Chapter 16
Reflecting on the Results of the Initiative ETiE for Using Tablets in Primary Schools

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ABSTRACT

Mobile devices, such as smartphones and tablets, have taken the world by storm. In education, they have exponentially increased the opportunities for mobile and ubiquitous learning, as their unique features give them a competitive edge over conventional teaching. In light of the above, the chapter summarizes and discusses the findings of a series of short research projects, conducted under the umbrella of the initiative Emerging Technologies in Education, involving the use of tablets for teaching science-related subjects, programming, and Greek mythology to kindergarten and primary school students. All in all, it was found that the learning outcomes, which can be considered as good compared to non-technologically enhanced teaching, are closely related to the teaching method, to certain tablets' features, and to the type of application being used. Then again, the impact on students' misconceptions was minimal. Finally, a number of suggestions to software developers as well as to education administrators and policymakers are being discussed.

INTRODUCTION

Technology is already sweeping through classrooms as the industry creates more and more products with the inherent potential to enhance education. At the same time, traditional educational methods are bound to become obsolete, as there is already an influx of novel teaching/learning models that make use of technology's advantages. The emergence and rapid spread of mobile devices (such as smartphones and tablets) added the element of portability, opening new and previously unexplored paths for research and practice. Indeed, a substantial number of studies concluded that the use of mobile devices can yield

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satisfactory learning outcomes (Bidin & Ziden, 2013). Similarly, a certain type of applications for these devices, described by the term Augmented Reality (AR), seems to be of particular interest.

Several learning theories and instructional methods provide ideas on how these devices can be integrated into education (e.g., mobile and ubiquitous learning). Among the key advantages of both mobile devices and AR are that they can assist the learning process by making it more productive, enjoyable, and interactive (Akçayır & Akçayır, 2017), that they can serve diverse students' learning styles and preferences (Dunleavy, Dede, & Mitchell, 2009), and that they allow a better understanding and visualization of concepts and phenomena. Needless to say, that all the above are among the fundamental requirements for contemporary teaching/learning (Sharples & Spikol, 2017). At the same time, students seem to form positive attitudes towards these tools (Bonds-Raacke & Raacke, 2008). However, as researchers pointed out, we are still in need of a sufficient number of research projects in order, on one hand, to understand, in-depth, the impact of mobile devices on students' learning and, on the other, to find ways to fully exploit their educational potential (Haßler, Major, & Hennessy, 2015).

The initiative Emerging Technologies in Education (ETiE) started about three years ago and although it is not a formal research project, a good number of academics, researchers, graduate, and undergraduate students has already contributed to a substantial number of projects conducted under its umbrella. In short, the objective is to examine the results of the educational use of emerging technologies in primary and junior high schools. As emerging can be considered technologies that either recently became available to the public or older ones that still have a controversial but certainly an unexplored educational potential. Examples of such technologies are drones, virtual reality, 3D printers, and AR. Reasonably enough, a number of ETiE's contributors set as a goal to examine the educational value of mobile devices and AR. As a result, a series of short research projects were designed and implemented over the past year, involving the use of tablets by kindergarten and primary school students for teaching them basic programming concepts, subjects related to plants and animals, geography, the human anatomy, and Greek mythology. Having accumulated a substantial number of such projects, thirteen in total, the chapter at hand re-visits the results and critically re-evaluates them.

BACKGROUND

The emergence of mobile devices, such as smartphones and tablets, liberated education from its spatial and temporal confines, allowing the implementation of what is called mobile and ubiquitous learning. In essence, mobile learning provides ideas on how one can utilize mobile devices in education (Sharples & Spikol, 2017). Respectively, ubiquitous learning refers to the constant opportunity for learning due to the easy access to teaching and other material from anywhere and at any time (Murphy, 2011).

There is a fairly extensive literature regarding the effectiveness of mobile learning; better learning outcomes and increased incentives for learning (Chang, Chang, Hou, Sung, Chao, Lee &, 2014), rich educational experiences (Wilkinson & Barter, 2016), personalization/customization to the learning needs of each student (Clarke & Svanaes, 2014), development of metacognitive skills (Kearney, Schuck, Burden, & Aubussona, 2012), opportunities for continuous self-assessment, greater autonomy and control over one's learning process (West, 2013), are some of its advantages. Also, mobile devices can assist collaborative learning, as they allow interactions and cooperation between students (Bidin & Ziden, 2013).

On the other hand, a number of problems have been reported that can act as barriers to the successful integration of mobile devices in education. For example, the implementation of mixed learning with the use of these devices requires changes in the way and the duration of teaching (Bidin & Ziden, 2013). Technical problems, such as the need for frequent charging and the small size of the screen, have also been reported (van't Hooft, 2013). A major problem is the lack of educationally sound applications (Bidin & Ziden, 2013). Others highlighted students' increased cognitive load due to the overuse of multimedia features in mobile applications (Chu, 2014). Finally, the distraction of students can be an issue, as they tend to use these devices for non-educational purposes during teaching (Henderson & Yeow, 2012; Wilkinson & Barter, 2016).

