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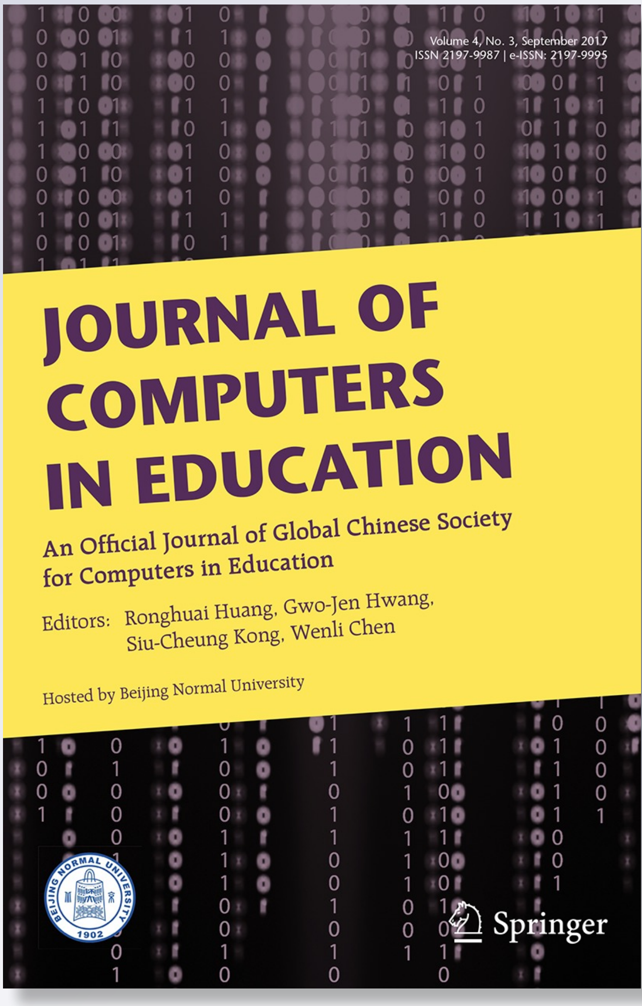

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To drone or not to drone? Results of a pilot study in primary school settings

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Abstract This study presents the results of a pilot project in which the use of drones for teaching primary school students was examined. In order to implement the project, a framework for their integration in teaching was developed, based on contemporary learning theories. Also, three short interventions were planned and carried out. Although teaching units from the mathematics, physics, and geography courses were selected, the underlying topic was common, namely, metric measurement conversions. The target group was 40 fifth-grade primary school students, divided into two groups. The first group was taught with the use of drones while the second was taught conventionally. Data were collected by means of evaluation sheets and a questionnaire. Results indicated that students in the drones group outperformed students in the conventional teaching group in the Maths evaluation sheet and in all the delayed post-tests. In the other two cases (Physics and Geography evaluation sheets), the results were the same. Students' attitudes toward drones were highly positive. Finally, the implications of the findings for education are also discussed.

Keywords Drones · Geography · Mathematics · Primary school students · Physics

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Introduction

Technological innovations are diffused across the whole spectrum of human activities, education included. Consequently, educational systems have to be in line with technological developments and adapt their content and methods accordingly. The study of emerging technologies is also essential, so as to find ways for their educational exploitation. In recent years, a new technological tool has become popular, the unmanned aerial system, a remotely controlled flying machine, widely known as a drone. Drones, as a concept, are not new. Remotely controlled airplanes and helicopters have been used by hobbyists for decades. The difference is that today they are mass produced, and they do not require the training and effort needed by hobbyists of the past.

The study of the use of drones in all levels of education is a new and interesting research field. By searching the Internet, one can find several ideas for their integration in education; however, most of these ideas are without the required experimental validation. While an extensive literature search was carried out before the study began, only a very limited number of related studies were located. Given the unavailability of previous studies, the task of conducting research regarding the educational uses of drones can be demanding, since it cannot rely on ideas and/or on the findings of previous research initiatives. Moreover, such an endeavor is not only interesting but also necessary as there are many unanswered questions and unexplored potentials that arise from the use of drones in education.

