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Tablets in Primary Schools:
Results of a Study for Teaching the Human Organ Systems

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ABSTRACT

This article presents the results of a short project in which tablets were used for teaching the respiratory, circulatory, and digestive systems to 162 sixth-grade primary school students who were divided into three groups. The first group was taught conventionally using a textbook, while in the second a constructivist teaching method was applied and the teachers actively participated in the process. The third group was also taught using the same constructivist teaching method, but the instruction was technologically enhanced with tablets and an application with augmented reality features. Data was collected by means of evaluation sheets and a questionnaire. The results indicated that students in the third group outperformed students in the other two groups. As for students' misconceptions, the only notable difference was between the third and first group. These results can be attributed to students' strong positive attitude towards the use of tablets, motivation, and enjoyment, as well as to the teaching method. The study's implications are also discussed.

KEYWORDS

Augmented Reality, Circulatory System, Digestive System, Mobile Applications, Respiratory System, Tablets

INTRODUCTION

The teaching of science at primary school level is a rather challenging task given that quite a lot of concepts related to science are the source of several pupils' problems (Forsthuber, Motiejunaite, & de Almeida-Coutinho, 2011). For example, the human anatomy and the systems of the human body, are subjects in which pupils have inadequate knowledge level and poor performance, while misconceptions are common (e.g., Carvalho, Silva, Clément &, 2003). On the other hand, more than a few research projects have demonstrated that contemporary instructional methods together with various Information and Communication Technology (ICT) tools have a significant positive impact on pupils' understanding of complex scientific phenomena. Alas, teachers still continue to apply conventional teaching methods, as they consider them more effective (Wilkinson & Barter, 2016). Moreover, teachers not only find it hard to use ICT tools, but they also regard ICT enhanced instruction quite difficult to implement (Zaranis, Kalogiannakis, & Papadakis, 2013).

Due to the constant technological developments, new ICT tools have emerged with interesting educational potential. In recent years, a noteworthy number of studies examined the educational uses of mobile devices (i.e., mobile phones and tablets). Coming to the teaching of science, most of the above studies demonstrated that the use of such devices had a positive impact on pupils' learning, collaboration, motivation, and creativity (e.g., Wilkinson & Barter, 2016). Also, a number of studies

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examined the use of mobile devices together with Augmented Reality (AR) applications (e.g., Fokides & Atsikpasi, 2017), which also present a very interesting educational potential.

The most significant limitations of the research to date, regarding the use of mobile devices for teaching science at primary level, are the small sample sizes and the limited timeframes. This led some to support the view that we lack thorough empirical studies (Dhir, Gahwaji, & Nyman, 2013) and robust evidence of the exact impact (positive or negative) of mobile devices on pupils' learning (e.g., Clarke & Svanaes, 2014). It seems that more research is needed in order to develop an appropriate pedagogy which can support the use of such devices in schools (Clarke & Svanaes, 2014; Dhir et al., 2013). Moreover, the use of mobile devices for teaching the human anatomy to primary school pupils is sparse.

In the light of the above, it was decided to examine whether the use of tablets can have an impact on pupils' knowledge and ease their misconceptions for certain human organ systems, namely the circulatory, digestive, and respiratory ones. Towards this end, a short project was designed and implemented, having a target group of sixth-grade primary school pupils. In the sections to follow, a brief review of the literature regarding the teaching of the above systems is presented, followed by the literature review regarding the educational use of tablets and AR applications. Next, the research rationale, methodology, and the results analyses are presented. Subsequently, the results are discussed and the conclusion completes the work.

BACKGROUND

The Digestive, Circulatory, and Respiratory Systems as Teaching/Learning Subjects

The human anatomy is a subject which is included, in primary level, in many educational systems. For example, in Greece and in the UK, it is taught in the sixth grade (Hellenic Ministry of Education, 2011; UK Department of Education, 2015), while in Sweden, the relevant modules are included in grades four to six (Swedish National Agency for Education, 2011). Then again, the teaching of this subject is challenging since the relevant literature suggested that pupils' understanding of several biological phenomena and functions is problematic. This holds true for most human organs and/or systems, including the respiratory (Tracana, Varanda, Viveiros, & Carvalho, 2012), the circulatory (Gatt & Saliba, 2006), and the digestive (Garcia-Barros, Martínez-Losada, & Garrido, 2011) ones. Moreover, pupils have trouble understanding how the various organs and/or systems interact with each other (Arnaudin & Mintzes, 1985), as they consider them independent components of the body (Reiss & Tunnicliffe, 2001).

The problems become even greater when it comes to pupils' misconceptions regarding the above systems. Misconceptions are incorrect views or opinions, the result of faulty thinking or understanding. Pupils form misconceptions because they tend to explain the world that surrounds them on the basis of their senses and everyday experiences (Allen, 2014). Thus, they tend to reject what is scientifically accurate and it takes a lot of time and effort to correct their misconceptions (Barman, Stein, McNair. & Barman, 2006).

Examples of common pupils' misconceptions regarding the respiratory system are the inclusion of irrelevant organs such as the stomach (Garcia-Barros et al., 2011), the wrong size and placement of the lungs (Mintzes, 1984), the inclusion of two tracheas and two unconnected lungs (Tracana et al., 2012), and that the air we inhale remains to our neck or head (Allen, 2014). As for the circulatory system, the shape of the heart is often depicted as the well-known symbol of the heart (Gatt & Saliba, 2006; Mintzes, 1984) and with three cavities instead of four (Arnaudin & Mintzes, 1985). Its role is also misunderstood; pupils think that it filters the blood (Özgür, 2013). The understanding of how the organs of the digestive system function is also problematic. For example, the stomach is thought to be a balloon, not connected to the mouth, and without an entrance or exit (Shaw, 2010). In other cases, the digestive system is depicted like a simple tube (Carvalho et al., 2003) that its role is to melt the food (Cakici, 2005). Also, digestion is considered the removal of food from the stomach just to make room for more food (Garcia-Barros et al., 2011)

Conventional teaching methods are ineffective for teaching science or for easing misconceptions, although teachers still use them widely (Wilkinson & Barter, 2016). Few use contemporary teaching approaches such as role-playing games, diagrams, experiments, teamwork, cognitive conflict, concept maps, and problem-solving, which are more resultful instructional techniques when it comes to science-related courses (Novak, 2010). Apparently, we need to change how we teach science by applying more effective and, at the same time, more appealing (to pupils) teaching methods (Osborne & Dillon, 2008).