Quite interestingly, teachers can be a problem too. Their lack of relevant experience and, possibly, their negative views on the use of such tools, can lead them to avoid using mobile devices during their teaching (Domingo & Garganté, 2016). There are reports in the literature where the learning outcomes were not that good (Perry & Steck, 2015), and, because of that, a number of specialists expressed the view that we are in need of a well-developed pedagogy that will allow a better utilization of mobile devices in teaching (Clarke & Svanaes, 2014). Finally, in research, many people argue that the data is not yet sufficient, because most studies had small sample sizes, that the number of interventions was small, and that, in general, detailed empirical studies are scarce (Clarke & Svanaes, 2014).

An interesting category of applications for mobile devices is that of AR. AR is a technology that mixes, in real-time, the real world with virtual objects (2D or 3D), multimedia elements, and information, while the user can interact with the above (van Krevelen & Poelman, 2010). These characteristics of AR applications can facilitate the learning process and make it more attractive (Dunleavy, Dede, & Mitchell, 2009). Indeed, research has demonstrated that the use of tablets and AR applications for teaching, primarily science-related courses, yielded satisfactory results (Fokides & Atsikpasi, 2017), increased the interest of students and their motivation for learning (Bower, Howe, McCredie, Robinson, & Grover, 2014). A possible explanation for these results is that the increased interaction between the user and the cognitive material presented to him/her in AR leads to a better understanding of complex or abstract concepts that need good visualization in order to be understood (Ibáñez, Di Serio, Villarán & Kloos, 2014).

Having in mind the arguments presented above, under the umbrella of ETiE and during the last year, thirteen short research projects were designed and implemented. Their purpose was to examine the learning outcomes when primary school students use tablets for studying various subjects. Their attitudes and views regarding the use of these devices were also examined. Thus, the main research hypotheses were that (a) the learning outcomes are better when students use tablets compared with other teaching schemes and (b) students form positive attitudes and views when they are taught using tablets.

A BRIEF PRESENTATION OF THE PROJECTS AND OF THEIR RESULTS

The total sample size of the projects was 1,163 students. Table 1 summarizes the projects, their method, and results. In two projects, basic programming concepts were the learning subject. The characteristics of animals were the learning subject in one project, while plants were the theme in three projects. In another project, the learning subject was the Greek mythology and in two projects geography was taught. Lastly, human organ systems were taught in four projects.

Research Design and Procedures

A quasi-experimental design was applied to all projects because data were collected from intact classes. All students attended public primary schools and the samples were homogeneous in terms of students' socioeconomic status and performance. In each project, the participating students were divided into three groups (with the exception of one project in which there were only two groups), two control and one experimental. The teaching to the first control group was conventional and reflected the way students are usually taught on a daily basis in Greece; the teachers presented the learning material, students studied the relevant units from their textbooks (while the teachers provided guidelines and help) and completed the exercises and activities. The second control group was taught utilizing contemporary teaching methods grounded in the views of constructivism; students worked in pairs, they were free to collaborate and discuss, while the teachers acted as facilitators of the process by constantly discussing, exchanging ideas, and collaborating with students.

Coming to the experimental groups, it has to be noted that the same teaching scheme was not applied to all of them; however, all had in common students' work in pairs, the use of tablets, and all were based on constructivist teaching methods. From then on, two alternatives were tested regarding the type of application being used and two regarding the teacher's role. In five cases the applications were developed by the teachers or by the researchers and in eight cases, commercial applications were used. In all but two projects (the ones where programming was the learning subject) AR applications were used. Also, in five projects students in the experimental groups worked completely on their own, while the teachers' role was limited to providing technical assistance. In the remaining eight cases, the teachers were actively involved in the learning process by starting or joining in students' discussions and by providing ideas and directions, but without imposing their own views (as in the second control group). The ratio of tablets and students was 1:2, with the exception of one project in which tablets were provided to all students and the textbooks were removed so that students could study using tablets even at their homes.

The number of teaching sessions (control and experimental groups alike) varied and ranged from three to eight in each group, depending on the subject and the availability of teaching hours. In any case, each session lasted for two teaching hours.

Instruments

Data were collected using evaluation sheets, whose number was equal to the number of sessions. Also, pre-tests and delayed post-tests were administered. The purpose of the former was to determine the initial knowledge level of students and to confirm (or reject) the common cognitive starting point, which allowed the better interpretation of the rest of the results. The purpose of the latter was to determine the sustainability of knowledge. It should be noted that the questions in all the evaluation sheets (a) were of escalating difficulty, (b) half of them examined knowledge acquisition, and (c) the other half checked whether students were able to apply this knowledge to other situations and required a certain degree of critical thinking. Also, in three projects students' misconceptions were examined, with specially designed for this purpose evaluation sheets. Finally, a questionnaire was administered to students who used tablets, aiming to record their views, attitudes, and ideas regarding the use of tablets.