Taking into account that the impact of drones in education is largely unknown, it was quite logical to wonder how they could be used for teaching various subjects at a primary school level. In this context, a pilot project was designed and implemented in order to study exactly this. The target group was fifth-grade primary school students. Although the teaching units were drawn from the mathematics, physics, and geography courses, the common denominator was the topic of metric measurement conversions. Thus, it was examined whether the use of drones in the teaching of the above topic yields better learning outcomes in comparison to a contemporary, but not technologically enhanced, teaching method. The sustainability of the acquired knowledge and the attitudes of students toward drones were also examined. The research rationale and methodology, as well as the results of the project, are presented and analyzed in the coming sections.

Drones in education

As stated in the previous section, the examination of the educational impact of drones is at a very early stage. On the other hand, they have certain advantages compared to similar technologies already used in education. For example, small structures or objects imaged by drones provide greater detail at small scales than freely aerial photos or Google Earth (Helmke et al. 2007). In addition, since they can fly, drones provide greater mobility and flexibility compared to ground mobile robots. As for the cost of drones, the ones addressed to hobbyists are cheaper than certain robotic kits (e.g., Lego's Mindstorms). One can argue that handling a drone is more difficult than handling a robot. Non-programmable robots are certainly easier to handle, but they have less (or the same) features as drones. Programmable robots certainly provide more features, but they have to be programmed in order to execute certain functions. Despite the above advantages, only a handful of studies and articles, relevant to their use in education, were found.

For example, in higher education, drones have been used for teaching robotics (Krajník et al. 2011), in designing applications for controlling them (Winterfeldt and Hahne 2014), in geography, as well as in the examination of the ethical and legal issues that come into focus from the use of this technology (Birtchnell and Gibson 2015). Jordan (2015), suggested that they can be used in geologic fieldwork and education of undergraduate students. Carnahan et al. (2016), discussed how drones can be used in the first two levels of education. They argued that kindergarten students can acquire orientation and motor skills. Primary school students can be taught physics' concepts, such as speed, the interaction of forces, and angles. In junior high school, geography (e.g., topography) and physics (conducting observations) are suitable subjects. In addition, drones can be used for the implementation of students' projects in all science courses. The authors concluded that the use of drones can -presumably- contribute to personalized learning, provide incentives for learning, and encourage the participation of students in the learning process, due to their playful nature.

Making/assembling a drone is also an interesting idea (Levy 2015). By doing so, students can learn concepts related to robotics, mathematics, electricity, chemistry, programming, and acquire technical skills through practicing (Levy 2015; Osborne 2016). The cameras that drones can carry seem to be an important feature; even students studying art can benefit, through the editing of photos and videos taken by them (Tran 2016; Vukovic 2016). Some other ideas that stand out are teaching the powers of ten and the understanding of the macro- and microcosm (Wolpert-Gawron 2015).

SOAR (safety, operation, active learning, and research) is a four-axis model proposed by Carnahan et al. (2016) for the successful integration of drones in teaching. Each of the above axes focuses on a different aspect: the first covers safety and legal issues, the second involves handling/operational issues, the third relates to teaching, and the fourth involves the research that should be done on this issue. Moreover, the authors proposed lesson plans and real-world applications, depending on students' age levels and subject areas.

Finally, during an actual research project, Smith et al. (2015) used drones in teaching geography to 9 year-olds. Students collected data using the drones' cameras. The goals were to have students understand the differences between small and large scales, to determine the distance, to calculate the dimensions of objects, and to estimate the time of the day the photos were taken. The majority of students reported that drones enabled them to understand the above concepts. The results were attributed to the freedom of places that drones can get to during their flight, thus, creating unique sets of photographic shots and/or video recordings.

Summarizing the above, some useful conclusions can be drawn. It seems that all views converge on the idea that drones can be used in education in three main areas:

(a) for teaching science concepts through the construction of a drone, (b) in learning through operating (flying) drones, associated again with science subjects but also with arts courses, and (c) to explore topics related to legislation, ethical and privacy issues, and security. An important outcome of the literature review is that there is a considerable gap between what is theorized that can be done and what has actually been done. Most of the above studies examined the subject from a theoretical perspective, without relying on actual experimental data. Consequently, research regarding the utilization of drones in teaching is vital.

