. Every day the experimental group played mathematical computer games on Sony Play Station for 40 minutes during 11 days. The control group did not play any computer games, but learned mathematics in a traditional way. The research results indicated that regarding the knowledge of mathematics there was no statistically significant differences between the groups. This is one of the rare studies where a positive impact was not detected. This can possibly be explained by Sony Play Station games not having an educational dimension. The second reason can be that children played games daily, always at the same time and in the same form, which can become discouraging, tiring and boring for pre-school children. At this age

children want new and varied activities, new enticements, i.e. a combination of educational computer games with other methods of teaching and learning. The research by Kebritchi and Hirumi (2008) supports this idea. Together with the game authors they investigated pedagogical foundations of contemporary educational computer games by studying 55 computer games created between 2000 and 2007. Only 22 games fulfilled pedagogical criteria, i.e. were based on established learning theories and instructional strategies. In 1998 Klawe conducted a research which attempted to determine the influence of different factors on educational computer game efficiency in improving learning mathematics in primary school. The considered factors were: software and hardware design, different methods of teaching with games, gender differences. He determined that computer games can be extremely efficient (better motivation, better knowledge, satisfaction with mathematics as a subject). However, he also proved that different factors such as pupils' and teacher's expectations, the level of integration with other educational activities and game design influence the final result, so one should pay attention to these factors when using computer games in teaching. If computer games are intended for increasing motivation and making learning mathematics easier, he concluded that mathematical computer games should contain:

- Subject matter that pupils are supposed to learn
- Activities for learning
- A basic learning model (or models)
- The way and concept of presenting the content
- Interface for manipulating with words and objects
- Navigation structure and order of activities
- Feedback information and reward systems
- Fun elements (graphics, sound, story, characters, humour).

Another research (Rosas, Nussbaum, Cumsille, Marianov, Correa, and Flores, 2003) established that a well-designed computer game is an important motivational factor for learning mathematics. Their aim was to evaluate the effects of introducing educational computer games into teaching as well as their influence on motivation and learning. The games were specifically designed to facilitate the realisation of mathematical educational goals in grade 1 and 2 of primary school, with the emphasis on learning the basics of mathematics. The research was conducted in Chile on a sample of 1274 pupils divided into three groups: experimental, control and external control. The experimental group played computer games for 30 hours during three months. Their mathematical skills and motivation were evaluated as well as teacher's expectations. The evaluation of the results was carried out by ad hoc testing and by talking to teachers about their observation of pupils' work. The results indicated significant differences between experimental, control and external control group in favour of the experimental group. Teachers' reports confirmed experimental group's increased motivation for learning mathematics overlapping with the research results. This research also proved that mathematical computer games were a useful aid in motivating and promoting learning mathematics. A number of studies carried out in upper primary grades confirmed that computer games are not good motivation only in pre-school and younger school age. In fact, computer games help realise educational goals, but they also improve motivation and make learning easier. This was proved by the research (Ke and Grabowski, 2007) which confirmed that playing computer games influenced motivation, attitudes and learning mathematics in grade 5 of primary school. It was carried out on a sample of 125 pupils divided into cooperative groups who were competing. The pupils took a mathematical test before and after the experiment. The research results indicated that playing computer games was more efficient than doing traditional mathematical tasks. Games improved pupils' test results, motivated them and created a positive attitude toward mathematics regardless of their individual differences. Çankaya and Karamete (2009) examined attitudes of 176 pupils (grades 7 and 8) who played educational computer games *Proportional Tetris and Proportional Clown.* They determined a significant, proportional connection between

