Epistemological Approaches to Digital Learning in Educational Contexts

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Digital educational games in primary education

Revisiting the results of the research projects of the ETiE initiative

Emmanuel Fokides

Introduction

The research initiative Emerging Technologies in Education (ETiE) was launched in 2015. Although not a formal project, a substantial number of studies were conducted under its umbrella. ETiE's main objective is to examine the results of the educational uses of emerging technologies in primary and high school settings. In an educational context, emerging are technologies that recently found their way to classrooms and their instructional value is yet to be unveiled. For example, ETiE examined the educational uses of drones, virtual reality, 3D multi-user virtual environments, and augmented reality. Also, a portion of the research effort focused on digital games, because it was considered that their use in education presents interesting and still unexplored aspects.

Young people spend a substantial part of their leisure time by playing digital games, which are the predominant entertainment medium even of very young children (OfCom, 2013). At the same time, it is generally accepted that digital games can play a notable role in education. Indeed, digital game-based learning (Prensky, 2001) can be applied in all levels of education and in almost all courses (Nie et al., 2014). The relevant literature reports learning gains and improved conceptual understanding, increased motivation for learning (Ke, 2008), development of a number of skills, and an impact on creativity (Hsiao et al., 2014).

Given the above, it was considered interesting to examine under which conditions the strong relationship between children and digital games can be exploited to promote the learning objectives related to the teaching of various subjects in primary school. As a result, a series of research projects were designed and implemented over the past couple of years, involving the use of digital games to examine whether their use in teaching results in better learning outcomes compared to other teaching tools. Having accumulated a number of such projects, 11 in total, this chapter revisits their results and critically re-evaluates them.

Digital games in education

Students are increasingly dependent on technology for information retrieval/exchange and for communicating (Spires, 2008). Reasonably enough, appealing digital environments, such as digital educational games (DEGs), are compatible with their skills and interests. A multitude of definitions has been given for DEGs, having in common the idea that they are games that offer entertainment but, at the same time, have an instructional value (Susi et al., 2007).

There is a consensus in the literature that digital games can become vital teaching/learning tools (Guillén-Nieto & Aleson-Carbonell, 2012). Indeed, Prensky (2001) supported the view that there is actually no distinction between games and education. Their use in education is embraced by almost all learning theories (Braghirolli et al., 2016). On one hand, many games seek to train students in concepts or skills using repetitive practices, thus, realizing behavioural principles. In this case, repetition reinforces responses and increases the likelihood of another occurrence of the desired behaviour when the stimulus is present again. On the other hand, DEGs based on constructivist perceptions, seek the active participation of the player/student in the learning process, so that the new knowledge is constructed through the game (Shute et al., 2011). In this case, the purpose of using DEGs is to achieve a student-centred interactive experience that changes the relationship between the student, the media, and the teacher. Finally, Game-Based Learning seeks to balance the learning subject, the game, and the players' ability to maintain and apply what they have learned. This concept transcends the development of games just for students to play, as it is about designing learning activities that gradually introduce concepts and guide users towards a final goal (Pho & Dinscore, 2015).

There are many examples about the pedagogical utilization of digital games and the results they yielded, covering a wide range of learning subjects such as sciences, mathematics, and language (e.g., Bakker et al., 2014; Hummel et al., 2010). Most of them converge on the fact that digital games have a lot to offer if they are systematically exploited and when the objectives of the game are directly related to the learning goals (Sung & Hwang, 2013). In addition to the satisfactory results in knowledge acquisition, the following have also been reported: An increased effort to achieve the learning goals, active participation, enjoyment, reinforcement of motivation for learning, and improvement of students' attitudes to either specific subjects or to education as a whole (e.g., Ke, 2008; Robertson, & Miller, 2009; Tüzün et al., 2009). The development of collaborative capacities, the reinforcement of problem-solving skills, as well as the development of specialized knowledge and skills (Connolly et al., 2012) have also been mentioned.

