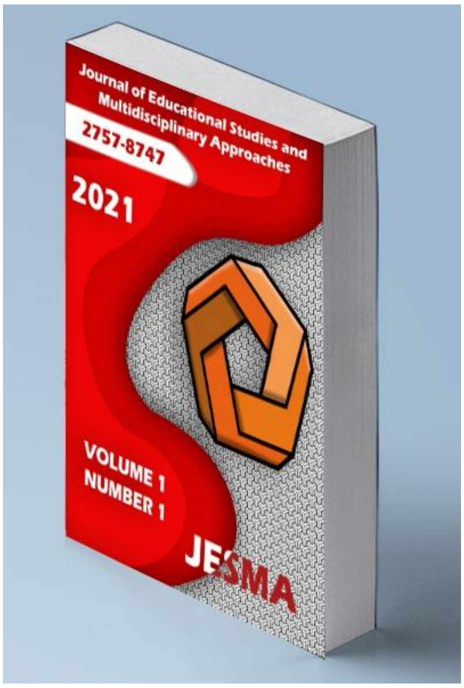

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Lessons learned from a project examining the learning outcomes and experiences in 360º videos

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Lessons learned from a project examining the learning outcomes and experiences in 360° videos

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ABSTRACT

Advances in technologies associated with virtual reality provide interesting tools for e-learning. One such is 360° videos. Although their educational potential is supported by a number of researchers, there is limited empirical evidence backing such a claim, given that they have recently become popular. The study at hand presents the results of a project in which 360° videos were used by primary school students. Eighty-four students, aged ten to eleven, participated in the experiment. The results demonstrated that 360° videos helped them to acquire more knowledge compared to printed material. Then again, no statistically significant differences were noted when comparing 360° and regular videos. 360° videos provided a more immersive, motivational, and enjoyable learning experience. However, the low-cost head mounted displays used for viewing 360° videos and the applications in which they were embedded, were considered the least easy to use. Moreover, participants expressed the view that all tools fostered their learning. Overall, while the results give support to the hypothesis that 360° videos provide positive educational experiences, their actual impact on learning has to be further explored.

Keywords: 360° videos, enjoyment, immersion, learning, motivation, primary school

Introduction

Videos are among the predominant forms of entertainment, also having a significant educational value (Smith et al., 2012). Their success, both as educational and entertainment tools, probably lies in the fact that viewers identify themselves -to some extent- with what they are watching (Carr-Chellman & Duchastel, 2001). On the other hand, videos, in their current form, have certain limitations. For instance, what viewers see is actually what the director or the cameraman chose to record. They cannot view a scene from a perspective/angle of their choice because multiple cameras should have been used for simultaneously recording the same scene.

In recent years, technological advancements have offered an interesting alternative to regular videos, that of omnidirectional panoramic videos, also called 360^o videos. Although they surfaced as a research technology almost two decades ago (Pintaric et al., 2000), only recently they have been transformed into a product widely available to the masses. In short, the cameras that are used for capturing such videos are able to record images from a field of view that covers a whole sphere; hence, the term "360^o videos." For processing/editing them, similar techniques to that of regular videos are followed. Viewers can watch them using computers, smartphones, and head-mounted displays (HMDs). In the last two cases, users are placed at the center of the video-sphere, turn their smartphones or heads in any direction they like, the built-in gyroscopes and accelerometers track the movement, and the portion of the sphere that corresponds to the direction they are looking at is displayed. Moreover, additional content (e.g., images, text, audio, and scene transitions) can be added with which users can interact by triggering hotspots embedded in the video. Users can activate these hotspots by either keep looking towards the direction of a hotspot and holding their position for a few seconds or by point-and-clicking using hand-held controllers.

There are several types of HMDs, that can roughly fall into three categories: (i) tethered to a computer, having their own mini LCD/OLED displays and electronics, but it is the computer that is responsible for all the image processing; (ii) untethered, also having their own mini LCD/OLED displays, but they are -more or less- miniaturized computers because the image processing is done by the device itself; and (iii) low-cost/low-tech Google cardboard compatible devices; their main body (made of cardboard or plastic) houses two lenses and no electronics, a smartphone (inserted into a compartment) displays the video and does all the image processing. Out of the above, it was the Google cardboard devices that made 360^o videos and other virtual reality (VR) applications accessible to millions of people (Curcio et al., 2016).