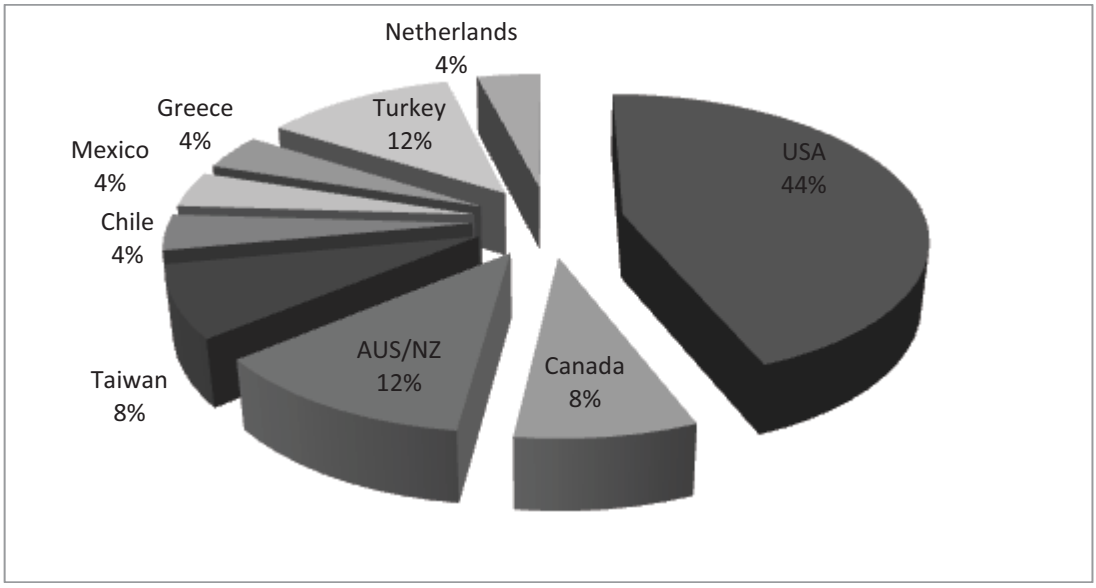
attitudes toward mathematics and attitudes toward educational computer game. The game had a positive impact on pupils developing their positive attitude toward learning mathematics. The research results emphasised that educational computer games can be used as a support for other teaching methods directed at improvement of teaching and goals realisation. In the research conducted in grade 7 Sedig (2007) showed that playing *Super Tangrams* pupils understood geometry better and at the same time had fun learning it. The study showed that this learning model was good and very efficient. Moreover, the research indicated that, especially when teaching geometry, there are great possibilities for using mathematical computer games for increasing motivation and pupils' educational achievements. The pupils' progress observed in post-testing in comparison to pre-testing and regarding control groups was significant and it justifies the use of this learning model. Yang and Chen (2010) suggest that playing computer games can help develop spatial orientation and spatial abilities, which might represent a problem to pupils in geometry in grade 5. Additionally, they determined that there was a big difference in spatial orientation between boys and girls in favour of boys. For the purpose of the research a computer game aimed at development of spatial abilities was designed. The results indicated that pupils' spatial abilities were considerably improved after playing the computer game, and the difference between boys and girls' skills was reduced. By observing, interviewing and testing pupils in a case study, Ping Lim (2009) established that using computer games for teaching increased pupils' active participation and motivation as well as their socialisation. The primary school pupils taking part in the research played a game in which they assumed a role of global citizens and in that way they learned not only mathematics, but science and English as well. Costu, Aydınb and Filiza (2009) examined how playing browser-based educational games (short games which can easily be downloaded from the Internet) during lessons influenced motivation and learning of primary school children. The sample of 16 children (grades 6 to 8) played the game during one lesson. After that the pupils' attitudes and opinions were examined by using a 5-question interview. Most pupils' attitude was that the computer game had a positive impact on their learning motivation and it made learning easier and more interesting. The research by Harter and Heng-Yu (2008) was carried out on a sample of 98 pupils in grade 6 divided into two groups. One group had traditional lessons and the other had computer games integrated into teaching. Their knowledge of mathematics was evaluated by pre-tests. The research indicated that the pupils who played computer games had better results in post-test than the other group. The pupils were also given a questionnaire which determined that pupils who played computer games were more satisfied with their learning. If the satisfaction is greater, the subject itself becomes more interesting resulting in higher achievements. Sedighian, K. and Sedighian, A. S. (1996) point out that children usually do not like mathematic and find it boring. In their paper they presented issues connected to child's psychology of learning mathematics in the context of mathematical computer games emphasising some elements of computer games which satisfy children's need for learning and motivate them for learning mathematics. The research was conducted during a two-year period in 50 groups of 7 and 8 grades. At the beginning of the research the pupils played commercial educational games, and the authors visited each group at last once a week (one – two hours) and observed the pupils playing games for more than a year. They also observed their discussions. After designing *Super Tangrams* game, whose goal was to facilitate learning two-dimensional transformational geometry, the pupils were playing it and the authors again visited and observed each group at least once a week. The game consisted of a number of riddles which were gradually becoming more difficult. At the end all pupils were given an unannounced test. The research results are the following: computer games are an integral part of children's lives and learning mathematics in computer games surroundings becomes important and motivating. Moreover, they determined that learning with computer games (game-based learning) makes mathematics more meaningful and useful for pupils who are then more motivated. Additionally, this research addressed another important question – is playing an existing game more efficient than pupils creating their own game? Vos, Van der Meijden and Denessen (2011) examined this issue in the research which involved 235 primary school pupils. One group was asked to create their own *Memory* game using 'drag and drop' principle while the