Research hypotheses, rationale, and methodology

Emerging Technologies in Education (ETiE) is a research initiative that was started approximately a year ago by a team of academics, researchers, pre- and post-graduate students, as well as Ph.D. candidates, at the Department of Primary School Education at the University the Aegean. Its main purpose was to study the educational uses of emerging technologies (e.g., tablets, virtual and augmented reality, 3D printers, and drones) in subjects taught at a primary and junior high school level. The present study falls under/within the scope of ETiE. As already mentioned, its main purpose was to examine whether drones have an impact on primary school students' knowledge acquisition. The topic that was examined was metric measurement conversions, and the target group was fifth-grade primary school students (ages 10–11). The initial sample of the study consisted of 46 fifth-grade students, in a primary school in Rhodes, Greece, divided into two groups. The reasons for these decisions will be further elaborated in the coming paragraphs. The project was implemented in October of 2016. The following hypotheses were formed:

H1: The learning outcomes immediately following the teaching of the above topic using drones are better compared to conventional teaching.

H2: The sustainability of knowledge is also better.

H3: Students form positive attitudes and perceptions regarding the use of drones as part of their teaching.

To examine the above, a pilot project was designed and implemented. The first step was to select what drones to use. The cost was the first criterion since it was necessary to obtain several of them. High-definition cameras were an essential feature because taking photos and videos is a key element of their possible educational uses (e.g., Levy 2015). Outdoors as well as indoors use was the third criterion that resulted in the exclusion of oversized -but also extremely expensive-drones. Users' safety was considered an important factor because injuries might occur if the propellers are not surrounded by a protective grille. The ease of controlling a drone was the next criterion. It was found that most remote controls allow the switching between two different settings: one for beginners and one for advanced users, altering the sensitivity and responsiveness of the controls. Flight autonomy was the last criterion. It was found that the entry-level drones (intended for hobbyists) have limited autonomy (about 10 min), while those intended for professional use clearly have greater autonomy, but also a high cost. Finally, five entry-level drones, but with high-definition cameras, were obtained, with a cost of approximately €100 each.

Constructivism provided the theoretical framework for drones' integration in teaching. 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). Another important element in the theory of constructivism, but also in other contemporary views for learning, is collaborative learning, students working together in teams (Tolmie et al. 2010). Finally, because of drones' game-like nature (Carnahan et al. 2016), elements of game-based learning were used, since literature suggests that by doing so, students achieve better learning outcomes (e.g., Khine 2011; Prensky 2001a).

The next stage was the selection of the teaching subjects and of the teaching method. The literature, as presented in the preceding section, suggests that drones can be primarily used in science courses (e.g., Birtchnell and Gibson, 2015; Carnahan et al. 2016; Wolpert-Gawron 2015), such as mathematics, physics, and geography. In the Greek educational system, and more specifically in primary school, a topic common to these courses (although examined through the perspective of each), and, at the same time suitable for teaching it using drones, is metric measurement conversions (e.g., from meters to centimeters and vice versa), that is included in the fifth-grade's curriculum. Having in mind the constructivist learning principles (e.g., collaboration, active learning, authentic activities, importance of motivation, and learning as a social activity), the teaching method was based on the constructivist instructional model, specifically the Driver-Oldham Model (1986), the Predict-Observe-Explain model (White and Gunstone 1992), and the Conceptual Change Model (Posner et al. 1982). In short, these models propose a five-stages teaching approach:

- Orientation, for motivating students towards the topic.
- Elicitation, for assessing students' prior knowledge and concepts.
- Restructuring, in which students clarify and exchange their ideas and concepts with peers and teachers, and construct new ideas.
- Application, where students test what they have learned.
- Review, which provides students the time to reflect on what they have learned.

Drones were used in the elicitation, restructuring, application, and review stages.