Instead of using ready-made digital games, a body of research examined how game authoring enabled students to understand programming concepts and practices. Game authoring has been mainly studied in tertiary and secondary education (e.g., Kazimoglu et al., 2012), but the literature is not extended. Studies in which the target group was primary school students are scarce (e.g., Baytak & Land, 2010) and the same applies to studies that examined the effects of computer game development as a pedagogical activity (Owston et al., 2009).

There are a number of explanations for the effectiveness of DEGs. For example, it has been observed that when students play educational games, they tend to spend more time in trying to learn, and, in turn, this affects learning outcomes (Tobias et al., 2011). Also, students pay more attention to a learning activity when it is presented through a game (Garris et al., 2002). Another element is the direct feedback they offer; students can immediately see the results of their actions (e.g., if they answered a question correctly). Thus, students are encouraged to explore, experiment, and discover new concepts and strategies (Kirriemuir, 2002).

However, the introduction of DEGs in education is not free of problems. While in many studies improved learning outcomes were reported, there are studies in which the outcomes were neutral or even negative (e.g., Perrotta et al., 2013). Also, researchers pointed out that the pedagogy of DEGs is not well-developed (Ulicsak & Williamson, 2011) and that learning with games has to be supported by effective instructional measures (Egenfeldt-Nielsen, 2006). Finally, perhaps the most important problem is the effort, time, and cost required for developing DEGs (Westera et al., 2008).

A brief presentation of the projects and of their results

As already mentioned, from 2015 to 2018, as part of the ETiE initiative, 11 research projects related to the use of DEGs were carried out, having as a target group primary school students. Their main objective was to examine whether the use of DEGs enables students to achieve better learning outcomes compared to other teaching tools, as suggested by the literature. In five projects, programming concepts were taught to students aged 7–9 (135 individuals), 8–9 (75 individuals), 10–11 (138 individuals), and 11–12 (130 individuals). In four projects maths was the subject and the target groups were students aged 6–7 (129 individuals), 9–10 (189 individuals), and 11–12 (66 individuals). One project had as a theme the teaching of English as a foreign language (60 students, 10–11 years old) and, in another, modules from the study of an environment course were taught (54 students, 8–9 years old).

A quasi-experimental design was applied to all projects since data from whole classes were collected. Also, in all cases, the participating students were split into three groups (one control and two experimental). In all but five projects (in which programming was taught), the teaching in the control groups was conventional, using a teacher-centred method and the school textbooks, thus, reflecting the way students are usually taught, on a daily basis, in a Greek primary school. In the experimental groups, combinations of various instructional methods were applied, that were based on the principles of constructivism (e.g., group work and active participation of students). Such methods were (a) without the use of games, (b) exclusively with the use of games, without the teachers' active participation, and (c) with games and with the teachers' active participation. In all the above interventions and in all groups, each session lasted for two teaching hours (one and a half hour in total). The number of sessions varied from three to six (in each group), depending on the learning subject and the availability of teaching hours. A summary of the projects can be found in the Appendix, while the complete data analysis of all projects can be found at http://opensimserver.aegean.gr/data for publications/Data games_EN.htm.

It should be noted that in all cases Microsoft's Kodu Game Lab (www.kodugamelab.com/) was used for the games' development. Kodu allows the rapid and relatively easy development of 3D cartoonish games, through visual programming using a set of very simple rules that are based on natural terms and concepts such as "see", "hear", and "bump". It is also very important to stress that the games were not developed by groups of experts, but by the teachers who participated in the projects. For that matter, they attended seminars and the research team provided technical assistance and guidance, but there was no further involvement in the type and philosophy of the games the teachers developed. The reason for this approach was to check whether teachers are capable of being producers rather than consumers of educational software.