Tablets, Mobile Devices, and Augmented Reality in Education

Tablets, smartphones, and mobile devices in general released education of its spatial and temporal limitations, allowing what is called mobile and ubiquitous learning. In short, mobile learning is the utilization of mobile devices for educational purposes (Sharples & Roschelle, 2010), while ubiquitous learning is the capacity to access any kind of learning material, anywhere, and anytime (Murphy, 2011). Researchers embrace the view that mobile learning offers novel educational experiences and that it can improve the learning process (e.g., Ferdousi & Bari, 2015; Zaranis, 2018). That is because, besides the better learning outcomes (e.g., Hahn & Bussell, 2012; Huang, Chen & Ho, 2014), pupils become motivated (e.g., Al-Mashaqbeh & Al Shurman, 2015), actively engaged in the learning process, and develop positive attitudes towards learning (Görhan, Öncü & Şentük 2014). Furthermore, learning using mobile devices is flexible and can adapt to different learning preferences/styles (Rossing, Miller, Cecil, & Stamper, 2012). As a result, these devices allow personalized and independent learning (Kearney, Schuck, Burden & Aubussona, 2012), by facilitating self-directed learning (Wong, 2012). Also, pupils can constantly evaluate their progress, thereby achieving even greater autonomy (West, 2013). At the same time, collaborative learning is fostered (Clarke & Svanaes, 2014; Ferdousi & Bari, 2015) because their use in teaching boosts the interaction and cooperation between pupils (Rossing et al., 2012).

However, there were cases in which the learning outcomes were not that good (e.g., Perry & Steck, 2015), probably because the use of portable devices in teaching/learning still has a relatively undeveloped pedagogy (Clarke & Svanaes, 2014). Other negative aspects include the increased pupils' cognitive load (Chu, 2014) and distraction, as pupils tend to use mobile devices, during teaching, for purposes irrelevant to their learning tasks (Henderson & Yeow, 2012; Wilkinson & Barter, 2016). Technical problems, such as the need to charge the devices frequently, and incompatibilities of the software being used with the curriculum were also noted (Al-Mashaqbeh & Al Shurman, 2015).

An interesting category of mobile applications is that of AR. AR is a technology which 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 features of AR applications can ease 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 the teaching of science courses yielded satisfactory results (e.g., Sun, Looi, Wu & Xie, 2016), increased pupils' interest and motivation for learning (Bower, Howe, McCredie, Robinson, & Grover, 2014). A plausible explanation for these outcomes is that since, in AR, the user interacts with the material presented to him/her, this can lead to a better understanding of concepts which are abstract and complex (Ibáñez, Di Serio, Villarán & Kloos, 2014) or impossible to observe in real life (Billinghurst & Dünser, 2012). Chemistry (Cai, Wang & Chiang, 2014), Astronomy (Fleck & Simon, 2013), and Biology (Crompton, Burke, Gregory, & Gräbe, 2016) are some examples of the use of AR in science teaching. Finally, tablets together with an AR application with 3D features were used for the teaching of the human anatomy, with equally interesting results (Wilkinson & Barter, 2016).

MATERIALS AND METHODS

Given that tablets and AR applications present an interesting alternative method for teaching science to primary school pupils, a short project was designed in order to examine the learning outcomes of such an endeavor. The respiratory, digestive, and circulatory systems were chosen as the teaching subjects, because in these systems pupils face significant problems, as presented in a previous section. A quasi-experimental design with three groups (one control and two experimental) was selected because data from intact classrooms were analyzed for their differences in the learning outcomes.

Participants and Duration of the Project

Sixth-grade primary school pupils (ages 11 to 12) were the target group, because, according to the Greek primary school curriculum, at this grade pupils are taught subjects related to the human anatomy. An email invitation was issued, addressed to primary schools in Athens, Greece. Although quite a lot of schools responded affirmatively, most had to be excluded because they (a) had few pupils, (b) were too far apart, and (c) were private schools thus, the sample would not be homogeneous in terms of the socioeconomic status of pupils. A second set of selection criteria was applied to pupils of the shortlisted schools (a) to have never before used tablets during their teaching, (b) to have never before been taught the human organ systems included in this study, and (c) to reflect the spread of ability in a typical Greek sixth-grade class.

As a result, a total of 177 pupils were recruited from nine sixth-grade classes of five neighboring public primary schools. To each class one of the three instructional methods, described in the "Procedure" section, was assigned forming three groups of -more or less- equal size. Pupils' parents were briefed about the project and their written consent for their children's participation was obtained. Also, the teachers were briefed and they were asked to strictly follow the teaching method that was assigned to them. The project lasted for about two months (eight two-hour sessions in each class, two sessions per week), from early October to late November 2017, since it was not conducted simultaneously to all schools.

Hypotheses

On the basis of what was presented in the previous sections, the following research hypotheses were tested:

- **H1:** A constructivist teaching method together with the use of tablets and of an application with AR features, yields better learning outcomes, with respect to the human respiratory, digestive, and circulatory systems, compared to other teaching methods.
- **H2:** The same applies to pupils' misconceptions.
- **H3:** Pupils form positive views and attitudes for their teaching using tablets.

Materials

In order to select the most suitable application for the project, an extensive search was conducted, revealing a significant number of interesting applications. However, most of them had to be rejected during the initial screening, because they either provided a minimal amount of information or the information was so complex and detailed, that it exceeded the mental capacities of an average primary school pupil. The remaining applications were evaluated using a set of criteria (a) related to the project's specific needs and (b) suggested by the relevant literature (e.g., Zydney & Warner, 2016). For example, the application had to have AR features and 3D models, to be easy to use, to include questions and tests for pupils' self-assessment, and the learning material to be scientifically correct and compatible with Greece's primary school curriculum. As a result, Arloon's "The human anatomy" (Arloon, 2015) was selected to be used in the project (Figure 1).

Also, a short handbook was written, which included all of the application's learning material (texts, images, exercises, additional information, and tests). In addition, a series of PowerPoint presentations were written, based on the above learning material. Finally, a series of worksheets were written, which included activities related to the three organ systems. The handbook's, as well as the application's learning material, were organized into eight two-hour units/sessions; two for the respiratory, three for the circulatory, and three for the digestive system.