For mathematics, the unit that was selected was not only about metric measurement conversions but also about quick multiplications and divisions of the numbers 10, 100, and 1000. Students worked in groups, flew the drones in a straight line in the school's corridors or in the classroom, and then measured the distance that the drones had flown. The idea behind these settings was that students face difficulties in measuring the exact distance and expressing it in multiples and subdivisions of a meter (elicitation stage) and redo the flights (if they considered it necessary) for testing their ideas (restructuring stage). In the application stage, they flew the drones once more, measured the distances and practiced converting that distance in multiples and subdivisions of a meter. In order to add a game element, small challenges took place. For example, the teacher instructed the groups to fly their drones at an exact distance (expressed in various meter's multiples and subdivisions) and the winning team was the one able to -approximately- reach that distance (review stage). Students flew the drones entirely by themselves.

For physics, the unit that was selected was about the equation for speed (speed = distance/time). Thus, students had to deal with both time and metric measurement conversions. The settings were the same as in mathematics, but this time chronometers were also used and sometimes the drones were flown outdoors (in the schoolyard). The idea was that students to face difficulties in calculating drones' speed (elicitation stage), test their ideas, find the relationship between speed, time, and distance, and come up with the equation for speed (restructuring stage). During the application stage, students tried to apply the equation and calculate one of the three variables when the other two were given. For example, they flew the drones for a certain amount of time, knew the speed, calculated the distance that the drones were supposed to travel, and checked whether their calculations were accurate. During the review stage, small challenges took place once again. For example, students tried to find which drone was the fastest and challenged the other teams to find the distance that their own drone traveled, or tried to figure if there was a decrease in speed, if the drones' batteries were not fully charged.

As for geography, the unit that deals with a map's scale was selected. Metric measurement conversions were, once again, the underlying topic. This time the drones were flown in the schoolyard and the teacher helped students when drones had to be flown to great heights. Videos and pictures of the school and other objects were taken during the elicitation stage. Students were not able to calculate the actual size of objects but noted that their apparent size is changing as the height changes (elicitation stage). In the restructuring stage, the concept of scale was introduced, followed by another set of drones' flights and photos/videos for calculating the scale of objects (application). At the review stage, the groups challenged one another by presenting photos taken during the flights, giving the scale and asking for the actual size of objects to be calculated or by asking for the scale of an object. An overview of when and how drones were used is presented in Table 1.

In order to examine the significance of the project's results, two groups of students were formed. The first was taught using drones. The second was the control group. It was taught the exact same subjects, with the same duration and teaching method, but without the drones. While the control students worked in groups and the Driver-Oldham's Model was applied, the school textbooks as well as conventional media such as images, videos, and worksheets, were used. Game-like activities were also included. For example, in Geography, during the orientation stage, students were given photos of various places (taken from above) and were asked to try to determine the actual sizes of the pictures' objects. In the elicitation stage, they exchanged ideas and wrote down their ideas and explanations on why, for example,

Table 1 Where and how drones were used

Subject	Unit	Topic	How	Operated by	Where	When	Class's organization
Maths	Metric measurement conversions	Length conversions	Distance measurements	Students	Indoors	Elicitation restructuring application review	Groups
Physics	Equation for speed	Time and length conversions	Distance/time/speed measurements		Indoors/outdoors		
Geography	Map's scale	Length conversions	Photos/videos	Students/teacher	Outdoors		

the buildings look small in the pictures and if their actual sizes can be calculated (by their sizes in the photos). During the restructuring stage, the notion of the scale was introduced, the objects' scales were given, students re-examined the initial photos, discussed and calculated the objects' dimensions. During the application stage, for adding a game element to teaching, the groups challenged one another, by asking objects present in the classroom to be drawn on a certain scale, by providing photos of buildings and their scales and asking for their actual sizes, and by placing objects and their scaled down images side by side and asking for the scale. During the review stage, students were given exercises similar to the application's activities.

For data collection purposes a total of nine tests were devised (three for each teaching subject, common to both groups): (a) pre-tests to verify students' prior knowledge, (b) evaluation sheets, administered immediately after the end of the teaching of a subject and, (c) delayed posts-tests, which were given about fifteen days after the end of the interventions, to check the sustainability of knowledge. These tests included, mostly, multiple choice, fill-in-the-blanks, and right-wrong questions. On the other hand, in about a third of the questions, students were asked to solve problems. For example, in physics, students solved problems related to the calculation of speed, time, and distance. In geography, they were given photos and maps and they were asked to calculate the scale or to find the size of an object (given its scale on the photo). Also, students in the drones group completed a short questionnaire for the evaluation of their experiences and views regarding the use of drones (15 Likert-type and open-ended questions).