other group played the existing game of this type. The research results suggested that designing a game can be a better way to improve motivation and have higher achievements. Yet, the research had some drawbacks – the low level of game complexity which reduced the credibility of the results. There is no doubt that computer games have an impact on a positive attitude toward mathematics and their motivation, but the problem is how to make mathematics more interesting to pupils with lower abilities, lacking prior knowledge of mathematics and with insufficient experience in IT, i.e. those who require individual approach? Moreno (2002) presented cognitive learning theories using multimedia and the impact of individual differences on such learning. Pupils in grades 5 and 6 were taught to add and subtract by using a multimedia interactive game which visually and symbolically presented arithmetic procedures. The results indicated that the computer game helped to reduce cognitive load, especially for pupils with insufficient prior knowledge and limited experience in using computer technologies. In their study on the impact of mathematical computer games on secondary school pupils' motivation and achievements Kebritchi, Hirumi and Bai (2010) included a variable of prior mathematical knowledge. The research involved 193 pupils and 10 teachers. The results indicated considerably higher achievements of the group who played computer games. Considering motivation there were no significant differences. Prior mathematical knowledge did not have any relevant impact on achievements and motivation. Chun-Yi and Ming-Puu (2009) examined how the level of pupils' prior knowledge affected mathematical problems solving. They designed a computer game consisting of comprehension tasks and the research involved 78 pupils in grade 9 in two public schools. It lasted for six weeks, and the results indicated that regardless of their prior knowledge, specific and more precise instructions and questions were more useful for pupils than general questions and instructions. This means that specific instructions including tables, graphs and symbols have a better impact on reasoning. The pupils who were given more specific questions were able to concentrate better on the efficiency and the correct task solving than those who were given generalised questions. Laffey, Espinosa, Moore and Lodree (2003) studied how playing computer games affects at-risk pre-school children and first graders and their mathematical achievements. They observed a significant improvement of children's achievements as well as greater attention when playing computer games, which was the same for the pupils who did not have behavioural problems. Therefore, using computer games for learning has numerous effects both on pupils and teachers as suggested by Lim, Nonis and Hedberg (2006), they observed primary school pupils (grades 1 to 6) and their teachers during lessons with computer games and interviewed them after lessons. They established that participation in the lesson, both by pupils and teachers, was greater when computer games were used. The importance of using computer technologies, i.e. computer games in teaching at all levels of education can be confirmed by the research conducted in secondary schools and at universities. Karakus, Inal and Cagiltay (2008) attempted to find out what secondary school pupils thought of playing computer games in mathematics lessons and their expectations from these games. 1223 pupils from eight different vocational schools in eight cities participated in the research. The pupils stated that computer games could be used for teaching mathematics primarily for improving their mental abilities. However, girls had different expectations from games than boys. Girls expected computer games to be educational, whereas boys expected fun and competition. Different answers were given to the question where it was best to play computer games – girls emphasised the advantages of playing games at home or school, while boys preferred other places like internet cafés. Lopez-Marteo and Lopez (2007) directed their research at the impact of electronic cooperative surroundings on learning mathematics in secondary school. They created educational software, specialised for mathematics, adjusted to secondary pupils' needs. The results indicated that using electronic cooperative surroundings had an impact on developing positive attitudes toward mathematics which strengthened their motivation for learning it. The goal of Papastergiou's (2009) research was to assess students' motivation and knowledge after playing a computer game designed in accordance with Greek higher education curriculum. The sample consisted of 88 students divided into two groups – one played a computer game and the other did not. Computer pre-test and post-test were given to students to assess their