360^o videos present environments that are real and not based on graphics (as are VR applications). For that matter, they have found their way in areas in which a high degree of realism is necessary (e.g., Biology, Engineering, and Health Sciences), as well as in education (Ardisara & Fung, 2018). With regard to education, a number of studies reported a positive impact on learning (e.g. Pham et al., 2018; Ritter et al., 2019), and on learning facilitating factors (e.g., enjoyment and motivation; Lee et al., 2017; Wu et al., 2019; Xie et al., 2019). That is because, besides the imposing presentation of the visual material, the use of HMDs removes external stimuli, allowing users to feel immersed in the environment that is presented to them (Rupp et al., 2019), which, in turn, significantly enhances their learning experience compared to other less immersive technologies.

Considering the above, it seems that 360^o videos might be an important supplement to existing teaching frameworks. In fact, their educational use is on the rise, as they are easily produced, provide a low-cost solution, and are widely available (Sun et al., 2018; Zhou et al., 2017). Then again, given that they were recently commercialized and, consequently, the body of knowledge on their educational use is limited (Rupp et al., 2016), leaves plenty of room for additional research. Having that in mind, we decided to implement a project, having as a target group primary school student, with the objective to investigate whether they can outperform, in terms of learning outcomes, other tools commonly used in teaching, such as printed material and regular videos. In addition, we examined what were the views and feelings of students regarding their use. The following sections present the existing research on 360^o videos' educational potential, the reasoning behind the research questions we examined, the experimental setup, the results from the experiment, and their subsequent discussion.

360° videos

Research on the educational uses of 360° videos, while not yet adequately systemized, seems to cover a rather wide and diverse set of learning domains and sciences. They are commonly used for delivering virtual tours to places of interest, museums, and archaeological sites (e.g., Argyriou et al., 2020; Fokides et al., 2020; Skondras et al., 2019), as well as for presenting experiments and medical procedures (e.g., Ardisara & Fung, 2019; Sankaran et al., 2019). They have been also used for the teaching of subjects related to Ecology (e.g., Fokides & Kefalinou, 2020; Ritter et al., 2019), Physics (Wu et al., 2019), Physical Education (Kittel et al., 2020; Paraskevaidis & Fokides, 2020), Religion Education (Johnson, 2018), language learning (Berns et al., 2018; Xie et al., 2019), Public Health Education (Dawson et al., 2019), Safety Education (Pham et al., 2018), and for delivering virtual courses (Lee et al., 2017).

360° videos have similarities with regular videos, as well as with VR applications. Because of their resemblance with the former, the theoretical frameworks guiding their educational use are probably the same, namely Mayer's (2009) multimedia learning theory and Sweller's (2005) cognitive load theory. Mayer postulated that humans use a channel for processing visual stimuli (e.g., images, printed text, or text displayed on a screen) and a channel for processing audio stimuli (e.g., speech). Due to the limited capacity of the brain, not many "chunks" of information can be processed at the same time. Moreover, he assumed that learning involves the selection of what is relevant, organizing it into models (verbal and visual), which are later integrated into prior knowledge. He suggested -among other things- that individuals learn better when: (i) the inessential material is removed, and (ii) graphics/images are presented together with narration, something that holds true for both regular and 360° videos. Central to Sweller's theory is the concept of "schemas", which represent organized blocks of information retained in long-term memory. The instructional material should help students to develop those schemas by not overloading them with unnecessary information. In fact, he suggested that cognitive load can be: (i) extraneous, which is the (wasted) effort for learning something unrelated to the learning objectives), (ii) intrinsic, meaning the effort one has to put for representing the material into their working memory, and (iii) germane, which is the required effort for understanding the material. While the first two types of cognitive load should be avoided, the germane load has to be promoted because it helps the transfer of schemas to long-term memory. Although research suggested that multimedia learning material is likely to increase all types of cognitive load, including the undesirable ones, research related to the use of 360° videos found increased levels of germane cognitive load compared to the other two types (Lin et al., 2019).

360° videos also share some features with VR that led researchers to label them as VR experiences (e.g., Rupp et al., 2019), despite the fact that the former are based on real-life recordings while the latter is based on 3D graphics. Because HMDs can be used in both cases, users are cut-off from the distractions of the outside world, allowing them to be immersed in the virtual experience, and, thus, be more engaged with the content (Dede, 2009). Reduced distraction and engagement with the content, offered by the sense of immersion, were correlated with better conceptual learning (Dede et al., 2017; Tüzün & Özdinç, 2016). Moreover, researchers argued that immersion, by offering -somehow- direct experiences, allows situated learning to take place and the transfer to the real world of what was learned in the virtual environment (Dede et al., 2017). The emotions evoked by a virtual experience also contribute to the above (Diemer et al., 2015). For example, the emotional responses to a virtual car accident proved to have a significant impact on the training of individuals learning to drive (Sheridan, 2016). Closely connected with immersion is the feeling of presence, the illusion of "being" in the virtual environment, perceiving it as real (Slater, 2009). Because of that, the perceptual cues offered to the users are more accurate, allowing them to improve their performance (Slater & Sanchez-Vives, 2016).