Table 1. The research projects

Project	Subject	Ages	Sample	Application type	Method			Number of 2-hour sessions/ group	Results
					Group1	Group2	Group3		
1	Anatomy	11-12	162 (3 groups)	commercial	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher actively participated	8	Group3 outperformed groups 1 and 2
2	Anatomy	11-12	75 (3 groups)	commercial	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher actively participated	4	same as above
3	Anatomy	11-12	50 (2 groups)	commercial	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher did not actively participate	-	3	Group 2 outperformed Group1
4	Anatomy	11-12	66 (3 groups)	commercial	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher did not actively participate	3	groups 2 and 3 had the same results and outperformed Group1
5	Geography	11-12	66 (3 groups)	tailor-made	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher did not actively participate	4	same as above
6	Geography	11-12	60 (3 groups)	tailor-made	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher did not actively participate	3	same as above
7	Programming	7-9	135 (3 groups)	commercial	conventional teaching	constructivist teaching, group work, the teacher actively participated, board game	constructivist teaching, group work, tablets, the teacher actively participated	6	Group3 outperformed groups 1 and 2
8	Programming	7-8	75 (3 groups)	commercial	conventional teaching	constructivist teaching, group work, the teacher actively participated, board game	constructivist teaching, group work, tablets, the teacher actively participated	3	same as above
9	Plants	11-12	246 (3 groups)	commercial	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher actively participated	5	same as above
10	Plants	11-12	60 (3 groups)	commercial	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher actively participated	3	same as above
11	Plants	11-12	60 (3 groups)	tailor-made	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher did not actively participate	4	all groups had the same results
12	Animals	5-6	45 (3 groups)	tailor-made	conventional teaching	constructivist teaching, group work, the teacher actively participated, computers	constructivist teaching, group work, tablets, the teacher actively participated	3	Group3 outperformed Group1
13	Mythology	8-9	63 (3 groups)	tailor-made	conventional teaching	constructivist teaching, group work, the teacher actively participated	constructivist teaching, group work, tablets, the teacher actively participated	3	Group3 outperformed Group2

Results

Coming to the results, presented in detail in the Appendix, in almost all cases, students who used tablets outperformed students who were taught conventionally. This holds true even in those cases where the students worked on their own and the teachers had an extremely limited role. On the other hand, when compared with students of the second group (contemporary teaching but without the use of tablets), the results were mixed; in some cases, the results were the same, in others students who used tablets had better results. By taking a closer look to these results, it becomes evident that when students worked on their own the results were the same (projects 4, 5, 6, and 11; tables 7, 8, 9, and 14) and when the use of tablets was combined with the active participation of teachers the results were better (projects 1-3, 7-10, 12-13; tables 4-6, 10-13, 15-16).

As far as students' misconceptions are concerned, there was one case in which all three groups had the same results (project 5, Table 8) and two cases where students who were taught conventionally were outperformed by the other two groups (projects 1 and 9; tables 4 and 12). Then again, in all three cases, there were no statistically significant differences between the two groups that were taught using constructivist methods (with or without the use of tablets).

Finally, the results in the questionnaires clearly indicated that, in all cases, students found their teaching with the use of tablets interesting and formed positive views and attitudes (tables 2 and 3). Also, the cooperation with their classmates seemed to have worked out successfully. Although observations were not a research tool utilized in the projects, the teachers reported a number of technical problems such as poor Wi-Fi connectivity and slow Internet connection, the low battery life of tablets, and that sometimes the applications stopped functioning properly and they had to reset the devices in order to overcome this problem. Also, some teachers reported that, during the first and second sessions, a number of students used the tablets for playing games. Although the games were uninstalled before the tablets were handed

Table 2. Questionnaire 1, applicable to projects 1, 2, and 5

	Project 1	Project 2	Project 5
Question	*M (SD)*	*M (SD)*	*M (SD)*
I collaborated with my fellow student nicely.	4.11 (0.33)	4.30 (0.45)	4.11 (0.39)
I feel that working as a pair helped me to learn.	3.87 (0.62)	4.40 (0.55)	4.20 (0.60)
I think that using tablets during the lesson is boring.	4.03 (0.76)	4.11 (0.81)	3.95 (0.76)
I think that using tablets during the lesson is an enjoyable activity.	4.20 (0.55)	4.60 (0.70)	4.62 (0.50)
Working with tablets was fun.	4.32 (0.58)	4.48 (0.77)	4.51 (0.42)
I enjoyed working with tablets.	3.94 (0.81)	4.36 (0.86)	4.12 (0.76)
Working with tablets made me want to learn more about the human body	3.71 (0.60)	3.94 (0.70)	4.22 (0.40)
I was eager to conduct the project's lessons.	4.42 (0.50)	4.14 (0.90)	4.05 (0.70)
I found the courses very interesting	4.42 (0.54)	4.21 (0.67)	4.07 (0.77)
I do not feel that I have learned anything.	3.58 (0.66)	3.81 (0.44)	3.72 (0.48)
I believe that the application was like a game	4.02 (0.57)	4.16 (0.31)	4.20 (0.33)
Working with tablets was difficult.	4.12 (0.61)	4.52 (0.71)	4.41 (0.50)
I did not like the courses at all.	4.32 (0.60)	4.30 (0.51)	4.22 (0.60)

to students, access to the Internet was not restricted, because the tablets had to have access to the servers hosting the applications, so games could be downloaded. Browsing the Internet, for reasons not related to what students were taught, was also reported.