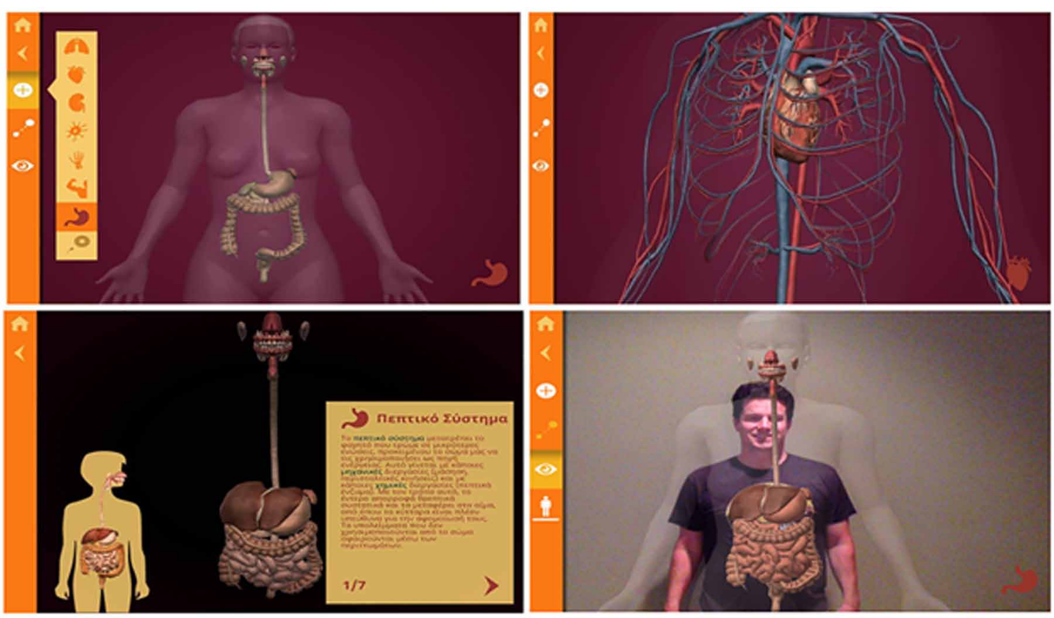
Procedure

As already mentioned, the participating pupils were divided into three groups. To the first, which served as the control group, the prevailing teaching procedure in Greece's primary schools was followed. The teachers made a short introduction, followed by examples and presentations (using the classes' video projectors) on what pupils were about to learn. Next, pupils studied the relevant units in the textbooks, while the teachers provided guidelines and examples to the whole class when needed. Finally, pupils completed the exercises, presented the answers/solutions to the rest of the class, and checked whether their answers were correct.

Constructivism provided the theoretical framework to the other two groups. According to this theory, social interactions help learners to build their personal interpretations of the world, knowledge has to be embedded in the situation in which it is used, engagement of the learner in real-world situations allows the effective use of his/her knowledge, and knowledge validation is done through social negotiation (Ertmer & Newby, 2013). Moreover, in the teaching of science courses, it is advised pupils to work in small groups (Harlen & Qualter, 2014). Consequently, it was decided pupils to work in pairs and to apply Driver's and Oldham's (1986) teaching model. This model suggests five distinct instructional stages (a) orientation, (b) elicitation, (c) restructuring, (d) application, and (e) review.

As in the first group, the second group of pupils did not use tablets. In the orientation stage, introductory presentations and discussions tried to motivate pupils about the new knowledge/concept. During the elicitation stage, the pupils articulated their current understanding of the subject by working with worksheets, by discussing, and by recording their views and ideas. In the restructuring stage,

Figure 1. Arloon's "The human anatomy"



they studied the relevant units in the textbook and exchanged ideas. During the application phase, the pupils checked whether their initial views and ideas were correct, studied the additional information available in the textbooks, and tried to apply the newly acquired knowledge to other situations by working with worksheets. In the review stage, they completed the textbook's exercises, discussed and reflected on their answers. In all stages, the teachers acted as facilitators of the process by initiating or joining in pupils' discussions, by drawing their attention to important aspects of the subject, and by providing guidelines.

The third group was the one that used the tablets and the AR application. As in the second group, pupils worked in pairs, were free to discuss and collaborate. Each pair had one tablet at its disposal because the literature suggested that there is a positive impact on learning when tablets are shared and not used as personal devices (Henderson & Yeow, 2012). Also, Driver's and Oldham's teaching model was used, but the tablets replaced the textbooks in the restructuring, application, and review stages. It has to be noted that in a session prior to the beginning of the project, the pupils explored the affordances and constraints of tablets, without running the application, in order to proactively face any difficulties while using them.

One might argue that the teaching procedure followed in the first group was very different compared to the other two groups. On the other hand, this group provided the baseline, what can be achieved during everyday teaching, without any special settings or the use of technology. Consequently, it would be easier to assess the differences between everyday teaching, a well-organized teaching, and a well-organized teaching which is technologically enhanced.

Instruments

For data collection purposes, a total of ten evaluation sheets were devised (pre- and delayed post-tests, and one for each of the eight teaching units), consisting of yes-no, multiple choice, fill-in-the-blanks, and open-ended questions. All evaluation sheets were structured so as (a) to fully cover the content of each unit, (b) the questions to be of escalating difficulty, (c) half of the questions to check the knowledge that pupils acquired, and (d) the other half to require a certain degree of critical thinking, since pupils were asked to apply this knowledge to everyday and/or new situations. The pre-test was administered prior to the beginning of the project; its purpose was to check whether pupils, in all groups, had initially the same knowledge level regarding the human anatomy. The evaluation sheets were administered immediately after the end of each session. The delayed post-test was administered two weeks after the end of all sessions and included questions from all the teaching units.

A questionnaire for evaluating pupils' experiences and views regarding the use of tablets/application was also devised, consisting of two open-ended and fifteen five-point Likert-type questions. This questionnaire was administered to the third group. Scores were obtained by allocating numerical values to responses: "Strongly Disagree" scored 1, "Disagree" scored 2, "Neutral" scored 3; "Agree" scored 4, and "Strongly Agree" scored 5.