Coming to the projects in which programming was taught, Kodu was used once again. In three of them (see Appendix, No. 7, 8, and 9) specific programming concepts were taught (e.g., sequences, variables, loops, and subroutines). Two were addressed to very young students and, in these projects, one of the control groups used a board game instead of printed material. In the last two cases (No. 10 and 11), students were asked to develop their own games and they were taught all the available programming concepts as well as game design. Moreover, the projects' duration was large (35 and 50 two-hour sessions, respectively). While the sample was once again divided into three groups, this time what students can achieve was checked either by using only notes, with a limited, or an active teachers' participation in the process.

In all projects, with the exception of the last two related to programming, evaluation sheets were used for collecting data and their number was equal to the number of sessions. Pre-tests were used, for establishing students' initial knowledge level (allowing a better interpretation of results). Also, delayed post-tests, administered two weeks after the end of each project, established the sustainability of knowledge. The evaluation sheets included questions of escalating difficulty, examining not only knowledge acquisition, but also whether students were able to apply the new knowledge in other situations, to associate different pieces of information/knowledge, and make informed decisions. In the last two projects, the students' games were evaluated by analysing their content both in terms of programming and game design adequacy. Finally, in most projects, short questionnaires were administered to the groups of students that used or developed games, for recording their views and attitudes towards the use of games in their teaching.

As for the projects' results, these were interesting, to say the least. A key conclusion is that in all but one project, the use of DEGs (with or without the active participation of teachers) resulted in better learning outcomes than conventional teaching. In projects with English as a foreign language as the subject, the use of DEGs without the active participation of the teachers had equally good results with well-organized constructivist teaching without the use of games. In the project where units from the study of the environment were taught, the groups that used games (one with the active participation of the teacher and one without) had equally good results and the results of both were better than conventional teaching. In one out of the four projects where maths was taught, DEGs and conventional teaching had equally good results; in the other three, DEGs surpassed conventional teaching. Then again, well-organized constructivist teaching methods and DEGs had equally good results.

As far as the programming projects were concerned, the development of digital games led to a better understanding of programming concepts compared to both conventional and constructivist teaching. However, the most interesting results were obtained from the two interventions that had a long duration (70 and 100 hours). In both cases, it seems that while the teaching method initially played a role, over time even the students who had only notes and received no other support, managed to develop equally good games and with equally few mistakes with the other groups that received partial or significant support by their teachers.

Finally, on the basis of the results in the questionnaires for recording students' views and attitudes, it was clear that, in all cases, the participating students found that teaching with games was interesting and fun. In addition, they were more motivated to learn, no problems related to the use of games were reported, and collaboration seemed to have worked well.

Discussion

The projects' results are in line with the existing literature, which pointed out that the use of DEGs results in the same or better learning gains compared to other conventional forms of instruction (e.g., Fokides, 2018; Sung & Hwang, 2013). A number of reasons, related to the games per se and to the teaching methods that were followed, may have contributed to these results. The first fact is that students, even the younger ones, did not experience any problems when playing the games, confirming the special relationship children have with technology (Prensky, 2001). On the contrary, students considered the whole process amusing, a fact that emerged in the analysis of all projects' questionnaires. The fun and enjoyment may be attributed to Kodu's graphics and cartoonish characteristics, which appear to attract the interest of younger children (Fowler, 2012). The link between the playful character of the teaching because of the use of DEGs and the improved conceptual understanding has been highlighted by others (e.g., Mawer & Stanley, 2011). Moreover, the increased motivation for learning when playing DEGs (Ke, 2008), was also confirmed by students' responses to the relevant questions. Students' interest may have been intensified by the fact that the games included scoring systems, which "rewarded" them upon their successful completion of a task. Furthermore, the scores provided students' immediate feedback for the results of their actions. The control of the learning process, through constant feedback, which DEGs allow, has been identified by previous research (McClarty et al., 2012).