Prior to the beginning of the project, students' parents were briefed about the project, its methodology, and objectives. Their written consent for their children's participation was obtained. The fifth-grade teachers were also briefed, and they were explicitly asked not to intervene in terms of trying to teach students anything related to the project's teaching subjects during their regular teaching. The time allocated for each intervention was four teaching hours (two, 2 h sessions), so that students to have enough time to complete their activities.

Results

Six students had to be excluded from the study because they were absent for one or more sessions. The final sample size was 40 students, divided into two groups of 20 students each (conventional-Group0 and drones-Group1). For the analysis of the results, scores on the basis of the number of correct answers in each evaluation sheet were computed. Mean scores per group of participants and per test are presented in Table 2.

One-way ANOVA tests were to be conducted to compare the scores of the two groups in all tests, in order to determine if they had any significant differences. Prior to conducting these tests, it was checked whether the assumptions of ANOVA testing were violated. It was found that: (a) all groups had the same number of participants ($N = 20$), (b) there were no outliers, (c) the data was not normally distributed in some tests, as assessed by Q-Q plots and the Shapiro–Wilk test, and (d) the homogeneity of variance was violated in some cases, as assessed by

Table 2 Means and standard deviations on all evaluation sheets

	Group0 ($N = 20$)		Group1 ($N = 20$)	
	M	SD	*M*	SD
Pre-test maths (max = 28)	11.60	6.12	14.85	6.12
ES maths (29)	14.00	7.61	23.70	3.54
Delayed post-test maths (29)	13.35	6.56	20.55	5.71
Pre-test physics (20)	17.35	2.89	16.70	3.63
ES physics (21)	16.95	2.92	16.55	3.17
Delayed post-test physics (22)	13.10	3.70	16.10	2.99
Pre-test geography (20)	4.15	3.07	3.10	1.59
ES geography (20)	13.50	1.91	12.00	4.62
Delayed post-test geography (20)	7.20	4.76	12.50	4.70

Maximum scores for each test are reported in parenthesis

ES evaluation sheet

Levene's Test of Homogeneity of Variance. In tests where all the assumptions were met, ANOVA testing was conducted. Where both the normality of the data and the homogeneity of variance were violated, the Kruskal–Wallis H test was used, 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 was in these cases. Where only the homogeneity of variance was violated, the Brown-Forsythe test (1974) was used, which is robust in cases of heteroscedasticity. The results of these tests are presented in Table 3.

Taken together, these results suggested that:

- The two groups of students had the same knowledge level in all subjects prior to conducting the research since they did not have statistically significant differences in the pre-tests. As the two 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 drones outperformed students in the conventional teaching group only in one evaluation sheet (maths).
- Students who used drones outperformed students in the conventional teaching group in all delayed post-tests (maths, physics, and geography).

As a result of the above, H1 was not confirmed, while H2 was confirmed.

According to the results of the questionnaire that was given to the drones group, it was found that: (a) 70% of students knew about drones, (b) 45% had their own or had previously used one, and (c) all students would like to use them again, if they were given the chance to do so. Additionally, students believed that drones helped

Table 3 One-way ANOVA results

Test	Analysis	Result
Pre-test maths	$F(1, 38) = 2.82$, $p = 0.101$	NS
ES maths	Brown-Forsythe $F(1, 26.86) = 3.45$, $p < 0.001$	Group1 ($M = 23.70$, SD = 3.54) outperformed Group0 ($M = 14.00$, SD = 7.61)
Delayed post-test maths	$H(1) = 2.931$, $p = 0.003$	Group1 (*mean rank score* = 25.90) outperformed Group0 (*mean rank score* = 15.10)
Pre-test physics	$H(1) = -0.328$, $p = 0.758$	NS
ES physics	$H(1) = -0.332$, $p = .762$	NS
Delayed post-test physics	$F(1, 38) = 7.96$, $p = 0.008$	Group1 ($M = 16.10$, SD = 2.99) outperformed Group0 ($M = 13.10$, SD = 3.70)
Pre-test geography	$H(1) = -0.584$, $p = .583$	NS
ES geography	$H(1) = -0.332$, $p = .762$	NS
Delayed post-test geography	$H(1) = 3.057$, $p = 0.002$	Group1 (*mean rank score* = 26.12) outperformed Group0 (*mean rank score* = 14.88)