Finally, two tests for examining pupils' misconceptions were devised (a pre- and a post- one). It has to be noted that both were four-tier multiple-choice tests since such tests accurately measure pupils' misconceptions (Gurel, Eryilmaz, & McDermott, 2015). Each test had twenty questions, inspired by the relevant literature regarding common pupils' misconceptions, as presented in the "The circulatory, digestive, and respiratory systems as teaching/learning subjects" section. For each question, the first tier had three answers. The third tier had a set of three possible explanations for each answer given to the first tier. The second and fourth tiers asked pupils for their confidence level (sure/not sure) for the first and third tiers respectively. An answer was considered correct if the answers to the first and third tiers were correct and the confidence levels to tiers two and four were high. An example of a question related to the digestive system was as follows:

1st Tier. The role of the stomach is to: 1. provide a temporary storage place for food, 2. perform just the second stage of digestion, 3. perform all the important stages of digestion

2nd Tier. Are you sure? Yes, I'm sure; Well, not so sure
3rd Tier. You selected 1. because:

1. The small intestine is, well, small, so all that food has to be stored before moving there
2. It takes some time for the juices from the pancreas and liver to be produced, so we have to temporarily store, to our stomach, the food we ate before moving it to the small intestine
3. It takes some time for the digestive juices from our gastrointestinal tract to be produced, so we have to temporarily store the food we ate to our stomach before moving it to the small intestine

You selected 2. because:

1. Our saliva (first stage of digestion) needs to be mixed well with food and this is done during the second stage of digestion with the movements of our stomach muscles
2. The second stage is when the digestive fluids from our gastrointestinal tract are mixed with food in our stomach (with the movements of our stomach muscles) and the chime is produced
3. The second stage is when the digestive fluids from our pancreas and liver are mixed with food and saliva in our stomach (with the movements of our stomach muscles) and the chime is produced

You selected 3. because:

1. All the digestive fluids (from our gastrointestinal tract, pancreas, and liver), are mixed with food in our stomach. So, in reality, all the important stages of digestion are done in our stomach
2. The water absorption, performed at a later stage, is not really an important part of digestion. So, yes, our stomach performs all the important stages of digestion
3. The most important thing is to produce the chime in our stomach. So, yes, our stomach performs all the important stages of digestion

4th Tier. Are you sure? Yes, I'm sure; Well, so sure

RESULTS

A number of pupils had to be excluded from the study because they were absent in one or more sessions. Thus, the final sample was 162 pupils, divided into three groups of equal size; Group1 conventional teaching, Group2 constructivist teaching, and Group3 constructivist teaching with tablets. The sample size was considered adequate for an inferential statistical test, such as one-way Analysis of Variance (ANOVA), given that for 3 groups with 54 participants in each, a significance level of .05, and an expected effect size of .25, the power value was .81, which is considered acceptable (Cohen, 1988). The distribution of boys and girls in all groups was approximately the same, with girls being slightly more than boys (53% and 47% respectively). Scores in all the evaluation sheets (including the pre- and delayed post-tests, as well as both misconceptions tests) were computed on the basis of the number of correct answers. Table 1 presents the mean scores and standard deviations per group of participants and per evaluation sheet.

In order to determine whether the scores of the three groups had any statistically significant differences, one-way ANOVA tests were to be conducted. Before doing so, it was checked if the assumptions for ANOVA testing were met. It was found that all groups had an equal number of participants (N = 54), no outliers were found, the data in all tests were normally distributed (as assessed by the Shapiro-Wilk test and Q-Q plots), and the homogeneity of variance was not violated (as assessed by Levene's test). Given that all the assumptions were met, the one-way ANOVA tests were conducted. The results are presented in Table 2.

Table 1. Means and standard deviations per group and per evaluation sheet

	Group					
	Group1 (N = 54)		Group2 (N = 54)		Group3 (N = 54)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Pre-test (max = 35)	16.45	3.22	15.86	2.98	16.28	3.20
Misconceptions pre-test (max = 20)	7.18	3.02	6.49	2.12	7.40	2.32
ES1 circulatory system 1 (max = 25)	13.36	2.18	12.85	1.67	13.29	1.99
ES2 circulatory system 2 (max = 25)	12.68	2.46	13.59	2.22	13.05	1.87
ES3 circulatory system 3 (max = 25)	15.18	2.11	17.91	2.41	18.92	2.45
ES4 respiratory system 1 (max = 25)	14.17	2.47	16.92	2.12	18.64	2.71
ES5 respiratory system 2 (max = 25)	11.45	3.04	13.33	2.51	16.62	2.89
ES6 digestive system 1 (max = 25)	14.86	2.27	18.35	3.04	20.28	3.22
ES7 digestive system 2 (max = 25)	15.99	1.63	17.63	2.32	21.09	1.95
ES8 digestive system 3 (max = 25)	13.88	1.99	16.31	2.05	18.07	2.31
Average of ESs	13.95	2.27	15.86	2.29	17.50	2.42
Delayed post-test (max = 35)	19.18	3.31	22.65	2.87	25.76	3.24
Misconceptions post-test (max = 20)	11.71	2.05	12.59	1.89	13.02	2.19

Notes. ES = evaluation sheet; in parentheses the maximum score for each ES

Table 2. One-way ANOVA results

Test	*F*	*Sig.*
Pre-test	$F(2, 159) = 0.51$	$p = .604$
Misconceptions pre-test	$F(2, 159) = 1.92$	$p = .150$
ES1	$F(2, 159) = 1.08$	$p = .343$
ES2	$F(2, 159) = 2.34$	$p = .099$
ES3	$F(2, 159) = 37.29$	$p = .001$*
ES4	$F(2, 159) = 45.91$	$p < .001$*
ES5	$F(2, 159) = 46.43$	$p < .001$*
ES6	$F(2, 159) = 49.37$	$p < .001$*
ES7	$F(2, 159) = 92.73$	$p < .001$*
ES8	$F(2, 159) = 53.12$	$p < .001$*
Delayed post-test	$F(2, 159) = 59.12$	$p < .001$*
Misconceptions post-test	$F(2, 159) = 5.75$	$p = .004$*

Note. * = statistically significant difference

Post-hoc comparisons on all possible pairwise contrasts were conducted in the evaluations sheets where statistically significant differences were noted, as presented in Table 3.