Working in pairs and students' collaboration formed the basis of all projects. Students' responses to the relevant questions indicated that they highly appreciated their collaboration with their peers. Therefore, it seems that DEGs offered a fertile ground for the development of collaborative activities (Sauvé et al., 2010) and together with active engagement, and experimentation, students were able to attain good learning results (Westera et al., 2008). In a number of projects (i.e., in projects 1, 2, 3, and 6), the teachers' role was purposefully minimized, allowing increased students' autonomy and control over their learning process. Given that even in these projects the learning outcomes were better than conventional teaching, confirmed the views of those who (a) considered autonomy and collaboration as factors that work alongside when playing DEGs (Fokides, 2018) and (b) asserted that when students have a high degree of autonomy, positive learning outcomes are to be expected (Nunes et al., 2009). Moreover, the learning outcomes in these groups and in groups in which students had the help and guidance of their teachers (with or without the use of games) were equally good. This finding may lead to the assumption that games were so effective that they successfully assumed the teachers' role, demonstrating the power of Game-Based Learning (Sung & Hwang, 2013).

The results in the projects related to programming (projects 7–11) are similar to the findings of previous research, which underlined the contribution of Kodu in making the learning process more enjoyable and in helping students to have a better understanding of the basics of programming (e.g., Shokouhi et al., 2013). It seems that the effectiveness of Kodu is mainly due to its playful character; after all, its main purpose is to develop games. Also, students did not encounter any particular problems. On the basis of the above, it can be argued that Kodu is quite an effective tool compared to conventional means.

The results in projects concerning programming that also had an extended duration (projects 10 and 11) were challenging, as they contradicted the majority of the existing literature. Indeed, it is suggested that when learning a programming language, direct instruction, formal introduction, and demonstration of programming concepts are needed (Denner et al., 2012). There is also the view that game authoring does not allow the understanding of more complex concepts, at least without explicit teaching (Denner et al., 2012). Contrary to the above, it was found that even without systematic instruction, students learned and used quite a lot of programming concepts and successfully developed functional digital games. The critical factors in both projects were time and collaboration. Thus, the views of Kafai (2012), who supported the implementation of extended projects for teaching programming, were verified by the findings of these two studies.

Implications for practice

The above results have several implications for educators as well as for education policy-makers. First, it should be reminded that the games were developed by the teachers who participated in the projects. In Greece, teachers who wish to introduce innovative teaching methods with the use of technological tools are left without substantial support and this holds true for DEGs as well. Thus, given the lack of DEGs that have been certified for their educational value, the burden of developing them is passed on to the teachers. Indeed, some very interesting observations emerged from this effort. First, the time required for the games' development ranged from 50 to 150 hours (depending on the number of sessions and the games' complexity), which, in any case, is considerable. At the same time, the teachers encountered difficulties in materializing their ideas, due to Kodu's limited number of available objects/characters. This led to the need to devise other ways of presenting the cognitive material, which required reflection and experimentation. Therefore, the effort required for the development of DEGs by "amateurs" is disproportional in relation to the final product (Kluge & Riley, 2008).

In addition, all games were, in essence, "trial and error" applications, realizing behaviorism's concepts, although the teaching framework was based on constructivism. It is also true that an expert could characterize the games as incomplete or that they did not implement the learning objectives correctly, which may have adversely affected the learning outcomes. On the other hand, since "amateurish" DEGs had quite good results, one might assume that DEGs developed by experts might have been able to produce even better results. In this respect, the need for collaboration between educators and ICT specialists for the development of DEGs is emphasized. That is because the former have the necessary pedagogical knowledge, but not the necessary ICT skills, while the latter have the appropriate technical background, but are lagging behind in understanding the pedagogical principles. Moreover, if we want teachers to be able to develop their own DEGs, it is necessary to make available to them tools that make the whole process much more flexible and accessible to the average user (Scacchi, 2012).

With regard to the projects relating to programming, interesting implications can be noted. A major problem was the large number of sessions that caused considerable disruption in the schools' timetables and there were justified complaints by the teachers. Thus, it is necessary to find a balance between the duration and the need to apply an effective teaching strategy, such as the one implemented in the projects (through the development of digital games by the students) (Ke, 2014). Of course, to achieve this, it is necessary for the educational policy-makers to revise the primary school's curriculum and increase the teaching hours dedicated to ICT-related subjects.