The presentation of the results differs due to different tests used

NS not statistically significant difference

them to understand the subjects that they were taught, with the exception of maps and scales (geography) where the mean score was slightly below the average ($M = 2.95$, SD = 1.10). Their handling was also considered quite easy. Finally, students stated that not only did they find the use of drones in teaching useful, but it was also an enjoyable experience (Table 4). Consequently, H3 was confirmed.

Some indicative responses to the relevant questions were:

- It was fun, a great experience.
- It was something new, different from normal lessons.
- It was like a game, but we also learned.
- Interesting, wonderful, amazing, fun!

Table 4 Questionnaire's results

Question	*M*	SD
Drones helped to learn about metric measurements conversions (maths)	3.80	1.11
Drones helped to learn about speed (physics)	3.95	1.00
Drones helped to learn about map scales (geography)	2.95	1.10
Easiness of use	3.45	1.50
Liked the use of drones (indoors)	4.50	1.15
Liked the use of drones (outdoors)	4.65	0.81
Usefulness of lessons with drones	4.45	0.61
Enjoyed the lessons	4.55	0.76

- Normally you “have to” learn during a lesson, but with drones, I think it was different.
- We have to use them in all lessons!

Discussion

The results, as presented in the preceding section, indicated that while no immediate effects were observed, the sustainability of the knowledge gained was better compared to a contemporary teaching method that used conventional means for delivering the learning content. This is because students in the drones group outperformed students in the conventional teaching group only in mathematics, in both the evaluation sheet and the delayed post-test. In the other two subjects, the results were not statistically significantly different in the evaluation sheets, whereas they were statistically significantly different in the post-tests. Due to the limited literature on the educational uses of drones, the interpretation of the results is -up to a degree- speculative.

Two factors could have affected the immediate learning outcomes:

- More than half of the students have never used drones before and a large percentage (30%) was not even aware of what drones are. Taken together with the fact that students did not practice handling drones prior to the beginning of the project, it is possible that valuable time was lost while students were getting familiar with their use.
- Moreover, the fun of using drones may have distracted students from concentrating on the subjects they were learning. This is also an issue in other emerging technologies. For instance, tablets are reported to 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). As a result, their scores on the evaluations sheets that followed immediately after the end of the teaching of a subject, might have been affected.

On one hand, the results in the evaluation sheets can be viewed as a -partial-failure. On the other hand, they can be viewed as a -partial- success. This is because the immediate learning outcomes of the drones group were as good as the ones of the conventional teaching group, in which the teaching was also based on the same contemporary teaching method. Consequently, it can be argued that:

- The teaching method was quite effective in both cases. Indeed, the teaching method was based on constructivist views for learning, specifically on Driver-Oldham’s Model (1986). Active learning and authentic activities prevailed during lessons, leading to satisfactory learning outcomes as suggested by other researchers (Fosnot 2013; Selley 2013). Collaboration was also an important feature. In this respect, the learning outcomes can be attributed to students working together as others pointed out (e.g., Tolmie et al. 2010). Also, students

worked mostly by themselves. The fact that they achieved satisfactory learning outcomes, seems to confirm the views of other researchers, who believe that students with high degree of autonomy can perform better compared to the ones that constantly receive help from their teachers (e.g., Hong et al. 2000; Mayer and Moreno 2003).
- Even if distraction was an issue, other factors came into play that functioned as a counter-balance to distraction's negative effects. Such factors were students' enthusiasm and positive attitude toward drones (as was evident in the questionnaire) due to drones' game-like nature, which turned into motivation for learning, as Carnahan et al. (2016) suggested. Drones, together with the game-based learning activities, enabled students to achieve satisfactory learning outcomes as others pointed out (Khine 2011; Prensky 2001a).

