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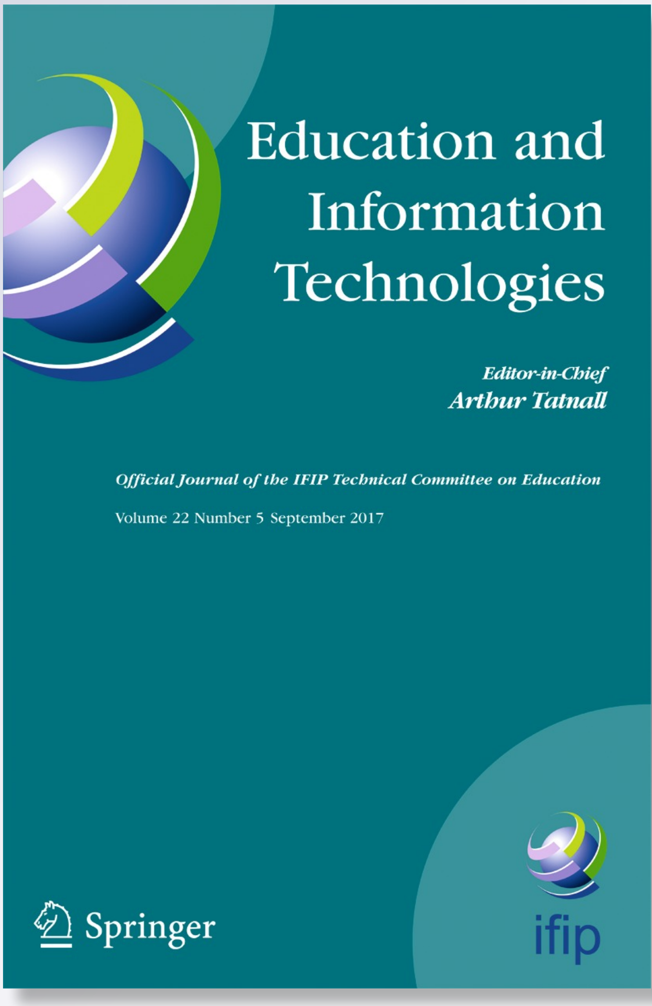

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Tablets in education. Results from the initiative ETiE, for teaching plants to primary school students

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Abstract The study presents the results from the first phase of the initiative Emerging Technologies in Education. At this stage, we examined the learning outcomes from the use of tablets and an application as content delivery methods for teaching plants' parts, reproduction types and organs, photosynthesis, and respiration. The project lasted for four months and the target group was 246 sixth-grade primary school students, divided into three groups. In the first, students were taught conventionally, using notes and the textbook. In the second, a contemporary teaching method was used, but the instruction was not technologically enhanced. The third group of students used the application. Data were collected by means of questionnaires and evaluation sheets. Results indicate that students in the third group outperformed students in the other two groups. On the other hand, there were no differences between the last two groups, regarding students' misconceptions. The findings point to the need of further investigation of the educational uses of tablets and their applications.

Keywords Mobile learning · Plants · Science education · Tablets · Ubiquitous learning

1 Introduction

The term "Emerging Technologies" (ET) includes a variety of novel and/or older -but still with a somehow controversial but definitely with an undeveloped potential- technologies, many of which are inherently educational and could easily be exploited by schools. Having that in mind, in mid-2015, in the Department of Primary School

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Education at the University of the Aegean, we laid the groundwork for the research initiative Emerging Technologies in Education (ETiE). Its main purpose is to study the results from the use of a variety of ET (e.g., tablets, virtual and mixed reality, 3D printers and drones) in an educational context. ETiE does not focus on a single teaching subject or on a single age group; on the contrary, it seeks to cover most, if not all, of primary and high school's classes and subjects. The paper at hand presents ETiE's first phase which involved the use of tablets for teaching subjects related to plants.

In recent years, the rise of smartphones and tablets has taken the world by storm. In education, they have exponentially increased the opportunities for mobile and ubiquitous learning, as their unique capabilities and affordances give them a competitive edge over computers as well as other mobile technologies. Studies conducted worldwide suggest noteworthy positive effects when using them; increased collaboration among students, increased motivation, more creative work, a greater variety of resources and types of learning material, development of IT skills, and a more personalized learning experience, to name but a few (Karsenti and Fievez 2013).

Science subjects are challenging for both teachers and students. Many teachers face problems when teaching such subjects (Appleton 2002), and, as a result, they usually revert to more conventional instruction (Mueller et al. 2008). Students also have problems in comprehending science concepts and their performance is generally poor (Forsthuber et al. 2011). A knowledge domain in which students' misconceptions and problems in understanding are quite significant is plants, and more specifically the purpose and function of plants' parts, reproduction types and organs, photosynthesis, and respiration (Barman et al. 2006).

Although there is a growing body of research regarding the use of tablets in education, their use still constitutes a novelty in the Greek educational mainstream. Furthermore, and to the best of our knowledge, the use of tablets for teaching plants' concepts is limited (e.g., Liu et al. 2014). Towards this end, in the context of ETiE, a project was designed in order to investigate the learning outcomes of teaching plant's concepts to sixth-grade primary school students using tablets, in comparison to conventional and contemporary teaching methods, which were not technologically enhanced. The project's results are presented in the coming sections.