Summarizing the results, the following can be noted:

Table 3. Post-hoc results

Test	Pair (groups)	*Sig.*	Group	Effect size (Cohen's *d*)
ES3	1-2	$p < .001$*	2	1.20 (large)
	1-3	$p < .001$*	3	1.63 (large)
	2-3	$p = .065$	-	-
ES4	1-2	$p < .001$*	2	1.19 (large)
	1-3	$p < .001$*	3	1.72 (large)
	2-3	$p = .001$*	3	0.70 (medium)
ES5	1-2	$p = .002$*	2	0.67 (medium)
	1-3	$p < .001$*	3	1.74 (large)
	2-3	$p < .001$*	3	1.21 (large)
ES6	1-2	$p < .001$*	2	1.30 (large)
	1-3	$p < .001$*	3	1.95 (large)
	2-3	$p = .002$*	3	0.62 (medium)
ES7	1-2	$p = .001$*	2	0.82 (large)
	1-3	$p < .001$*	3	2.84 (large)
	2-3	$p < .001$*	3	1.61 (large)
ES8	1-2	$p < .001$*	2	1.20 (large)
	1-3	$p < .001$*	3	1.94 (large)
	2-3	$p = .001$*	3	0.81 (large)
Del. post-test	1-2	$p < .001$*	2	1.12 (large)
	1-3	$p < .001$*	3	2.01 (large)
	2-3	$p < .001$*	3	1.02 (large)
Misc. post-test	1-2	$p = .069$	-	-
	1-3	$p = .003$*	3	0.62 (medium)
	2-3	$p = .521$	-	-

Notes. * = statistically significant difference; in the Group column the number indicates the group that had better results

- All three groups had the same initial knowledge level since no statistically significant differences were observed in both the pre-test and the misconceptions pre-test. Thus, it can be argued that any differences found in the evaluation sheets can be attributed to the different teaching methods.
- Group1 was surpassed in all cases, except in ES1 and ES2 where no statistically significant differences were noted. Thus, it is quite safe to assume that the other teaching methods were better compared to the teaching method that was followed in Group1.
- Group2 did not outperform Group3 in any case, while in three cases both groups had the same results. On the other hand, Group3 outperformed Group2 in six cases. Thus, it can be concluded that the teaching method that was followed in Group3 yielded better results compared to the teaching method that was followed in Group2.
- In all but one case, when comparing Group1 with Group2, and Group1 with Group3, the effect size was large.
- When comparing Group2 with Group3, the effect size in two cases was medium, while in four cases it was large.
- Although in the misconceptions post-test the mean score of Group3 was higher compared to the other groups, the only statistically significant difference that was observed was between that group and Group1 and the effect size was medium.

All in all, the above results confirm H1, but, on the other hand, H2 has to be partially rejected.

Coming to the questionnaire that was administered to pupils in Group3, a reliability analysis was run and Cronbach's alpha coefficient was found to be $\alpha = .875$, which is considered good for social research (deVellis, 2003). A strong positive attitude towards tablets and their use during teaching was evident in almost all of the pupils' responses, as seen in Table 4. Therefore, H3 was confirmed. Collaboration also seemed to have worked well ($M = 4.11$, $SD = .33$). As for the two open-ended questions, these were about what problems pupils faced and what they liked most. Some pupils ($N = 11$) reported that they had trouble handling the application's augmented reality features, especially the overlaying of 3D models in pupils (see Figure 1), but these problems were eased after some practicing. On the other hand, it seems that they liked many of the application's features; the augmented reality features ($N = 51$), the 3D models ($N = 49$), the 3D animations ($N = 46$), and the way the information was presented ($N = 43$). They also liked that they had the chance to "learn something in an unusual way" ($N = 47$).

Table 4. Pupils' questionnaire

Question	*M (SD)*
1. I collaborated with my fellow pupil nicely	4.11 (.33)
2. Working as a pair helped me to learn	3.87 (.62)
3. Using tablets during the lesson is boring*	4.03 (.76)
4. Using tablets during the lesson is an enjoyable activity	4.20 (.55)
5. Working with tablets was fun	4.32 (.58)
6. I enjoyed working with tablets	3.94 (.81)
7. Working with tablets made me want to learn more about the human body	3.71 (.60)
8. I was eager to conduct the project's lessons	4.42 (.50)
9. I found the courses very interesting	4.42 (.54)
10. I do not feel that I have learned anything*	3.58 (.66)
11. I believe that the application was like a game	4.02 (.57)
12. Working with tablets was difficult*	4.12 (.61)
13. I did not like the courses at all*	4.32 (.60)
14. I would like to use tablets again in my teaching	4.14 (.52)
15. It would be nice to use tablets in all lessons/courses	4.00 (.71)

Notes. * = a question for which its scoring was reversed; standard deviations are reported in parentheses

DISCUSSION

The first thing that it is worth noting is the results of the first two evaluation sheets which were low (in all three groups). There are two plausible explanations for this outcome. The circulatory system is difficult to understand (Gatt & Saliba, 2006), as the terminology used, the structure, and function of the heart are quite complicated. Also, pupils in groups 2 and 3 were not yet familiar with the teaching method, as it was the first time they worked in pairs, with worksheets, and with tablets. Therefore, it is logical to assume that it took some time to adjust to the way they were taught and that this had an impact on their scores.

The average mean score of the eight evaluation sheets for Group1 was 13.95 (approximately 56% of the expected maximum), for Group2 15.86 (63%), and for Group3 17.50 (70%) (see Table 1). So, there was clearly a difference between the three groups and the same applied for the delayed post-test. A well-organized and contemporary teaching method, such as the one used in groups 2 and 3, was expected to yield better learning outcomes compared to conventional teaching, such as the one used in Group1. That being said, it was not a surprise that Group1 was surpassed from the other groups in all but two cases. Thus, the real question this study was called to answer was whether the use of tablets had a measurable and meaningful effect. The short answer to the above question is that the effect was indeed significant (since in most cases the difference from the other groups was statistically significant) but also a quite large one (since the effect sizes were mostly large) (see Table 3 and the summary of the results). These results are in agreement with previous studies, which compared various teaching methods with teaching using tablets (e.g., Fokides & Atsikpasi, 2017; Furió, Juan, Seguí & Vivó, 2015; Hahn & Bussell, 2012; Huang, Chen & Ho, 2014).