knowledge and questionnaires to estimate their motivation. The results suggested that learning with computer games resulted in better motivation and knowledge. The results, in spite of male students initially having more extensive computer knowledge and bigger interest for playing games, did not express any differences between genders, and the motivation was better for both genders. So, the results indicated that computer games can be used as an effective tool for promoting knowledge and motivation regardless of students' gender. Huang Wen-Hao, Huang Wen-Yeh and Tschopp (2010) emphasise the significance of digital, game-based learning in the last few years, above all concerning students' knowledge and motivation as well as development of some personality traits like curiosity, determination and obeying the rules. Shaffer (2006) proved that pupils, beside learning mathematics, can use their experience gained by playing computer games in everyday situations, i.e. they are better at solving everyday problems. All of the above mentioned studies established that mathematical computer games meeting pedagogical criteria, at all levels of education facilitate more efficient and quicker realisation of educational goals. Computer games boost motivation, develop mathematical skills and knowledge and participate in the formation of independent individuals who can deal with various situations in everyday life and train them for life-long learning, which is one of education's key goals.

4. Synthesis of results

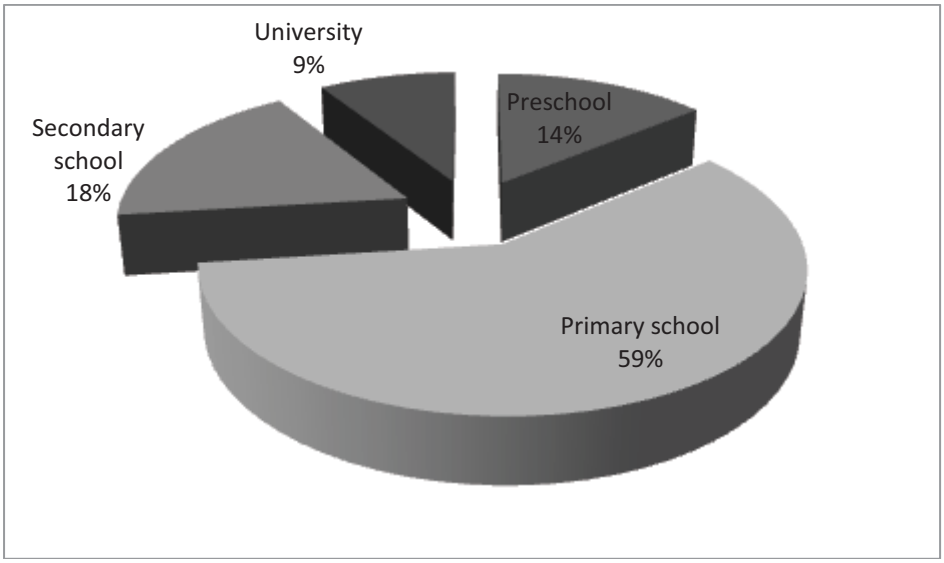
This part presents the synthesis of results. The total number of the reviewed research is 26 *(see Graph 1)*, 11 of which were conducted in the USA, 2 in Canada, 3 in Australia and New Zealand and 2 in Taiwan. These five countries represent 72% of studies covered in this review (44% was carried out in the USA). These numbers possibly indicate which countries have the biggest interest for using computer technologies for teaching and for research in this field. Besides, these countries are the ones with the highest usage of computer technologies for teaching. The other countries where research was conducted are Chile and Mexico, representing South America with 8% in this review. As for Europe, there are five papers (Greece and Netherlands with one and Turkey with 3) which comes to 20 %. It is interesting to see that of all European countries in this review, Turkey is represented by the largest number of papers. Those who are well-informed about Turkey know that Turkey invests a lot in education, especially in computer technologies for teaching.