2 Tablets in education

In recent years, mobile devices, such as tablets and smartphones enabled users to have an unparalleled access to communication and information, due to their increased affordability and functionality. In an educational context, these devices can support learning in new ways, leading to what is called mobile learning (Shuler et al. 2012b). Their portable nature allows them to be used virtually everywhere and anytime, facilitating what has been termed as "ubiquitous or seamless learning" (van't Hooft 2013; Wong 2012); bridging formal and informal learning as well as school and everyday life (Seipold and Pachler 2011).

Research has highlighted a number of key benefits for students when they use mobile devices for learning. Among them, personalized and independent learning, and the development of metacognitive skills are noted (Kearney et al. 2012), which, in turn, facilitate self-directed learning (Wong 2012). Greater motivation for learning and a better understanding of the learning process are also acknowledged (Snell and Snell-

Siddle 2013). Increased degree of collaboration is highlighted by others (e.g., Kearney et al. 2012). According to van't Hooft (2013), collaborative learning is supported due to the high mobility and the small form factor of the mobile devices and, as such, they do not obstruct or interfere with face-to-face interactions. Also, mobile devices give students the opportunity to constantly assess and reflect on their learning progress and therefore, achieve greater autonomy (West 2013). On the other hand, their successful integration requires changes to education in order to be used in meaningful ways (van't Hooft 2013).

Coming to tablets, it can be argued that they have certain advantages over other mobile devices (e.g., larger screens, greater processing and battery power). Since their prices continue to decline, they are becoming even more affordable. Then again, their educational impact is still largely unknown because of the absence of thorough empirical studies; more research is needed in order to assess their impact on learning/teaching (Dhir et al. 2013). Much of the research on tablets replicates the findings from studies on other mobile devices. Studies had shown that their use is associated with increased collaboration among students, increased motivation, more personalized learning, more creative work, improved quality of students' and teachers' presentations, a greater variety of resources and types of learning material, and development of IT skills (Karsenti and Fievez 2013). On the negative side, research had pointed out that tablets may be a source of distraction for students because they tend to use them for non-educational purposes during lessons (e.g., Henderson and Yeow 2012; Kinash et al. 2012).

Two important issues that have to be considered are the tablet-to-student ratio and whether students should be allowed to take and use them at home (in case they do not own one). While a survey concluded that the low device-to-student ratio was the main hindrance to carrying out the potential benefits of tablets (Rikala et al. 2013), on another, where they were shared and not used as personal devices, positive impacts on learning were observed (Henderson and Yeow 2012). Studies also suggest that personal ownership and/or the ability to take tablets at home are important factors for their successful use, for increasing motivation, autonomy, and self-efficacy (Burden et al. 2012), because pupils had the ability to access the learning material outside school (Grant and Barbour 2013) and, since learning is a highly personal experience, they could take responsibility for their own learning (Bjerede and Bondi 2012).

Tablets are not educational tools per se; suitable interactive learning content is needed to render them as such. Researchers stress that currently there are only a few studies on the impact of educational applications for mobile devices and that this is a field where academia and the industry must closely collaborate (Shuler et al. 2012a). For the past few years, one of the most debated types of mobile applications are the ones that employ Augmented Reality (AR). Though this technology is not new, it has become widespread due to mobile devices. In short, AR allows an enhanced (augmented) way of presenting the real world to the user, by adding to it multimedia elements, and/or 3D graphics, and/or GPS data (Graham et al. 2013). By doing so, reality is enriched (Klopfer and Squire 2008), while users can interact with data that "emerge" to the real world (Andújar et al. 2011).

AR applications can be found for almost all teaching/learning subjects and there is a growing body of research on their impact on education (Johnson et al. 2014). They allow learners to have a better understanding of complex spatial relationships and abstract concepts (Cheng and Tsai 2013) and to experience phenomena that cannot be the experienced in the real world (Klopfer and Squire 2008). Increased motivation for learning is also noted (Chang et al. 2014; Di Serio et al. 2013). These benefits for students have rendered AR an important educational asset (Martin et al. 2011).

A number of learning theories provide the necessary framework for the use of tablets and their applications in education:

- Constructivism. According to this theory, learners build personal interpretations of the world based on their experiences and interactions, knowledge has to be embedded in the situation in which it is used, effective use of knowledge comes from engaging the learner in real-world situations, and knowledge is validated through social negotiation (Ertmer and Newby 2013).
- Social learning theory, in which collaboration is also important (Bandura 1977). Concepts are presented in a theoretical and in a practical level, while students work as young scientists through applications that provide this functionality.
- Dual coding theory, which postulates that when both visual and verbal information is used to represent information, students' learning is advanced (Clark and Paivio 1991).
- Elements of game-based learning and place-based learning were also used as a theoretical framework in studies (e.g., Wojciechowski and Cellary 2013).