While the results regarding knowledge acquisition were fairly straightforward, the same did not apply for the results regarding pupils' misconceptions, which can be viewed as an indicator of a deeper understanding of the concepts that they were taught. In all groups, an improvement was noted (see Table 1 pre- and post-misconceptions tests), but the final outcome was not that impressive. That is because in the misconceptions post-test Group1 achieved 59% of the expected maximum, Group2 63% and Group3 65%. Moreover, the only statistically significant difference that was noted was that between groups 1 and 3, which was a moderate one (see Table 3). This means that when a contemporary teaching method is paired with the use of tablets, observable differences can be expected, regarding pupils' misconceptions, only when compared to conventional teaching and not when compared to a non-technologically enhanced contemporary teaching method. Then again, misconceptions are not easy to deal with, as they are persistent (Barman et al., 2006) and can be swayed by attitudes toward science (Usak, Prokop, Ozden, Ozel, Bilen, & Erdogan, 2009). Consequently, it would be unrealistic to expect pupils to overcome all their misconceptions regarding the human organ systems they were taught in the short period of time that the project lasted.

Coming to the interpretation of the results, a series of factors might have contributed, related to either the teaching method or to tablets per se. The learning theory that framed the project was constructivism and the teaching method was based on Driver's and Oldham's (1986) suggestions. Both embraced pupils' collaboration and active learning. Pupils' responses to questions one and two (see Table 4), indicated that they valued the contribution of their partner in their learning, confirming previous studies which suggested that collaboration was fostered when tablets were shared during teaching (Henderson & Yeow, 2012), leading to positive learning outcomes (Clarke & Svanaes, 2014; Murphy, 2011; Rossing et al., 2012). This view is reinforced by the fact that pupils in Group2, who also collaborated, achieved better results compared to pupils in Group1 who were taught conventionally. At the same time, pupils were in control of their learning. That is because they were able to study at their own pace; they could examine the organs, read the additional information, and take the self-assessment tests for as many times and anytime they liked. The link between tablets, positive learning outcomes, and pupils' increased control, self-directed learning, and autonomy has been noted in previous research (Clarke & Svanaes, 2014; Kearney et al., 2012; West, 2013; Wilkinson & Barter, 2016; Wong, 2012).

The responses to questions four to six and eleven, in pupils' questionnaire, are indicators of increased levels of fun and enjoyment when using tablets and the AR application, confirming the relevant literature (e.g., Akçayır & Akçayır, 2017). Fun and enjoyment when using tablets, act as facilitators of the learning process (Fulantelli, Taibi & Arrigo, 2015; Zydney & Warner, 2016), leading to increased levels of motivation for learning (Al-Mashaqbeh & Al Shurman, 2015), as it was evident in questions seven through nine. Also, questions three, ten, and thirteen through fifteen revealed pupils' positive attitude towards the use of tablets. Positive attitudes also act as facilitators of the learning process and, together with motivation, allow the successful utilization these devices in teaching (Chen et al., 2017; Furió et al., 2015; Görhan et al., 2014).

It also quite probable that the application's AR features also played a significant role. The presentation of the human organs in 3D, allowed pupils to study them from multiple perspectives and this holds true for the included 3D animations. The detailed visualization and interaction with the learning material enhanced pupils' learning experience (Al-Mashaqbeh & Al Shurman, 2015), allowed them to have a better understanding of how these organs function, and, consequently, their performance was better, compared to the other two methods (Dunleavy et al., 2009). It is also worth noting that previous research on mobile learning suggested that the detailed visualization of a learning subject had an impact on long-term retention of knowledge (Ferdousi & Bari, 2015), a fact that may well explain why a better performance of Group3 pupils was observed in the delayed post-test.

Finally, since no significant problems were reported regarding the use of tablets (see question twelve and the open-ended questions), it is safe to assume that these devices are compatible with pupils' ICT skills (Görhan et al., 2014) and that their integration into everyday teaching will not raise additional problems (at least as far as pupils are concerned).

The study's results have implications for software developers as well as for educators. In this study, a commercial application, out of the many available, was used, but during the selection process, an important issue was brought into light. Although a wealth of applications related to the human anatomy was found, few were suitable for educational purposes and even fewer were deemed appropriate (in terms of the complexity of the learning material and of the included tests and activities) for primary school pupils. Also, only a handful of them was in Greek, although this problem had an impact only on this study's target group and may not be a problem for English speaking pupils. In any case, the lack of suitable applications highlights the need for collaboration between software developers and educators as Shuler, Levine, and Ree (2012) suggested. The former do not have the necessary educational background, while the latter are not aware of technology's affordances and limitations. The only way to develop technically as well as educationally sound applications is through close collaboration between these two groups of experts.

Also, on the basis of the study's results, a number of suggestions to education administrators and policymakers can be made. The satisfactory learning outcomes together with pupils' positive attitudes towards the use of tablets during their teaching, renders their educational exploitation an interesting idea that needs further consideration. On the other hand, in order their integration to primary education to be a successful one, certain conditions have to be met. The first is to reconsider the school's timetable and allocate more teaching hours to subjects which are taught using tablets, so as pupils to study and use them at their own pace. The second is the development of a suitable pedagogy as others already pointed out (Clarke & Svanaes, 2014; Dhir et al., 2013). In this study, constructivism provided the theoretical framework and Driver's and Oldham's teaching method was utilized. Although this scheme seems to be suitable, one has to be reminded that both were developed well before tablets were invented. Thus, teaching methods that can utilize the full potential of tablets are urgently needed.

CONCLUSION

All in all, the results of the study were interesting, as well as thought-provoking. On the other hand, there are limitations that that require some attention. The sample size, though more than sufficient for statistical analysis, could have been larger and not restricted to one city or country; therefore, the generalizability of the results is limited. The number of teaching interventions was also limited; even more human organ systems could have been included. Unfortunately, the inflexible schools' timetable and other restrictions imposed by the schools, resulted in not being able to do so. Lastly, data were collected using quantitative tools (questionnaire and evaluation sheets); qualitative tools, such as interviews and observations, would have allowed an in-depth understanding of the impact of tablets on pupils' learning.

The above limitations can set the guidelines for future research. Larger sample sizes and different age groups can provide useful insights on the impact of tablets on all levels of education. The teaching/learning subjects can include not only more organ systems of the human body but also other science-related topics. Quantitative together with qualitative tools can help researchers to thoroughly understand the benefits that tablets bring to education. Given that teachers' views and attitudes towards the use of mobile devices can have a significant impact on if, how, and to what extent these devices are used during teaching, it would be interesting to study their views on this matter. Finally, comparisons between tablets and other ICT tools can provide a better understanding of the relative advantages (or disadvantages) that these devices have.