In contrast, the delayed post-tests were conducted about two weeks after the use of drones and when their immediate effects (e.g., students' enthusiasm emanating from their use) had faded. Thus, students were more focused on answering the questions and this, in turn, probably allowed the full range of the learning outcomes to be registered. Since, the literature suggests that short and long-term retention of the learning material are related to students' study processes (Biggs 1979) and that the testing tasks should require the learners' full attention and investment of substantial mental effort (Endres and Renkl 2015), the above hypothesis is quite probable. Consequently, it can be concluded that drones are a useful educational tool, even if the learning outcomes are not immediately observed.

As regards to the questionnaire, students stated that the lessons were enjoyable, useful, and helped them understand the subject they were learning. These views confirm the findings of Smith et al. (2015) study. Students also stated that they did not face any serious problems while using drones. Young people are adept technology users; they can easily assimilate the use of new technology gadgets (Beheshti 2012; Prensky 2001a). Finally, the lack of handling problems satisfies the "operation" axis in SOAR model for the successful teaching using drones (Carnahan et al. 2016).

On the basis of the above findings and the experience gained, some ideas for drones' integration into the educational practice can be suggested:

- Hands-on experience is quite important. Students can work and handle drones by themselves, although some precaution and help is recommended until they get familiar with their use.
- Collaboration among students is highly advised.
- The use of drones just for the sake of using them is futile. The teaching/learning of subjects has to justify their use.
- When paired with meaningful and well-organized activities, their impact in learning can be maximized.
- The constructivist views and specifically the Driver-Oldham Model provides a good basis for their integration in teaching.
- Fun and enjoyment are innate characteristics of drones; therefore, game-based learning is also a good theoretical framework. However, caution is advised

because the game-like characteristics of drones might become a source of distraction for students.

As a final note, one can argue that drones are not that useful, given the ambiguous results, the cost, the time, and the effort for organizing the experimental teaching. Then again, given that technology is highly compatible with students' mentality and skills (Prensky 2001b), the real problem is to find ways of strengthening the bond that students have with technology for their (educational) benefit. Despite its flaws, this is exactly the contribution this study makes to an emerging research field. It presents evidence that drones do have an educational potential, leading the way for others that will certainly follow, who will, hopefully, test better ideas and more effective methods.

Conclusion

The purpose of this study was to examine the learning outcomes and the sustainability of knowledge when drones were used for teaching metric measurement conversions to fifth-grade primary school students. It also examined the attitudes of students towards drones' use in teaching. It was found that students in the drones group outperformed students in the conventional teaching group in all the delayed post-tests. The results also indicated that students' attitudes toward drones were highly positive.

Despite the interesting results, the research has several limitations that need to be acknowledged. The sample size, although adequate for statistical analysis, was rather small and was from only one city in Greece. Therefore, the results reflect what that particular sample can achieve; thus, the results cannot be easily generalized. Time restrictions, enforced by the school, did not enable us to prolong the teaching of each subject; almost certainly some subjects needed more teaching hours. Also, the drones that were used were designed for amateurs; they lacked features of educational interest (e.g., instruments for measuring speed, height, etc.). However, the acquisition of more expensive drones is beyond the economic capabilities of a typical Greek primary school. Finally, the lack of relevant research posed a problem, so that the project "sailed without a compass in uncharted waters."

The unexplored educational potential of drones leaves plenty of room for future studies. Larger samples, greater duration of the interventions, and different grades/ages would provide more robust results. The same applies for the inclusion of more teaching subjects that can be paired with the use of advanced and better-equipped drones. The theoretical framework for their integration in teaching also requires further study. Finally, it would be interesting to contact research using similar technologies, such as mobile ground robots and compare the results. This would provide better insights regarding the advantages or disadvantages of using drones in education.

In conclusion, the learning outcomes from the inclusion of drones in the educational practice are promising, at least for the subjects that were examined in this study. Then again, in a broader context, it is too early to give a definite answer to the study's title; the question "to drone or not to drone?" is yet to be answered.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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