3 Plants as a teaching/learning subject

Children build their understanding of biological concepts through their interactions with the world around them and through direct experiences with living organisms (French 2004). Although young children have an innate interest in plants, this interest gradually wanes, mainly for two reasons:

- Plants are habitually described as immobile, faceless objects with a non-threatening presence and, as such, they are not "exciting".
- Plants are underrepresented in the curriculum (Lally et al. 2007) and, often, teachers overlook their teaching (Sanders 2007). This holds true for the Greek educational system, since the teaching units regarding plants are very few, scattered, and not well organized (Koumaras 2007). In addition, important concepts are not thoroughly examined (Tekos and Goumas 2007), while in one grade (fifth) there is not even a single page regarding plants (for the complete primary school's science curriculum in Greece see http://ebooks.edu.gr/new/ps.php, available only in Greek).

The above result to a "plant blindness" as coined by Wandersee and Schussler (2001); students have a limited knowledge on plants and develop a wide range of misconceptions regarding them. In fact, research has shown that these misconceptions are introduced and reinforced at early ages (Barman et al. 2006). For example, students do not consider trees to be plants, or they do not consider an organism to be a plant unless it has flowers (Bell 1981). Coming to plants' structure and nutrition, students' misconceptions become even more intricate. Students will often anthropomorphize explanations around plants (Anderson et al. 2014). For example, they think that plants need food to grow in much the same way that people need food (Smith and Anderson 1984) and ingest the same way that people ingest their food (Roth 1984).

The concepts of photosynthesis and plant respiration and the related misconceptions are widely studied. It was found that students of all ages and even high-school students do not comprehend the nature and function of plant respiration and have little understanding of the relationship between photosynthesis and respiration, even though they know that these processes take place in the green parts of plants (Anderson et al. 1990). For example, they think that plants respire only if photosynthesis is not occurring (Özay and Öztaş 2003). It was also found that these misconceptions are persistent even after teaching (Marmaroti and Galanopoulou 2006).

Finally, concepts related to plant reproduction, although not so widely studied, are also known to be a source of students' problems and misconceptions (Barman et al. 2006). Apparently, students exhibit a lack of understanding of how plants reproduce and, in particular, the mechanism of sexual reproduction. For example, students do not understand that flowers are the source of fruit and that pollination is related to sexual reproduction (Schussler and Winslow 2007). On another study, it was noted that students could not cite a discernable mechanism for sexual reproduction in plants (Lewis and Wood-Robinson 2000). Students also confuse pollination with fertilization and have the tendency to think that pollination is solely dependent on animals and insects (Hershey 2004).

There is a debate on how these misconceptions must be viewed and treated. If viewed as simple mistakes, or lack of knowledge, their role in students' learning is minimized. On the other hand, they can be utilized as starting points for science instruction (Smith et al. 1994). Toward this end, Vosniadou (2002) argues that misconceptions, though naïve, are the result of complex processes by which children organize their perceptual experiences and information; thus, instead of replacing them, they have to be reorganized through instruction.

It seems that students are not the only ones facing problems in understanding science concepts. Teachers have problems too, because of their limited science content knowledge and are highly dependent on curriculum materials to guide their pedagogical decisions and teaching (Trundle et al. 2002). What is more, textbooks, sometimes, serve as the only source of their own science learning (Remillard 2005). Supporting teachers in learning basic physics concepts has proven to be a challenging task (McDermott et al. 2000). It was also noted that their misconceptions are very similar to the ones that younger students have (e.g., Frede 2006) and it is possible to convey their misconceptions to their students (Grossman and Thompson 2004).

4 Research design, methodology, and implementation

On the basis of the problems students face regarding plants and the educational potential of tablets and their applications, as presented in the preceding sections, a project was designed and implemented having the following research hypotheses:

- H1. The use of tablets for teaching plant's concepts produces better learning outcomes compared to conventional and contemporary teaching methods.
- H2. The results are also better regarding students' misconceptions.

The target group was sixth-grade students (11–12-year-olds) since photosynthesis was going to be among the teaching subjects and this concept is taught in this grade. As for the teaching/learning content of the project, a holistic approach was taken. Even though sixth-grade students already know a few things about plants, since they studied related subjects in previous years, we assumed that this knowledge is fragmented and, mostly, incomplete, because plants are not thoroughly taught in the Greek primary schools. Thus, it would be appropriate to reorganize students' prior knowledge, to enrich it, to start from the basics and, gradually, move to more complex concepts. Accordingly, the following subjects were included, that each would be completed in two, two-hour sessions:

- Plants' structure. Overview of plants' parts, the function and the types of roots, shoots, and leaves (rough categorization).
- Reproduction organs. The basic parts of the flower and fruit, the function of the flower's organs, fruits and seeds, seed types, stages of seed germination.
- Pollination, fertilization, sexual reproduction with and without a flower, asexual reproduction.
- Plants' nutrition and the process of photosynthesis.
- The process of respiration.