Another issue to consider is the suitability of Kodu for teaching programming concepts to primary school students. Although some programming concepts are easily implemented and the students found it amusing, the programming language is very different from the usual ones. Thus, some argued that Kodu is more appropriate for instilling the initial interest of students for programming or for teaching game design principles (Morris et al., 2017). On the other hand, Scratch, which is widely used for the systematic teaching of programming, has also been criticized (Meerbaum-Salant et al., 2013). The issue is not an easy one to resolve and largely depends on the objectives set.

The last issue to be discussed is who can teach programming at the primary level. In all five projects, this task was undertaken by the classes' teachers and not by the ICT teachers. There were specific necessities that imposed this arrangement. ICT teachers share their working hours in many classes if not in different schools. So, it is impossible for them to devote several consecutive hours to a class, as the projects required. On the other hand, it appeared that the teachers, with a relatively short training, could carry out this task. Therefore, this is also a matter for the education policy-makers to consider.

Conclusion

The results of the studies presented in the previous sections were at least interesting. On the other hand, there are limitations to the generalizability of the results. The sample sizes, on several occasions, although adequate for statistical analysis, could have been larger. Also, all projects were conducted in Greek primary schools. The teaching subjects were limited, mainly, to maths and programming. Moreover, in nine cases, data were collected using quantitative tools (questionnaires and evaluation sheets). The above restrictions set the framework for future studies. Larger sample sizes, a wider variety of teaching subjects, and different age groups can provide useful information on the impact of digital games. Quantitative as well as qualitative data collection tools, such as interviews and observations, will allow researchers to better understand the impact of digital games on education. Finally, comparisons between digital games and other technological tools can provide a better picture of their relative advantages (or disadvantages). ETiE is already planning the next wave of research interventions following the above guidelines.

In conclusion, DEGs are indeed an interesting alternative method for teaching several subjects to primary school students. However, there is still a long way ahead until their education potential is fully realized.

Appendix: The projects in brief

No	*Subject*	*Target group (ages)*	*Sample size*	*Groups*	*Duration (two-hour sessions)*	*Results*
1	English as a foreign language	10–11	60	1 Conventional teaching 2 Group work, constructivist based, active participation of teachers and students 3 Games, group work, constructivist based, active participation of students, no teachers' participation	5	Findings: Group 3 outperformed Group1 in zero cases and Group 2 in three cases. In all the other cases, as well as in the delayed post-test, there were no statistically significant differences. Interpretation: Games produced better results compared to constructivist teaching without games and equally good compared to conventional teaching. Positive attitudes of students towards games.
2	Science	8–9	54	1 Conventional teaching 2 Games, group work, constructivist based, active participation of teachers and students 3 Games, group work, constructivist based, active participation of students, no teachers' participation	3	Findings: Group 3 outperformed Group 1 in all cases and Group 2 in zero cases. Group 2 outperformed Group 1 in all cases. In the delayed post-test Group 3 outperformed Group 1 and Group 2. Interpretation: Games produced better results compared to conventional teaching even without the active participation of teachers. Given that Groups 2 and 3 had equally good results, the teacher had no impact on students' learning outcomes.
3	Maths	9–10	63	1 Conventional teaching 2 No games, group work, constructivist based, active participation of teachers and students 3 Games, group work, constructivist based, active participation of students, no teachers' participation	4	Findings: Group 3 outperformed Group 1 in two cases and Group 2 in zero cases. In the delayed post-test Group 3 outperformed Group 1. Interpretation: Games produced better results compared to conventional teaching and equally good compared with constructivist teaching, even if in Group 3 the teachers had no active role. Positive attitudes of students towards games. Students were motivated to learn.