Table 3. Questionnaire 2, applicable to projects 3, 4, 6, 9, 10, and 13

	M (SD)					
Question	**Project 3**	**Project 4**	**Project 6**	**Project 9**	**Project 10**	**Project 13**
How much did you like the application?	4.60 (0.70)	4.36 (0.66)	3.63 (1.46)	3.90 (1.15)	3.80 (1.28)	4.48 (0.50)
How much did you like the animations?	4.36 (0.81)	4.91 (0.29)	2.74 (1.15)	3.75 (1.42)	4.30 (0.92)	4.41 (0.42)
How much did you like the 3D objects?	4.48 (0.77)	4.50 (1.01)	3.32 (1.29)	4.26 (0.94)	3.95 (1.28)	4.67 (0.51)
How much did you like the information?	4.16 (0.90)	4.50 (0.60)	3.74 (1.45)	3.80 (1.10)	3.85 (1.14)	4.44 (0.51)
How much did you like collaborating?	4.64 (0.64)	4.68 (0.48)	3.84 (1.42)	3.90 (1.50)	3.65 (1.42)	4.05 (0.42)
How easy was to use the application?	4.52 (0.71)	4.27 (0.77)	4.00 (1.29)	4.50 (0.76)	4.50 (0.76)	4.95 (0.16)
How much do you agree that the application was like a game?	3.96 (0.93)	4.55 (0.86)	3.58 (1.61)	4.20 (1.05)	4.00 (1.26)	4.75 (0.38)
Did you enjoy working and playing at the same time?	4.64 (0.70)	4.41 (0.59)	3.68 (1.42)	3.95 (1.24)	4.40 (0.68)	4.64 (0.42)
How much do you think that you have learned?	4.80 (0.58)	4.18 (0.73)	4.11 (0.88)	3.70 (0.92)	3.60 (0.88)	4.54 (0.48)

SOLUTIONS AND RECOMMENDATIONS

An interesting observation that emerged during the analyses of the results was that, in most cases, to the first couple of sessions there were no statistically significant differences between the three groups of students. A plausible explanation is that students needed some time to adapt either to the teaching method or to the use of tablets or to both. Consequently, the differences between the teaching methods became clearer a bit later. Also, conventional teaching rarely was able to produce the same (or better) learning outcomes compared with constructivist teaching methods (with or without the use of tablets); in the vast majority of cases, the results were clearly worse. As a result, what the studies were called to answer was whether the use of tablets/AR can lead to measurable and substantial differences compared with well-organized teachings, grounded in contemporary pedagogical perceptions. The answer to this question is affirmative. That is because, in the worst case, the results were the same, usually when the applications were "amateurish", (i.e. developed by the teachers or the researchers involved, who were definitely non-specialists in software development) (see projects 5-6 and 11-13; tables 8-9 and 14-16). In the majority of cases where commercial software was used (see projects 1-4, 7-10; tables 4-7 and 10-13), the differences were statistically significant.

Although the results related to knowledge acquisition were quite clear and satisfactory, the same does not apply to students' misconceptions. In two out of the three cases in which this parameter was examined (see projects 1, 5, and 9, tables 5, 8, and 12), some differences were observed and only between the groups that used tablets and the ones that were taught conventionally. This means that well-organized teaching, either with or without the use of tablets, will have the same effect on students' misconceptions for a given learning subject. Then again, one has to keep in mind that misconceptions are particularly persistent and it takes time for one to overcome them (Barman, Stein, McNair, & Barman, 2006). It would be unrealistic to expect tablets to have a significant impact on projects lasting for a short period of time and with a small number of sessions.

Results' Interpretation

The interpretation of the above results can be based on the teaching methods used, on the use of tablets/AR, or on a combination of both. First, the results in students' questionnaires indicated that cooperation between them was trouble-free and, in fact, students appreciated the contribution of their peers to their own learning (see tables 2 and 3). These findings confirm previous research which indicated that the use of tablets enhanced collaboration (Henderson & Yeow, 2012), leading to positive learning outcomes (Clarke & Svanaes, 2014). Also, the teaching schemes allowed students to work at their own pace and study the learning material for as long and whenever they liked. Increased autonomy, control of one's own learning process, and self-guided learning are closely linked to positive learning outcomes (Clarke & Svanaes, 2014; Kearney et al., 2012; Wilkinson & Barter, 2016).

In addition, elevated levels of enjoyment were noted when using tablets/AR (see tables 2 and 3) which confirmed the relevant literature (Akçayır & Akçayır, 2017). Fun and enjoyment act as facilitators of the learning process (Zydney & Warner, 2016), leading to motivation for learning (Al-Mashaqbeh Al & Shurman, 2015), as demonstrated by students' responses to the corresponding questionnaires' items. Other items reflected students' positive attitudes in the use of tablets, which also act as a facilitator of the learning process (Chen et al., 2017).

It is very likely that certain features of the AR applications (especially of the commercial ones) to have played an important role. The multimodal presentation of the learning material (e.g., 3D models, 3D animations, videos, and illustrations) allowed students to study it from multiple perspectives and in diverse ways, leading to enhanced learning (Al-Mashaqbeh Al & Shurman, 2015), as well as to the sustainability of knowledge (Ferdousi & Bari, 2015) as noted in the delayed-post tests.

The lack of problems related to the use of tablets per se indicated that they are compatible with students' ICT skills (Görhan, Öncü, & Şentük, 2014) and that their introduction in teaching will not cause additional problems to them. On the other hand, there were cases in which problems related to how students used the tablets during teaching and technical problems were observed. As Wilkinson and Barter (2016) noted, distraction was an issue, although not in that many cases; students browsed the Internet or used the schools' Wi-Fi to download and play games. A better organization of teaching and keeping students occupied with learning activities might help to deal with such incidents. Some technical issues were also observed and were a cause for concern (Bidin & Ziden, 2013). Tablets' low battery life, the need to reset them when the applications were not running smoothly, and the schools' slow Internet connection resulted to the loss of valuable time, students became restless and lost their interest.