In conclusion, tablets together with applications with AR features, are indeed an interesting alternative method for teaching the human anatomy to primary level. The pupils' enthusiasm and engagement in the learning process, the increased levels of collaboration and the learning outcomes are in support of this view. On the other hand, more and pedagogically sound applications, together with a more well-developed pedagogy are needed. Consequently, there is still a long way ahead before the full potential of tablets is realized.

REFERENCES

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1–11. doi:10.1016/j.edurev.2016.11.002

Al-Mashaqbeh, I., & Al Shurman, M. (2015). The adoption of tablet and e-textbooks: First grade core curriculum and school administration attitude. *Journal of Education and Practice*, *6*(21), 188–194.

Allen, M. (2014). *Misconceptions in Primary Science* (2nd ed.). Berkshire, UK: Open University Press.

Arloon. (2015). *The human anatomy*. Retrieved from http://www.arloon.com/en/apps/arloon-anatomy/

Arnaudin, M. W., & Mintzes, J. J. (1985). Students' alternative conceptions of the human circulatory system: A cross-age study. *Science Education*, *69*(5), 721–733. doi:10.1002/sce.3730690513

Barman, C. R., Stein, M., McNair, S., & Barman, N. S. (2006). Students' ideas about plants & plant growth. *The American Biology Teacher*, *68*(2), 73–79. doi:10.1662/0002-7685(2006)068[0073:SIAPPG]2.0.CO;2

Billinghurst, M., & Dünser, A. (2012). Augmented reality in the classroom. *Computer*, *45*(7), 56–63. doi:10.1109/MC.2012.111

Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented reality in education-cases, places and potentials. *Educational Media International*, *51*(1), 1–15. doi:10.1080/09523987.2014.889400

Cai, S., Wang, X., & Chiang, F. K. (2014). A case study of augmented reality simulation system application in a chemistry course. *Computers in Human Behavior*, *37*, 31–40. doi:10.1016/j.chb.2014.04.018

Cakici, Y. (2005). Exploring Turkish upper primary level pupils' understanding of digestion. *International Journal of Science Education*, *27*(1), 79–100. doi:10.1080/0950069032000052036

Carvalho, G. S., Silva, R., & Clément, P. (2003). Epistemological and didactical learning obstacles identified in Portuguese primary school pupils (synopsis). In *Proceedings of ESERA 2003: Research and the Quality of science Education*, Noordwijkerhout, Holland. ESERA.

Chen, C. H., Huang, C. Y., & Chou, Y. Y. (2017). Integrating augmented reality into blended learning for elementary science course. In *Proceedings of the 5th International Conference on Information and Education Technology* (pp. 68-72). New York, NY: ACM. doi:10.1145/3029387.3029417

Chu, H. C. (2014). Potential negative effects of mobile learning on students' learning achievement and cognitive load-A Format assessment perspective. *Journal of Educational Technology & Society*, *17*(1), 332–344.

Clarke, B., & Svanaes, S. (2014). *An updated literature review on the use of tablets in education. Tablets for Schools*. UK: Family Kids & Youth.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New Jersey: Lawrence Erlbaum.

Crompton, H., Burke, D., Gregory, K. H., & Gräbe, C. (2016). The use of mobile learning in science: A systematic review. *Journal of Science Education and Technology*, *25*(2), 149–160. doi:10.1007/s10956-015-9597-x

deVellis, R. F. (2003). *Scale development: Theory and applications* (2nd ed.). Newbury Park, CA: SAGE Publications.

Dhir, A., Gahwaji, N. M., & Nyman, G. (2013). The role of the iPad in the hands of the learner. *Journal of Universal Computer Science*, *19*(5), 706–727.

Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education*, *13*(1), 105–122. doi:10.1080/03057268608559933

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, *18*(1), 7–22. doi:10.1007/s10956-008-9119-1

Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, *26*(2), 43–71. doi:10.1002/piq.21143

Ferdousi, B., & Bari, J. (2015). Infusing mobile learning into undergraduate courses for effective learning. *Procedia: Social and Behavioral Sciences*, *176*, 307–311. doi:10.1016/j.sbspro.2015.01.476

Fleck, S., & Simon, G. (2013). An augmented reality environment for astronomy learning in elementary grades: an exploratory study. In *Proceedings of the 25th Conference on l'Interaction Homme-Machine* (pp. 14-22). New York, NY: ACM. doi:10.1145/2534903.2534907

Fokides, E., & Atsikpasi, P. (2017). Tablets in education. Results from the initiative ETiE, for teaching plants to primary school students. *Education and Information Technologies*, *22*(5), 2545–2563. doi:10.1007/s10639-016-9560-3

Forsthuber, B., Motiejunaite, A., & de Almeida-Coutinho, A. S. (2011). *Science education in Europe: National policies, practices and research*. Education, Audiovisual and Culture Executive Agency, European Commission.

Fulantelli, G., Taibi, D., & Arrigo, M. (2015). A framework to support educational decision making in mobile learning. *Computers in Human Behavior*, *47*, 50–59. doi:10.1016/j.chb.2014.05.045

Furió, D., Juan, M. C., Seguí, I., & Vivó, R. (2015). Mobile learning vs. traditional classroom lessons: A comparative study. *Journal of Computer Assisted Learning*, *31*(3), 189–201. doi:10.1111/jcal.12071

Garcia-Barros, S., Martinez-Losanda, C., & Garrido, M. (2011). What do children aged four to seven know about the digestive system and the respiratory system of the human being and of other animals? *International Journal of Science Education*, *33*(15), 2095–2122. doi:10.1080/09500693.2010.541528

Gatt, S., & Saliba, M. (2006). Young children's ideas about the heart. In M. F. Costa, & B. V. Dorrío (Eds.), *Proceedings of the 3rd International Conference on Hands-on Science. Science Education and Sustainable Development*, 17-23.

Görhan, M. F., Öncü, S., & Şentük, A. (2014). Tablets in education: Outcome expectancy and anxiety of middle school students. *Educational Sciences: Theory and Practice*, *14*(6), 2259–2271. doi:10.12738/estp.2014.6.2230

Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics*. *Science & Technology Education*, *11*(5), 989–1008.