The next step was to select a suitable application. In general, for a successful teaching, applications have to follow certain guidelines (Pengcheng et al. 2011): a) to present accurate and scientifically correct information, but with a coherent and straightforward way, b) the content should be flexible enough so as to adapt to students' needs, and c) to maximize the opportunities for learning and to guide students on important points. What was evident, after a thorough search, was that while there are quite a lot of applications regarding plants, only Arloon's Plants™ (see http://www.arloon.com/apps/arloon-plants/ for a complete list of features) met the above prerequisites and, at the same time, covered all of the project's teaching subjects. On the other hand, the application was available only in English and Spanish. After contacting the developing team, access to the application's source code was granted and, in collaboration with them, it was translated into Greek. The process lasted for about two months. It has to be noted that all plants and plants' processes are illustrated using 3D models and 3D animations, while AR elements are included, but this is not the application's prevailing feature (Fig. 1).

Literature suggests that for science subjects it is recommended students to work in groups (Harlen and Qualter 2014). Accordingly, we decided students to work in pairs, but, since ETiE could provide a sufficient number of tablets, they would have their own at their disposal. Also, students would be free to take their tablets at home, totally replacing their textbooks, since this was considered as an important aspect of the study and endorsed by other researchers (Bjerede and Bondi 2012; Burden et al. 2012; Grant and Barbour 2013).

Each teaching session would largely depend on students' active participation, having four distinct stages: a) engagement and exploration of a new concept through short activities and experiments, b) use of the application for exploring and studying the relevant material, c) application of new knowledge/concepts to

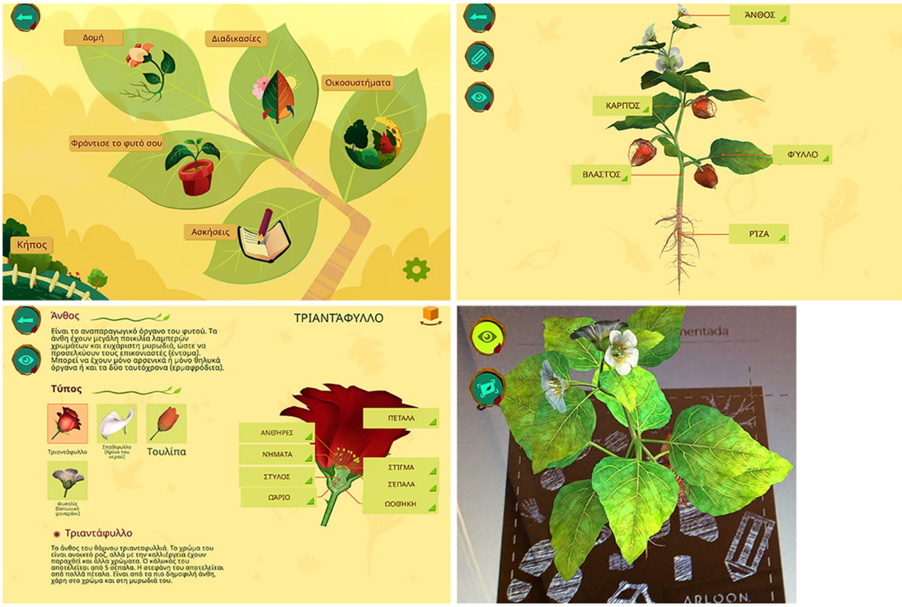

Fig. 1 Screenshots from the translated version of Arloon's Plants

everyday situations using worksheets, and d) evaluation by completing exercises (included in the application). Students would be free to discuss and to cooperate during all stages. As for their teachers, their role would be that of a facilitator; initiating the discussion in each session's subject matter, guiding students to the application's relevant section, providing technical assistance if needed, and participating in the discussions in stage (c).

During the preparatory stage of the project we created presentations for each session and we wrote a short handbook, with the same learning material the application had. It also included the same worksheets, exercises, activities, and experiments used in the previously described teaching method. The reason for doing so was because we were going to compare the learning outcomes from the use of tablets with two other teaching methods and because all but one of the project's teaching subjects were not included in the students' textbook.

The first teaching method was a conventional, teacher-centered one. As for the second, we decided to employ the BSCS's 5Es instructional model, developed by Bybee and his colleagues (2006). In short, this model has five distinct stages: a) engagement of the students in a new concept through the use of short activities that promote curiosity and elicit prior knowledge, b) exploration within which misconceptions are identified and conceptual change is facilitated through activities and experiments, c) explanation which provides opportunities for students to demonstrate their conceptual understanding, process skills, and behaviors, d) elaboration in which teachers challenge and extend students' conceptual understanding, and e) evaluation for assessing students' understanding and abilities. The main reason for selecting this instructional model was that it has been widely used in elementary, middle, and high school biology and science subjects with very good results (e.g., Wilson et al. 2010). This model was very closely related to our model, with the exceptions of the absence of tablets and the teachers' more active role.