Implications for Practice

While the studies' results confirmed -more or less- previous research, it is quite important to discuss their implications for educational software developers, educators, and policymakers. On the basis of the results, when the applications were developed by amateurs (whether these were the teachers or the researchers involved) the results were not that different from well-organized conventional teaching. Statistically significant differences were noted when commercial applications were used. However, in this case, selecting the appropriate software was challenging. Although numerous applications are available, associated with the learning subjects which were studied, few were deemed suitable for educational purposes and even fewer were considered of high quality (in terms of the comprehensiveness of the educational material, compatibility with the curricula, and students' age). There are two possible solutions to the above problem. The first is teachers to become skilled producers of educational applications. Even though this will allow the development of software highly adapted to the needs of a specific class (or even to the needs of specific students), it is questionable whether teachers are able or willing to undertake such task. The second solution is the cooperation between software developers and education professionals, as suggested by Shuler, Levine, and Ree (2012). The former do not have the necessary educational background, while the latter are not fully aware of technology's affordances and limitations. Thus, close collaboration between these two groups of experts is probably the ideal arrangement for the development of technically, as well as educationally sound applications.

The availability of applications in languages other than English also proved to be a major problem. Since the studies were conducted in Greek schools, the applications had to be in Greek, but only a handful of them was available in this language. Other countries, in which the software industry is not well-developed and, at the same time, the language is not among the ones that are most commonly spoken internationally, probably face a similar situation. State-funded projects is a plausible solution, though in Greece it was tried a number of times but did not work out well.

Each session, in all the projects presented in this study, lasted for two teaching hours for two key reasons. First, to settle the students down, boot the devices, and load the applications, takes more than a few minutes. Not only that, but technical problems can always arise when ICT tools are used by students for in-classroom activities; valuable teaching time can be lost in trying to overcome such incidents. Second, it was considered of utmost importance for students to have enough time at their disposal for studying and using the tablets/applications at their own pace. Indeed, on the basis of the results, two-hour sessions proved to be sufficient. Therefore, for tablets to be successfully integrated into schools and become the norm, education policymakers should consider revising the school's timetable and allocate more teaching hours to subjects taught using tablets (or any other ICT tool for that matter).

As others have already suggested, we are also in need of a robust pedagogy for taking full advantage of tablets' educational potential (e.g., Clarke & Svanaes, 2014). In the projects presented, constructivism provided the theoretical framework and the teaching methods were -more or less- based on Driver's and Oldham's model (1986) or on Bybee et al.'s 5Es model (2006). While the application of both the theoretical framework and of the teaching models proved to be able to produce good results, one should be reminded that both were developed long before tablets became mainstream. Therefore, it is necessary either to update the existing or to develop new teaching methods to fully exploit the potential of these devices.

FUTURE RESEARCH DIRECTIONS

While the studies were meticulously designed and implemented, there are limitations that need to be addressed. The sample sizes were, in some cases, marginally sufficient for statistical analysis. Also, the teaching/learning subjects were limited to science-related, programming, and Greek mythology courses. Therefore, the generalizability of the results is limited. Finally, research data were collected using only quantitative tools (questionnaires and evaluation sheets). The above limitations can set the guidelines for future research. Larger sample sizes and different age groups can provide useful information about the impact of tablets on all educational levels. Towards this direction, a wider variety of subjects can also help. Quantitative together with qualitative data collection methods, such as interviews and observations, will allow the researchers to understand, in-depth, the benefits that tablets bring to education. Finally, comparisons between tablets and other ICT tools can provide a clearer picture of the advantages (or disadvantages) of these devices.

CONCLUSION

Overall, the studies' results, as presented in the preceding sections, were interesting, as well as thought-provoking, and helped to have a clearer picture regarding their educational potential. All things considered, it can be concluded that tablets together with AR applications are indeed an interesting alternative method for teaching several subjects to primary school students. However, it seems that a lot more can be done before they are fully integrated into education.

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KEY TERMS AND DEFINITIONS

Augmented Reality: A technology that provides to the user an interactive experience of a real-world environment which is "augmented" by computer-generated information.

Cognitive Load: A term used in cognitive psychology, that refers to the effort being used in the working memory. According to the cognitive load theory, there are three types of cognitive load intrinsic, extraneous, and germane.

Constructivism: A learning theory which argues that humans generate knowledge and meaning from their experiences. Although not a specific pedagogy, is the underlying theme of many education reform movements.

Misconception: A mistaken belief, a wrong idea, because it is based on faulty thinking or understanding.

Mobile Learning: Education or training conducted by means of portable computing devices such as smartphones or tablets.

Tablet: A portable computer, typically with a mobile operating system, a touchscreen, and a rechargeable battery in a single thin, flat package.

Ubiquitous Learning: An alternative term for learning anywhere, anytime; thus, it is associated with mobile devices. It is grounded in situated learning which supports the view that we learn better when learning takes place in the context of real-life activities.