Graph 1. Representation of the countries in the review

The reviewed studies involved examinees of different ages (from early childhood to youth, see *Graph 2*). The majority of researches, 59 %, were conducted in primary school (grades 1

to 8). Secondary school pupils were a sample in 18 % of studies, students in 9 %, and the youngest group – pre-school children in 14 %.



Graph 2. Examinees' age in the research

Considering research methods, the subject of research and the impacts, the results are the following: the total of researches is 26, one of which being theoretical. In the 25 researches, 15 used a quantitative method, 8 a qualitative method and two used a combined method. This means that 57 % of papers used a quantitative method, 31 % qualitative and 12% combined. *Table 2* presents the ratio of methods in relation to impacts (achievements and motivation).

	Qualitative method	Quantitative method	Combined method	Qualitative method	Quantitative method	Combined method
Achievement	3 positive impact	9 positive impact	1 positive impact	1 no impact	4 no impact	1 no impact
Motivation	5 positive impact	3 positive impact	1 positive impact	-	2 no impact	-

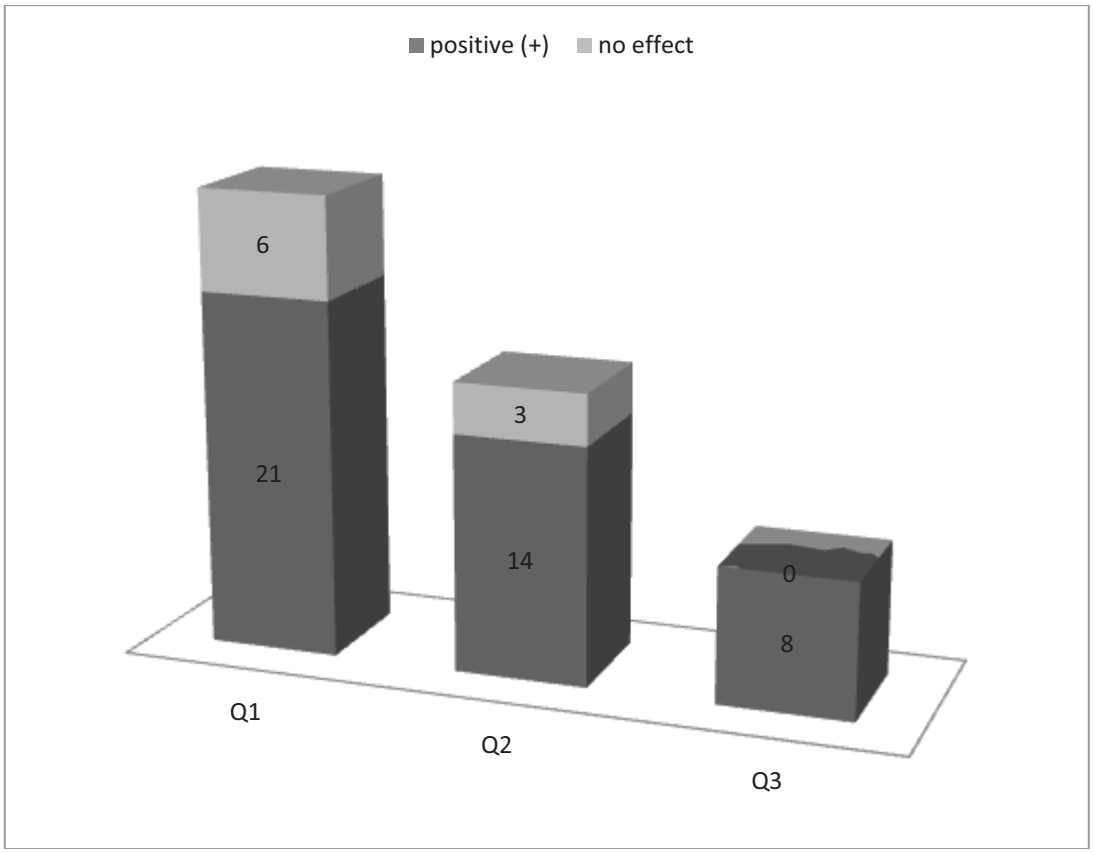
Table 2. Ratio of methods in relation to impacts (achievements and motivation)