For data collection purposes, we devised seven evaluation sheets (pre- and post-test, and one for each of the five teaching units), consisting of multiple choice, yes-no, and fill-in-the-blanks questions. We also devised a questionnaire for evaluating students' experiences and views regarding the use of tablets/application (15 Likert-type and open-ended questions), and a test for examining students' misconceptions, which was to be administered a month after the end of the lessons, together with the post-test. It has to be noted that this test was a four-tier multiple-choice test, with a total of 18 questions, inspired from Hershey's (2004) list of common students' misconceptions about plants. For each question, the first tier had three answers. The third tier had a set of three reasons for each answer to the first tier. In the second tier, students were asked to give their confidence level (sure/not sure) for the first tier, while the fourth asked students to give their confidence level (sure/not sure) for the third one. For example, a question related to respiration was as follows:

Plants respire: (a) Only when there is light, (b) only at night, (c) all day long.

Are you sure? Yes, I'm sure, Well, not so sure

You selected (a) because:

(a) The plant uses the oxygen produced by photosynthesis right away and photosynthesis takes place when there is light.
(b) When there is no light, plants' functions are minimal, close to none.
(c) To produce the respiration's carbon dioxide, the plant needs the light in pretty much the same way it needs light to photosynthesize.

You selected (b) because:

(a) Respiration is the opposite of photosynthesis and photosynthesis takes place when there is light.
(b) Respiration needs water. At night, there is more moisture in the air.
(c) Plants' stomata open at night. So, the carbon dioxide can come out of the plant only at night.

You selected (c) because:

(a) Plants' respiration is like our breathing; we breathe all the time.
(b) There is always oxygen in the air regardless if it is day or night. So, plants can use it all the time.
(c) Plants need food all the time. Respiration is their way of producing their food.

Are you sure? Yes, I'm sure, Not so sure

The reason for using this setting was because the literature suggests that such tests can accurately measure students' misconceptions (e.g., Gurel et al. 2015).

An email invitation was issued by us addressed to sixth-grade primary school teachers in Athens, Greece. We had to exclude most of the schools that responded affirmatively to the invitation because their sixth-grade classes had too few students and we wanted to avoid combining students from different schools in order to create a "pseudoschool", though others suggest it can be done (Ross 2005). Schools were also excluded because they were too far apart or because they were private schools and, consequently, the sample would not be homogeneous in terms of the socio-economic status of students (Institute of Education Sciences and National Science Foundation 2013). As a result, twelve sixth-grade classes of public schools located in nearby districts of the city of Athens were selected to participate in the project and to each, an instructional method was randomly assigned. Thus, the initial sample of the study consisted of 270 students, divided into three groups, who were taught the same subjects using three different methods.

Prior to the beginning of the project, we gathered and briefed students' parents about the project, its methodology, and objectives. Their written consent for their children's participation was obtained. Written consent was also obtained from the schools' headmasters. We also gathered and briefed the sixth-grade teachers of the participating schools and we explicitly asked them to follow the methodology that was assigned to them. Also, the teachers of the tablets group were asked to keep notes regarding major problems that might arise during the use of tablets and report them to us at the end of the project. Finally, prior to the beginning of the project, in one two-hour session, students that were going to use the tablets explored the affordances and constraints of these devices in order to proactively face difficulties while using them.

The project lasted for four months (it was not implemented simultaneously in all schools), from mid-January to mid-May 2016.

5 Results analyses

A number of students had to be excluded from the study because they were absent for more than one session. The final sample size was 246 students, coming from 12 schools divided into 3 groups of 82 students each, and each group was taught using a different method (conventional-Group0, 5Es-Group1, and tablets-Group2). For the analysis of the results, we computed scores on the basis of the number of correct answers in each evaluation sheet. It has to be noted that in the misconceptions test an answer was considered as correct only when the answer in tiers 1 and 3 were correct and the response in tiers 2 and 4 was "sure". Mean scores per group of participants and per test are presented in Table 1.

One-way ANOVA tests were to be conducted to compare the scores of the three groups in all tests, in order to determine if they had any significant differences. Prior to conducting these tests, we checked whether the assumptions of ANOVA testing were violated. We found that: a) all groups had the same number of participants (N = 82), b) there were no outliers, c) the data was normally distributed in all tests except ES1 and ES2, as assessed by Q-Q plots and Shapiro-Wilk test, and d) homogeneity of variance was not violated in all tests, except ES1, ES2, and ES3, as assessed by Levene's Test of Homogeneity of Variance. Since all assumptions for ANOVA testing were met

Table 1 Means and standard deviations on all evaluation sheets

	Group0 (N = 82)		Group1 (N = 82)		Group2 (N = 82)	
	M	*SD*	*M*	*SD*	*M*	SD
Pre-test (20)	11.49	3.99	10.81	3.81	11.33	3.55
ES1 (22)	12.79	4.71	15.15	4.78	17.45	3.32
ES2 (20)	11.91	5.22	13.30	4.39	15.33	3.80
ES3 (20)	11.30	5.00	13.49	3.53	15.87	2.33
ES4 (22)	10.71	3.69	15.27	3.78	16.43	3.43
ES5 (15)	9.83	2.90	11.06	2.83	11.93	2.35
Post-test (28)	14.90	4.41	18.02	3.66	20.83	3.85
Misconceptions test (18)	10.62	3.88	13.51	3.30	13.88	3.25

Maximum scores for each test are reported in parenthesis. ES = Evaluation sheet

for all tests except ES1, ES2, and ES3, we proceeded with the analysis. For ES1 and ES2, where both the normality of the data and the homogeneity of variance were violated, we proceeded using the Kruskal-Wallis H test, which is a non-parametric test. Even though this test does not assume that the data fit the normal distribution, it assumes that the data in different groups have similarly shaped distributions (Corder and Foreman 2009), as in our case. As for ES3, where only the homogeneity of variance was violated, we proceeded using the Brown-Forsythe test (1974), which is robust in cases of heteroscedasticity. The analyses showed that the teaching method had a significant effect on the scores in all tests, except on the scores in the pre-test, as presented in Table 2.