4	Maths	6–7 9–10 11–12	69 66 66	1 Conventional teaching 2 No games, group work, constructivist based, active participation of teachers and students 3 Games, group work, constructivist based, active participation of students and teachers	4 4 4	Findings: Group 3 outperformed Group 1 in 12 cases and Group 2 in 3 cases (and was outperformed by this group in 2 cases). In the delayed post-test Group 3 outperformed Group 1 in 3 cases and Group 2 in 1 case. Interpretation: Games produced better results compared to conventional teaching and equally good compared with constructivist teaching but without games. Given that in Groups 2 and 3 the teaching was constructivist based, the impact of the games was minimal. Positive attitudes of students towards games. Students were motivated to learn.
5	Maths	9–10	60	1 Conventional teaching 2 Games, group work, constructivist based, active participation of students, no teachers' participation 3 Games, group work, constructivist based, active participation of students and teachers	3	Findings: Group 3 outperformed Group1 in one case and Group 2 in one case. Group 2 outperformed Group 1 in zero cases. In the delayed post-test Group 3 outperformed Group 1. Interpretation: No clear advantage of games over conventional teaching. Positive attitudes of students towards games. Students were motivated to learn.
6	Maths	6–7	60	1 Conventional teaching 2 Board games, group work, constructivist based, active participation of students and teachers 3 Games, group work, constructivist based, active participation of students, no teachers' participation	6	Findings: Group 3 outperformed Group 1 in three cases and Group 2 in two cases. Group 2 outperformed Group 1 in zero cases. In the delayed post-test Group 3 outperformed Group 1 and Group 2. Interpretation: Games produced better results compared to conventional teaching and equally good compared to constructivist teaching with a board game, even if in Group 3 the teachers had no active role.

(*Continued*)

No	*Subject*	*Target group (ages)*	*Sample size*	*Groups*	*Duration (two-hour sessions)*	*Results*
7	Programming	8–9	75	1 Conventional teaching 2 Board game, group work, constructivist based, active participation of students and teachers 3 Games, group work, constructivist based, active participation of students and teachers	3	Findings: Group 3 outperformed Group 1 in three cases and Group 2 in two cases. In the delayed post-test Group 3 outperformed Group 1 and Group 2. Interpretation: Games produced better results compared to conventional teaching and also better compared to constructivist teaching with a board game.
8	Programming	7–9	135	1 Conventional teaching 2 Board game, group work, constructivist based, active participation of students and teachers 3 Games, group work, constructivist based, active participation of students and teachers	3	Findings: Group 3 outperformed Group 1 in six cases and Group 2 in four cases. In the delayed post-test Group 3 outperformed Group 1 and Group 2. Interpretation: Games produced better results compared to conventional teaching and also better compared to constructivist teaching with a board game.
9	Programming	11–12	60	Students were asked to develop games 1 Group work, no systematic teaching 2 Group work, conventional teaching 3 Group work, constructivist based, active participation of students and teachers	3	Findings: Group 3 outperformed Group 1 in two cases and Group 2 in three cases. Interpretation: Games produced better results compared to conventional teaching and also better compared to constructivist teaching with no use of games.

10	Programming	11–12	70	Students were asked to develop three games of escalating complexity 1 Group work, no notes, no systematic teaching 2 Group work, notes, no systematic teaching 3 Group work, notes, systematic teaching	35	Findings: Both Group 1 and Group 3 outperformed Group 2 in one case. Interpretation: No clear advantage of one method over the others. Positive attitudes of students towards games. Students were motivated to learn.
11	Programming	10–11	138	Students were asked to develop three games of escalating complexity 1 Group work, notes, no systematic teaching 2 Group work, notes, limited teachers' participation 3 Group work, notes, active teachers' participation	50	Findings: In Game 1, Group 3 outperformed the other groups. In Game 2, Group 3 outperformed only Group 1. In Game 3 there were no statistically significant differences. Interpretation: No clear advantage of one method over the others. Positive attitudes of students towards games. Students were motivated to learn.

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