APPENDIX

The projects' results (all tables present the means and standard deviations per group and per evaluation sheet, the results of the ANOVA testing, and the post-hoc pairwise comparisons when applicable)

Table 4. Project 1

	Group						**ANOVA testing**		**Post-hoc tests**	
	Group1 (*N* = 54)		**Group2 (*N* = 54)**		**Group3 (*N* = 54)**					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	**Pair**	*p*
Pre-test	16.45	3.22	15.86	2.98	16.28	3.20	$F(2, 159) = 0.51$	.604		
Misconceptions pre-test	7.18	3.02	6.49	2.12	7.40	2.32	$F(2, 159) = 1.92$	.150		
ES1	13.36	2.18	12.85	1.67	13.29	1.99	$F(2, 159) = 1.08$	.343		
ES2	12.68	2.46	13.59	2.22	13.05	1.87	$F(2, 159) = 2.34$	.099		
ES3	15.18	2.11	17.91	2.41	18.92	2.45	$F(2, 159) = 37.29$	.001	1-2	< .001
									1-3	< .001
									2-3	.065
ES4	14.17	2.47	16.92	2.12	18.64	2.71	$F(2, 159) = 45.91$	< .001	1-2	< .001
									1-3	< .001
									2-3	.001
ES5	11.45	3.04	13.33	2.51	16.62	2.89	$F(2, 159) = 46.43$	< .001	1-2	.002
									1-3	< .001
									2-3	< .001
ES6	14.86	2.27	18.35	3.04	20.28	3.22	$F(2, 159) = 49.37$	< .001	1-2	< .001
									1-3	< .001
									2-3	.002
ES7	15.99	1.63	17.63	2.32	21.09	1.95	$F(2, 159) = 92.73$	< .001	1-2	.001
									1-3	< .001
									2-3	< .001
ES8	13.88	1.99	16.31	2.05	18.07	2.31	$F(2, 159) = 53.12$	< .001	1-2	< .001
									1-3	< .001
									2-3	.001
Delayed post-test	19.18	3.31	22.65	2.87	25.76	3.24	$F(2, 159) = 59.12$	< .001	1-2	< .001
									1-3	< .001
									2-3	< .001
Misconceptions post-test	11.71	2.05	12.59	1.89	13.02	2.19	$F(2, 159) = 5.75$	.004	1-2	.069
									1-3	.003
									2-3	.521

Table 5. Project 2

	Group						**ANOVA testing**		**Post-hoc tests**	
	Group1 (*N* = 25)		**Group2 (*N* = 25)**		**Group3 (*N* = 25)**					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	**Pair**	*p*
Pre-test	15.16	4.06	15.80	3.23	16.32	3.06	*H*(2) = 0.975	.614		
ES1	14.16	3.76	15.88	3.59	17.92	2.20	*H*(2) = 14.18	.001	1-2	.084
									1-3	.001
									2-3	.028
ES2	14.86	3.45	16.70	3.87	17.68	2.60	*H*(2) = 7.91	.019	1-2	.064
									1-3	.005
									2-3	.510
ES3	14.36	3.87	15.64	3.98	16.64	3.05	*H*(2) = 4.30	.109		
ES4	12.84	3.27	14.72	4.62	17.80	1.91	*H*(2) = 24.25	.001	1-2	.033
									1-3	.001
									2-3	.017
Delayed post-test	21.40	7.90	26.44	5.14	30.68	3.61	*H*(2) = 21.30	.001	1-2	.016
									1-3	< .001
									2-3	.002

Table 6. Project 3

	Groups				**ANOVA testing**
	Group1 (*N* = 25)		**Group2 (*N* = 25)**		
	M	*SD*	*M*	*SD*	
Pre-test	15.80	3.23	16.32	3.06	*H*(2) = 0.975, *p* = .614
ES1	15.88	3.59	17.92	2.20	*H*(2) = 14.18, *p* = .001
ES2	14.72	4.62	17.80	1.91	*H*(2) = 24.25, *p* < .001
Delayed post-test	26.44	5.14	30.68	3.61	*H*(2) = 21.30, *p* < .001

Table 7. Project 4

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 22)		Group2 (*N* = 22)		Group3 (*N* = 22)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Pair	*p*
Pre-test	18.64	4.14	17.27	4.44	18.36	4.04	$F(2, 63) = 0.65$	.53		
ES1	16.82	6.35	17.73	4.33	2.64	4.74	$F(2, 63) = 29.14$	< .001	1-2	.83
									1-3	.001
									2-3	.001
ES2	11.90	3.68	14.18	3.28	16.27	3.84	$F(2, 57) = 11.5$	< .001	1-2	.016
									1-3	< .001
									2-3	.140
ES3	12.73	5.28	13.45	2.5	14.82	4.26	Brown-Forsythe $F(2, 46.04) = 1.42$	$p = .25$		
Delayed post-test	13.64	4.12	17.09	3.62	19.64	3.06	$F(2, 63) = 15.14$	< .001	1-2	.007
									1-3	< .001
									2-3	.059