We conducted post-hoc comparisons using the Tuckey HSD test on all possible pairwise contrasts in all tests except ES1, ES2, and ES3. For ES1 and ES2 we used the Bonferroni approach (controlling for Type I error across tests) for the pairwise comparisons (Dunn 1964). As for ES3, we used the Games-Howell test (1976). We found

Table 2 One-way ANOVA results

Test	Result
Pre-test	$F(2, 243) = 0.71$, $p = .492$
ES1	$H(2) = 37.80$, $p < .001$. The mean rank scores of groups 0, 1, and 2 were 89.32, 123.70, and 157.48 respectively
ES2	$H(2) = 19.79$, $p < .001$. The mean rank scores of groups 0, 1, and 2 were 101.80, 118.39, and 150.31 respectively
ES3	Brown-Forsythe $F(2, 241.37) = 65.63$, $p < .001$
ES4	$F(2, 243) = 56.63$, $p < .001$
ES5	$F(2, 243) = 12.47$, $p < .001$
Post-test	$F(2, 243) = 45.37$, $p < .001$
Misconceptions test	$F(2, 243) = 21.43$, $p < .001$

that (the presentation of results differs due to the different tests used for post-hoc comparisons):

- Pre-test. There were no statistically significant differences in all pairs.
- ES1.

  Group2 and Group1. The Mann-Whitney U value was found to be statistically significant (U = 2446.00, Z = −3.02, p = .003). The difference between Group2 and Group1 was small to medium (r = −.24).
  Group2 and Group0. The Mann-Whitney U value was found to be statistically significant (U = 1491.50, Z = −6.17, p < .001). The difference between Group2 and Group0 was large (r = −.48).
  Group1 and Group0. The Mann-Whitney U value was found to be statistically significant (U = 2430.00, Z = −3.07, p = .002). The difference between Group1 and Group0 was small to medium (r = −.24).

- ES2.

  Group2 and Group1. The Mann-Whitney U value was found to be statistically significant (U = 2447.00, Z = −3.02, p = .003). The difference between Group2 and Group1 was small to medium (r = −.23).
  Group2 and Group0. The Mann-Whitney U value was found to be statistically significant (U = 2078.50, Z = −4.23, p < .001). The difference between Group2 and Group0 was medium (r = −.33).
  Group1 and Group0. The Mann-Whitney U value was found not to be statistically significant (U = 2866.00, Z = −1.64, p = .102).

- ES3. The mean total score for Group2 (M = 15.87, SD = 2.33) was significantly higher (p < .001) than that of Group1 (M = 13.49, SD = 3.53), while both were significantly higher than that of Group0 (M = 11.30, SD = 5.00) (p < .001 and p = .004 respectively).
- ES4. The mean total score for Group2 (M = 16.43, SD = 3.43) was not significantly higher (p = .105) than that of Group1 (M = 15.27, SD = 3.78), while both were significantly higher than that of Group0 (M = 10.71, SD = 3.69) (p < .001 in both cases).
- ES5. The mean total score for Group2 (M = 11.93, SD = 2.35) was not significantly higher (p < .001) than that of Group1 (M = 11.06, SD = 2.83), while both were significantly higher than that of Group0 (M = 9.83, SD = 2.90) (p < .001 and p = .011 respectively).
- Post-test. The mean total score for Group2 (M = 20.83, SD = 3.85) was significantly higher (p = .780) than that of Group1 (M = 18.02, SD = 3.66), while both were significantly higher than that of Group0 (M = 14.90, SD = 4.41) (p < .001 in both cases).
- Misconceptions test. The mean total score for Group2 (M = 13.88, SD = 3.25) was not significantly higher (p = .103) than that of Group1 (M = 13.51, SD = 3.30), while both were significantly higher than that of Group0 (M = 10.62, SD = 3.88) (p < .001 in both cases).

Taken together, these results suggest that:

- All groups had the same knowledge level regarding plants prior to conducting the research since they did not have statistically significant differences in the pre-test. As all groups had the same initial starting point, any differences observed in the participants' knowledge acquisition after the interventions, can be attributed to the different teaching methods that were followed.
- Students who used the tablets/application outperformed students in the other two groups in four (out of six) knowledge acquisition tests: a) ES1-plants' structure, b) ES2-reproduction organs, c) ES3-reproduction types, and, most importantly, d) in the post-test.
- In two cases, they had the same results with students in Group1: a) ES4 (photosynthesis) and b) ES5 (plants' respiration).
- As for the misconceptions test, students in Groups 1 and 2 had the same results and both outperformed students in Group0.