Hahn, J., & Bussell, H. (2012). Curricular use of the iPad 2 by a first-year undergraduate learning community. *Library Technology Reports*, *48*(8), 42–47.

Harlen, W., & Qualter, A. (2014). *The teaching of science in primary schools* (6th ed.). Routledge.

Hellenic Ministry of Education. (2011). *Διαθεματικό ενιαίο πλαίσιο προγραμμάτων σπουδών* [Unified curricular framework]. Retrieved from http://www.pi-schools.gr/programs/depps/

Henderson, S., & Yeow, J. (2012). iPad in education: A case study of iPad adoption and use in a primary school. In *Proceedings of the 45th Hawaii International Conference in System Science* (*HICSS*) *2012* (pp. 78-87). IEEE. doi:10.1109/HICSS.2012.390

Huang, K. L., Chen, K. H., & Ho, C. H. (2014). Enhancing learning outcomes through new e-textbooks: A desirable combination of presentation methods and concept maps. *Australasian Journal of Educational Technology*, *30*(5), 600–618. doi:10.14742/ajet.538

Ibáñez, M. B., Di Serio, Á., Villarán, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & Education*, *71*, 1–13. doi:10.1016/j.compedu.2013.09.004

Kearney, M., Schuck, S., Burden, K., & Aubusson, P. (2012). Viewing mobile learning from a pedagogical perspective. *Research in Learning Technology*, *20*(1), 14406. doi:10.3402/rlt.v20i0.14406

Mintzes, J. J. (1984). Naïve theories in biology: Children's concepts of the human body. *School Science and Mathematics*, *84*(7), 548–555. doi:10.1111/j.1949-8594.1984.tb10179.x

Murphy, G. D. (2011). Post-PC devices: A summary of early iPad technology adoption in tertiary environments. *E-Journal of Business Education & Scholarship of Teaching*, *5*(1), 18–32.

Novak, J. D. (2010). Learning, Creating, and Using Knowledge: Concept maps as facilitative tools in schools and corporations. *Journal of e-Learning and Knowledge Society, 6*(3), 21-30.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: Nuffield Foundation.

Özgür, S. (2013). The persistence of misconceptions about the human blood circulatory system among students in different grade levels. *International Journal of Environmental and Science Education*, *8*(2), 255–268. doi:10.12973/ijese.2013.206a

Perry, D. R., & Steck, A. K. (2015). Increasing student engagement, self-efficacy, and meta-cognitive self-regulation in the high school geometry classroom: Do iPads help? *Computers in the Schools*, *32*(2), 122–143. doi:10.1080/07380569.2015.1036650

Reiss, M. J., & Tunnicliffe, S. D. (2001). Students' understandings of human organs and organ systems. *Research in Science Education*, *31*(3), 383–399. doi:10.1023/A:1013116228261

Rossing, J. P., Miller, W. M., Cecil, A. K., & Stamper, S. E. (2012). iLearning: The future of higher education? Student perceptions on learning with mobile tablets. *The Journal of Scholarship of Teaching and Learning*, *12*(2), 1–26.

Sharples, M., & Roschelle, J. (2010). Guest editorial: Special issue on mobile and ubiquitous technologies for learning. *IEEE Transactions on Learning Technologies*, *3*(1), 4–6. doi:10.1109/TLT.2010.7

Shaw, R. K. (2010). Truth and physics education: a heideggerian analysis [Doctoral thesis]. The University of Auckland.

Shuler, C., Levine, Z., & Ree, J. (2012, January). *iLearn II: An analysis of the education category of Apple's app stor*e. New York: The Joan Ganz Cooney Center at Sesame Workshop.

Sun, D., Looi, C. K., Wu, L., & Xie, W. (2016). The innovative immersion of mobile learning into a science curriculum in Singapore: An exploratory study. *Research in Science Education*, *46*(4), 547–573. doi:10.1007/s11165-015-9471-0

Swedish National Agency for Education. (2011). *Curriculum for the compulsory school, preschool class and the recreation centre*. Retrieved from https://www.skolverket.se/om-skolverket/publikationer/visa-enskild-publikation?_xurl_=http%3A%2F%2Fwww5.skolverket.se%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FBlob%2Fpdf2687.pdf%3Fk%3D2687

Tracana, R. B., Varanda, I., Viveiros, S., & Carvalho, G. S. (2012). Children's conceptions about respiration before and after formal teaching: identification of learning obstacles. In *Proceedings of the XV IOSTE Symposium (International Organization for Science and Technology Education)-The use of Science and Technology Education for Peace and Sustainable Development* (pp. 1-11).

UK Department of Education. (2015). *National curriculum in England: science programmes of study*. Retrieved from https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study/national-curriculum-in-england-science-programmes-of-study#key-stage-3

Usak, M., Prokop, P., Ozden, M., Ozel, M., Bilen, K., & Erdogan, M. (2009). Turkish university students' attitudes toward biology: The effects of gender and enrolment in biology classes. *Journal of Baltic Science Education*, *8*(2).

van Krevelen, D. W. F., & Poelman, R. (2010). A survey of augmented reality technologies, applications and limitations. *The International Journal of Virtual Reality*, *9*(2), 1–20.

West, D. M. (2013). *Mobile learning: Transforming education, engaging students, and improving outcomes*. Washington, DC: Center for Technology Innovation at Brookings.

Wilkinson, K., & Barter, P. (2016). Do mobile learning devices enhance learning in higher education anatomy classrooms? *Journal of Pedagogic Development*, *6*(1), 14–23.

Wong, L. H. (2012). A learner-centric view of mobile seamless learning. *British Journal of Educational Technology*, *43*(1), E19–E23. doi:10.1111/j.1467-8535.2011.01245.x

Zaranis, N. (2018). Comparing the effectiveness of using tablet computers for teaching addition and subtraction. In L. Daniela & M. Lytras (Eds.), *Learning Strategies and Constructionism in Modern Education Settings*. Hershey, PA: IGI Global.

Zaranis, N., Kalogiannakis, M., & Papadakis, S. (2013). Using Mobile Devices for Teaching Realistic Mathematics in Kindergarten Education. *Creative Education, 4*(7A1), 1-10. doi:10.4236/ce.2013.47A1001

Zydney, J. M., & Warner, Z. (2016). Mobile apps for science learning: Review of research. *Computers & Education*, *94*, 1–17. doi:10.1016/j.compedu.2015.11.001

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