One out of eight researches using a qualitative method established that using mathematical computer games had no influence on pupils' achievements. This research did not look into motivation. Three other papers dealt with achievements and all three confirmed positive achievements after playing computer games. Regarding motivation, all five papers using a qualitative method determined increased motivation for learning mathematics after playing computer games. As for a quantitative method, there are two papers examining only achievements and two examining achievements and motivation and they all established that there were no significant differences in learning and motivation after playing computer games. Four papers suggested that regarding achievements there were no considerable differences (31 %), and two papers that playing computer games had no impact on motivation (40 %). A positive impact on motivation was observed in 3 papers (60 %) and on achievements in 9 papers (69 %). Two papers used a combined method, one paper examining achievements did not discover a significant impact of game playing and the other examining

motivation and achievements established a significant impact of games on achievements and motivation.

Taking into account question Q1 dealing with the impact of computer games on the realisation on educational goals, there are 27 researches which looked into this issue on all levels of education on a sample of examinees of different ages, 21 researches determined a positive effect of using mathematical computer games. In six studies the effect was not observed and it was mostly in those carried out on younger children (pre-school and primary school). It is important to emphasise that a negative impact of mathematical games on educational goals was not observed in any of the reviewed papers.

Furthermore, based on the analysis of the papers it has been confirmed that using mathematical computer games for teaching influences formation of a positive attitude toward mathematics since 14 studies, out of 17 dealing with this issue, confirmed a positive impact.
It is especially important to determine which mathematical game is "a good game", i.e. establish pedagogical criteria which have to be fulfilled by games in order to have better results in educational process regarding educational goals and pupils' motivation. It is evident form *Table 1* that previous studies and papers did not pay enough attention to this issue. However, it is clear that as long as a computer game is pedagogically designed, the results are always positive since out of eight studied cases, all eight indicated a positive impact (see *Graph 3*).



Graph 3. Research questions and effects (positive or no effect)

5. Conclusion

Taking into account the existing studies, it is evident that using mathematical computer games for teaching contributes to more efficient and quicker realisation of educational goals at all levels of education (27 researches looked into this issue on a sample of examinees of different ages at all levels of education, 21 of which determined a positive impact of using mathematical computer games).

In addition, it was established that using mathematical computer games for teaching influences formation of a positive attitude of pupils of different ages toward mathematics as the most difficult subject and contributes to boosting their motivation, quicker acquisition and long-term knowledge when compared to teaching without mathematical computer games (17 researches looked into this issues, 14 of which confirmed a positive effect).
The existing researches have pointed out the fact that mathematical computer games have to be pedagogically designed in order to have a positive impact on the realisation of educational goals (eight researches directed at this issue were reviewed and all eight confirmed a positive effect).

The importance of incorporating mathematical computer games into education at all levels is emphasised in all the answers to questions addressed in the studies. Using computer games for teaching creates pupils' positive attitude toward mathematics, their active participation is greater and acquisition of mathematical knowledge, skills and routines is more efficient resulting in a better quality of the teaching process. Therefore mathematical computer games should become an integral part of contemporary teaching strategies and their usage one of the goals of contemporary education.

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