As a result of the above, H1 is confirmed, while H2 is partially confirmed.

Students made positive remarks regarding their experiences while using the tablets. More specifically, they liked the:

- 3D animations ($M = 4.26$, $SD = 0.94$).
- Application's game-like characteristics ($M = 3.95$, $SD = 1.24$).
- 3D models ($M = 3.90$, $SD = 1.15$).
- Way that the information was presented ($M = 3.80$, $SD = 1.10$).
- AR elements ($M = 3.75$, $SD = 1.42$).
- Music ($M = 3.35$, $SD = 1.50$).

In addition, they stated that they learned quite a lot ($M = 3.70$, $SD = 0.92$) and quite easily ($M = 4.50$, $SD = 0.76$). They found the application easy to use ($M = 4.20$, $SD = 1.05$) and, in general, they would like more subjects to be taught using tablets ($M = 3.90$, $SD = 1.50$). Some indicative responses to the relevant questions were:

- *It was fun. Even if I didn't understand something, it was explained to me step-by-step* (the student is referring to the application's helping system for each concept).
- *It was like playing a game but at the same time, I was able to learn about plants.*
- *I liked that I planted a flower and I was able to see it growing* (the student is referring to the 3D models that were "growing" with the passage of time).
- *With the student sitting next to me we exchanged information and learned together.*
- *I wish we were taught all lessons in the same way.*

As a final note, the teachers of the tablets group did not report any major problems regarding the in-classroom use of tablets by the students. On the other hand, few minor technical problems were indeed reported, but these were easily corrected by restarting the devices.

6 Discussion

Research emphasizes the need to combine technology, and tablets in specific, with a change in pedagogy in order the former to maximize its impact on learning (e.g., Cochrane et al. 2013; Henderson and Yeow 2012). We need to move away from the teacher-centered instructional model (Rikala et al. 2013), but we also need to change how technology is integrated into teaching and view it as an essential tool and not as a supplement (Norris et al. 2012). We embraced the above points of view and we investigated how tablets -together with an application- could be used for teaching plants' concepts. In order to compare results, we included two more groups of students, one of which was taught conventionally and the other was taught using the 5Es instructional model. Data analyses revealed that the conventional teaching did not produce good results. Especially in the post-test, students in this group scored significantly lower compared to students in the other two groups. To our view, these results emphasize the need to move away from conventional teaching methods, even if the methods that replace them are not technologically enhanced.

From the above, it becomes evident that the real question was which of the two remaining teaching methods was more effective. On the basis of the results, students in the tablets group outperformed all the other students in four evaluation sheets (including the post-test). In two cases (photosynthesis and plants' respiration) the results of the 5Es and of the tablets group were the same. Since the tablets group had statistically significantly better results in four out of six evaluation sheets, we can argue that students who participated in this group had better cognitive and metacognitive results. Consequently, we can conclude that the study's proposed method was effective, at least to a satisfactory level.

A number of key factors seem to have played an important role in achieving these results. The collaboration was not only eased by the use of tablets/application as suggested by van't Hooft (2013) but, to our view, it was enriched as suggested by Kearney et al. (2012). In addition, the application gave to students the opportunity to constantly assess and reflect on their learning progress as West (2013) also notes. The significance of the findings can be further highlighted if one takes into consideration that students in the tablets group did not receive any guidance when they used the application. Instead, they were free to work at their own pace, study the details that they were interested in for as long as they liked, and, in general, they were in control of their learning process during this lesson's phase. Students' autonomy as a crucial factor for having better learning outcomes is also noted by other researchers (Hong et al. 2000; Mayer and Moreno 2003). The increased autonomy, that was facilitated by the use of tablets, lead to personalized and self-directed learning, as suggested by other studies (Kearney et al. 2012; Wong 2012).

The results that were obtained can also be attributed to the teaching method that we used. The methodological approach was based on social learning theory and on constructivism. Both theories highlight the importance of collaboration among students as well as the elaboration of concepts on a theoretical but mainly on a practical level (Bandura 1977; Ertmer and Newby 2013). Accordingly, students should be given the chance to work as young scientists through applications that enable this feature (Bitter and Corral 2014). All of the above were actually implemented since students worked together on activities before and after the use of tablets. Studies suggest that collaboration together with the use of mobile devices allows a more thorough understanding of the physical phenomena that are studied and produces better learning outcomes (e.g., Rahn and Kjaergaard 2014).

The application that we used was not a purely AR one, though AR elements were present. Students were positive regarding its AR aspects but the 3D models and the 3D animations impressed them even more. Even though the application's AR elements seem to have played a role in attracting the interest of students, we cannot be conclusive regarding their exact role in achieving the learning outcomes that we observed.