Table 8. Project 5

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 22)		Group2 (*N* = 22)		Group3 (*N* = 22)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Pair	*p*
Pre-test	13.75	2.48	14.46	2.22	13.38	3.15	$F(2, 63) = 0.95$	.39		
Pre-misconceptions test	6.55	2.31	7.16	2.55	6.18	1.55	$F(2, 63) = 1.14$	.33		
ES1	14.18	4.15	16.54	3.84	16.89	4.19	$F(2, 63) = 2.90$	.14		
ES2	16.11	3.45	18.52	2.99	20.66	3.12	$F(2, 63) = 11.18$	.001	1-2	.039
									1-3	< .001
									2-3	.075
ES3	13.78	4.15	17.12	3.20	20.04	3.66	$F(2, 63) = 15.85$	< .001	1-2	.011
									1-3	< .001
									2-3	.029
ES4	17.69	3.50	21.51	3.18	22.88	4.01	$F(2, 63) = 12.42$	< .001	1-2	.002
									1-3	< .001
									2-3	.418
Delayed post-test	19.87	3.12	23.11	4.02	25.98	3.87	$F(2, 63) = 15.09$	< .001	1-2	.014
									1-3	< .001
									2-3	.032
Post-misconceptions test	11.85	2.19	13.58	3.11	12.66	2.44	$F(2, 63) = 2.42$	.10		

Table 9. Project 6

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 20)		**Group2** (*N* = 20)		**Group3** (*N* = 20)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	**Pair**	*p*
Pre-test	13.15	2.28	14.20	3.29	12.40	2.28	*F*(2, 57) = 2.32	.11		
ES1	12.60	3.02	13.20	4.43	15.20	1.58	*H*(2) = 6.91	.03	1-2	.253
									1-3	.004
									2-3	.355
ES2	10.00	4.05	11.85	5.90	13.80	3.33	Brown-Forsythe *F*(2, 46.040) = 3.48	.04	1-2	.487
									1-3	.007
									2-3	.413
ES3	10.85	1.98	18.10	4.22	15.35	2.06	*H*(2) = 32.67	< .001	1-2	< .001
									1-3	< .001
									2-3	.005
Delayed post-test	9.80	2.71	13.05	3.70	15.35	1.80	Brown-Forsythe *F*(2, 44.534) = 18.67	< .001	1-2	.010
									1-3	< .001
									2-3	.053

Table 10. Project 7

Test	**Group1** (*N* = 45)				**Group2** (*N* = 45)				**Group3** (*N* = 45)			
	2nd grade (N = 23)		*3rd grade (N =22)*		*2nd grade (N = 23)*		*3rd grade (N =22)*		*2nd grade (N = 23)*		*3rd grade (N =22)*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
ES1	12.48	2.42	13.05	1.88	15.35	1.85	15.18	1.59	17.88	1.34	18.25	1.68
ES2	6.54	1.68	7.15	1.55	9.85	1.48	10.18	1.35	10.56	1.57	10.82	1.36
ES3	9.56	1.52	10.55	1.69	11.38	2.12	11.84	1.45	13.46	1.70	14.05	1.85
Delayed post-test	10.13	2.45	11.08	2.18	13.58	2.91	14.01	2.57	16.85	2.17	17.15	2.28

Table 10. Project 7 (continued)

Test	Grade	*F*	*p*	Post-hoc tests	
				Pair	p
ES1	2nd	Brown-Forsythe $F(2, 51.45) = 35.78$	< .001	1-2	< .001
				1-3	< .001
				2-3	< .001
	3rd	$F(2, 63) = 50.76$	< .001	1-2	< .001
				1-3	< .001
				2-3	< .001
ES2	2nd	$F(2, 66) = 42.47$	< .001	1-2	< .001
				1-3	< .001
				2-3	.286
	3rd	$F(2, 63) = 41.76$	< .001	1-2	< .001
				1-3	< .001
				2-3	.302
ES3	2nd	$F(2, 66) = 27.10$	< .001	1-2	.003
				1-3	< .001
				2-3	< .001
	3rd	Brown-Forsythe $F(2, 50.89) = 37.54$	< .001	1-2	.034
				1-3	< .001
				2-3	< .001
Delayed post-test	2nd	$F(2, 66) = 40.63$	< .001	1-2	< .001
				1-3	< .001
				2-3	< .001
	3rd	$F(2, 63) = 37.74$	< .001	1-2	< .001
				1-3	< .001
				2-3	< .001

Table 11. Project 8

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 25)		**Group2 (*N* = 25)**		**Group3 (*N* = 25)**					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	**Pair**	*p*
ES1	11.12	1.45	14.16	1.78	14.86	2.32	*F*(2, 72) = 31.46	< .001	1-2	< .001
									1-3	< .001
									2-3	.067
ES2	8.87	1.51	11.06	1.85	13.65	2.05	*F*(2, 72) = 29.51	< .001	1-2	< .001
									1-3	< .001
									2-3	.011
ES3	11.96	2.30	14.80	1.85	17.88	2.13	*F*(2, 72) = 38.02	.006	1-2	< .001
									1-3	< .001
									2-3	< .001
Delayed post-test	10.24	2.85	12.33	2.19	16.59	2.22	*F*(2, 72) = 33.55	< .001	1-2	.028
									1-3	< .001
									2-3	< .001

Table 12. Project 9

	Group1 (*N* = 82)		Group2 (*N* = 82)		Group3 (*N* = 82)		ANOVA testing		Post-hoc tests	
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	**Pair**	*p*
Pre-test	11.49	3.99	10.81	3.81	11.33	3.55	*F*(2, 243) = 0.71	.492		
ES1	12.79	4.71	15.15	4.78	17.45	3.32	*H*(2) = 37.80	< .001	1-2	.002
									1-3	< .001
									2-3	.003
ES2	11.91	5.22	13.30	4.39	15.33	3.80	*H*(2) = 19.79	< .001	1-2	.102
									1-3	< .001
									2-3	.003
ES3	11.30	5.00	13.49	3.53	15.87	2.33	Brown-Forsythe *F*(2, 241.37) = 65.63	< .001	1-2	.004
									1-3	< .001
									2-3	< .001
ES4	10.71	3.69	15.27	3.78	16.43	3.43	*F*(2, 243) = 56.63	< .001	1-2	< .001
									1-3	< .001
									2-3	.105
ES5	9.83	2.90	11.06	2.83	11.93	2.35	*F*(2, 243) = 12.47	< .001	1-2	.011
									1-3	< .001
									2-3	.780
Delayed post-test	14.90	4.41	18.02	3.66	20.83	3.85	*F*(2, 243) = 45.37	< .001	1-2	< .001
									1-3	< .001
									2-3	< .001
Misconceptions post-test	10.62	3.88	13.51	3.30	13.88	3.25	*F*(2, 243) = 21.43	< .001	1-2	< .001
									1-3	< .001
									2-3	.103

Table 13. Project 10

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 20)		Group2 (*N* = 20)		Group3 (*N* = 20)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	**Pair**	*p*
Pre-test	4.43	1.11	5.02	1.27	4.77	1.38	*F*(2, 57) = 2,16	.41		
ES1	5.85	1.73	7.50	1.99	9.65	2.48	*F*(2, 57) = 16.68	< .001	1-2	.040
									1-3	< .001
									2-3	.028
ES2	3.70	1.56	4.50	1.85	5.95	1.79	*F*(2, 57) = 8.61	.001	1-2	.320
									1-3	.001
									2-3	< .001
ES3	3.25	1.62	4.40	1.35	5.55	1.44	*F*(2, 57) = 12.41	< .001	1-2	.041
									1-3	< .001
									2-3	.041
Delayed post-test	11.10	4.61	14.35	4.11	17.80	3.82	*F*(2, 57) = 12.78	< .001	1-2	.045
									1-3	< .001
									2-3	.031

Table 14. Project 11

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 20)		Group2 (*N* = 20)		Group3 (*N* = 20)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	**Pair**	*p*
Pre-test	8.10	2.91	7.95	2.56	5.95	2.4	*F*(2, 57) = 4.16	.021		
ES1	12.03	3.55	13.20	3.27	11.35	3.33	*F*(2, 57) = 1.53	.226		
ES2	9.30	4.55	13.08	5.27	12.03	5.38	*F*(2, 57) = 2.94	.061		
ES3	10.28	4.56	10.95	4.63	11.15	5.77	*F*(2, 57) = 0.17	.846		
ES4	8.55	2.44	11.48	2.39	10.95	4.2	*F*(2, 57) = 4.98	.010	1-2	.01
									1-3	.05
									2-3	.86
Delayed post-test	10.59	3.70	10.71	4.34	11.16	3.42	*F*(2, 57) = 0.12	.886		

Table 15. Project 12

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 15)		Group2 (*N* = 15)		Group3 (*N* = 15)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Pair	*p*
Pre-test	14.80	2.48	14.67	2.19	15.00	2.39	$F(2, 42) = .076$	.927		
ES1	13.20	1.97	14.93	2.19	16.13	1.25	Brown-Forsythe $F(2, 36.219) = 9.577$	< .001	1-2	.075
									1-3	< .001
									2-3	.178
ES2	14.80	2.57	17.80	2.48	18.40	1.81	$F(2, 42) = 10.444$	< .001	1-2	.003
									1-3	< .001
									2-3	.758
ES3	17.80	1.66	20.13	1.92	21.20	1.42	$F(2, 42) = 16.071$	< .001	1-2	.001
									1-3	< .001
									2-3	.203
Delayed post-test	22.33	2.19	23.73	1.87	24.60	1.50	$F(2, 42) = 5.573$	.007	1-2	.114
									1-3	.005
									2-3	.423

Table 16. Project 13

	Group						ANOVA testing		Post-hoc tests	
	Group1 (*N* = 21)		Group2 (*N* = 21)		Group3 (*N* = 21)					
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	Pair	*p*
Pre-test	15.81	1.63	15.43	1.96	16.62	1.35	$F(2, 60) = 2.783$	.070		
ES1	22.95	1.80	21.19	2.82	24.24	1.67	$F(2, 60) = 10.,534$	< .001	1-2	.028
									1-3	.140
									2-3	< .001
ES2	22.33	1.90	22.24	2.11	23.29	1.48	$F(2, 60) = 2.045$	.138		
ES3	23.24	1.18	21.81	2.64	24.19	1.07	Brown-Forsythe $F(2, 34.983) = 9.510$	.001	1-2	.078
									1-3	.025
									2-3	.002
Delayed post-test	19.52	1.60	19.67	1.68	21.24	1.44	$F(2, 60) = 7.615$	.001	1-2	.954
									1-3	.002
									2-3	.006