Also, the results were inconclusive regarding the effectiveness of tablets -and of the application that was used- in dealing with students' misconceptions. What is certain is that conventional teaching produced poor results (compared to the other two methods). On the other hand, misconceptions are persistent and hard to deal with (Barman et al. 2006; Smith et al. 1994; Vosniadou 2002). Furthermore, the literature suggests that misconceptions can be swayed by attitudes toward science (Usak et al. 2009). Therefore, it would be unrealistic to expect students to develop strong positive attitudes towards science and to overcome all their misconceptions regarding plants in the short period of time that the intervention lasted. Then again, given the similarities between our teaching method and the 5Es teaching method and the fact that both had better results compared to conventional teaching, we can assume that it is possible to develop a more comprehensive method based on the principles of the aforementioned methods.

According to students' responses to the relevant questionnaire, the application's characteristics had a positive impact on them; they were actively engaged, they enjoyed using it, they learned quite a lot about plants, and the whole process seemed to them like a game. Fun and the game-like settings as facilitators of the learning process when using tablets and their applications, as well as the resulting greater motivation for learning, are also noted by other researchers (e.g., Snell and Snell-Siddle 2013; Wojciechowski and Cellary 2013). In addition, students did not experience any problems when using the tablets/application, probably due to their familiarization with electronic devices as proposed by other researchers (Medicherla et al. 2010; Rahn and Kjaergaard 2014).

Although some suggest that the in-classroom use of tablets might be problematic since students can use them for non-educational purposes (e.g., Henderson and Yeow 2012; Kinash et al. 2012), no such problems were reported. Presumably, the teaching methodology and the lessons' organization did not allow the occurrence of such phenomena. We are also in support of the idea that students should have their own tablets and to be able to take them home, as suggested by other researchers (Burden et al. 2012; Grant and Barbour 2013). We believe that by doing so, students in our study were able to familiarize themselves with these devices and use them even more effectively (in contrast to sporadic and time-limited in-classroom usage).

The research imposed some restrictions that do not apply in real life. We purposively minimized the teacher's involvement and maximized the use of tablets. This does not imply that we underestimate the importance of teachers. In actual school settings, teachers are the ones that work closely with students. Also, the affiliation between a teacher and his/her students is an intimate one and fundamental for students' success in school (Hamre and Pianta 2006). For that matter, we expect the learning outcomes of interventions similar to ours to be even better.

The results, as discussed above, have implications that are not limited only to education. Our study had to rely on a ready-made application. What became evident was that, in some cases, there are more applications for mobile devices on a given topic than one can possibly absorb. Then again, this does not necessarily mean that they are quality applications. Furthermore, quality applications are not necessarily suitable for educational use. The above holds true for the present study. We were able to find a number of applications, but just one suited the study's needs and met our -educational- criteria. Even so, it was not perfect; certain aspects of it could have been better. Therefore, it is imperative educators and software houses to work closely together as Shuler et al. (2012b) suggested. As educators, we need to set the guidelines and software engineers need to inform us of technology's affordances and constraints. Sharing knowledge and experience, as well as close collaboration, are the keys to maximizing the educational potential of tablets and mobile applications.

7 Conclusion

The study has limitations that need to be acknowledged. Even though all necessary precautions were taken, one cannot be certain whether the tests and questionnaires accurately recorded students' knowledge and views. The study was limited to a relatively small number of participating students and in one country, therefore, its results cannot be generalized. We also had time restrictions, imposed by the schools that did not enable us to prolong the teaching of each subject; almost certainly some subjects needed more teaching hours. Since our focus was on students' performance, we did not collect data on how well teachers were able to implement each teaching method. Finally, we did not check students' misconceptions prior to the beginning of the project; therefore, we cannot be absolutely certain for the effectiveness, in this area, of any of the teaching methods that were examined.

Further studies are needed in order to identify differences or similarities to the findings of the present study. Research can be conducted with a different timetable and age group, to investigate possible advantages or disadvantages in teaching/learning with tablets. Future studies can check whether there are gender differences in learning outcomes. Additional data collection tools can be used, for example, interviews with students and teachers that would enable us to have an in-depth understanding of how they view tablets. It would also be interesting to conduct research maximizing or minimizing the teacher's role, and/or by using computers and/or other mobile devices and compare the results. By doing so, it would be possible to determine if the outcomes can be attributed to the medium used and/or to the method.

Nevertheless, taking all limitations into consideration and in conclusion, the experimental data that were obtained reinforced our view that tablets have a positive impact on learning/teaching. Not only students were more motivated and engaged in the learning process but, more importantly, the learning outcomes were good, compared to the other methods. A teaching method that allowed students to be actively involved in the learning process, increased levels of collaboration but also increased levels of autonomy, the compatibility of tablets and their applications with students' ICT skills, fun and the game-like characteristics of the application, were some of the factors that played an important role in achieving these results. On the other hand, it seems that a lot more can be done. We need to provide teachers with more and well organized applications. Towards this end, the software industry has to collaborate with educators. New teaching methods have to be devised. Our method, as well as the 5Es method, provides a good starting point. Lastly, we need to widen the research and include other teaching subjects and assessment methods. By doing so, we will be able to demonstrate the educational potential of tablets. It should be noted that ETiE is a work in progress. Our goal is to further investigate different technologies, under different contexts and settings, in order to increase the impact of technology in education.

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