However, the role of immersion is rather unclear in 360° videos. As viewers can explore their surroundings by watching different parts of the scene and focus their attention on details that otherwise could have been passed unseen, we can argue that 360° videos are more immersive than regular videos. In fact, research has demonstrated that, in 360° videos, the feelings of immersion and presence were rather strong (e.g., Argyriou et al., 2017; Berns et al., 2018; Elmezeny et al., 2018; Fokides & Kefalinou, 2020; Higuera-Trujillo et al., 2019) and that students were able to better understand concepts, processes, and problems (e.g., Chang et al., 2019; Dawson et al., 2018; Fokides & Arvaniti, 2020). However, research has suggested that 360° videos do not offer high levels of immersion and that the quality of experience is lower than that of VR experiences based on 3D graphics (e.g., Rupp et al., 2019). Others argued, that because 360° videos lack student-user agency, they limit situated learning (Dede et al., 2017). Moreover, immersion might be negatively affected when low-tech HMDs (such as Google Cardboard) are used, leading to a diminished impact on learning (Rupp et al., 2019).

As for the learning outcomes per se, either when 360° videos were used as the only tool or when they were compared with other teaching tools, the results, although promising, were mixed. Several researchers reported a positive impact on learning (e.g., Chang et al., 2019; Pham et al., 2018; Wu et al., 2019) and the acquisition of skills (e.g., Parmaxi et al., 2018). Then again, others reported that their impact was not that significant (e.g., Fokides et al., 2020; Karageorgakis & Nisiforou, 2018; Ulrich et al., 2019). The lack of a teaching framework that fully exploits their potential (e.g., Fokides et al., 2020; Fowler, 2015; Hodgson et al., 2019) and lack of understanding whether they foster self-directed learning and self-assessment (e.g., Whittleston et al., 2018) were also noted. Another issue that probably does not allow the full comprehension of 360° videos' impact, is that the majority of the studies we cited above mostly targeted university students and young adults, as they constitute a rather convenient sample; research on younger ages (e.g., primary school students) is rather scarce (e.g., Fokides & Arvaniti, 2020; Wu et al.,2019).

Besides attributing the positive learning outcomes to immersion and presence, researchers attributed the results to other learning facilitating factors as well. For example, they noted that the novelty of the experience (Lin et al., 2019) led to increased levels of enjoyment, satisfaction (e.g., Chang et al., 2019; Lee et al., 2017), and motivation (Fokides & Arvaniti, 2020; King-Thompson, 2017; Xie et al., 2019). In fact, students' responses regarding their experiences were highly positive, characterizing them as positive, useful, engaging, and that 360° videos facilitated their comprehension/learning of the subjects they were taught (Fung et al., 2019; Huang et al., 2019; Ulrich et al., 2019). On the negative side, distraction and/or disorientation are significant issues (Ardisara & Fung, 2018). For example, students might be looking at a certain part of the scene because something irrelevant draw their attention and miss something important taking place in another part of the scene. Overexcitement because of the novelty of the experience might also act as a distraction factor (Rupp et al., 2016). In low-tech HMDs some usability problems were noted, probably because navigation is not that easy without the use of hand-held controllers (Fokides et al., 2020). Symptoms of severe discomfort, vertigo, and nausea (called simulator sickness) were reported in a number of studies. Researchers theorized that this problem is more prominent in low-tech HMDs, as the lower display quality causes more severe mismatches between the simulated movement (the movement the user sees in the video) and the vestibular system (the lack of movement perceived by the user's inner ear) (Rupp et al., 2019). Logically enough, the learning experience is negatively affected by this unpleasant situation (Lackner, 2014).

Statement of the problem, formation of the research questions

The On the basis of the research we presented in the preceding sections and considering the fact that 360° videos can be used in a wide range of scientific disciplines and teaching scenarios, we can support the view that they have interesting educational potential. Then again, it is also true that research on this matter is still at its infant stage, given that its volume is not extensive and the underlying technology is constantly evolving. Moreover, just a few of the studies were methodologically sound; most seemed to be concerned with testing prototypes or initial ideas, the sample sizes were small, the number of interventions/tests was small, and comparisons with alternative tools were not that common. We also noted that most studies had adults as their target group (e.g., professionals and university students); very few targeted young students. In addition, the body of research that examined differences between sexes or took into consideration participants' prior knowledge on the subject matter they were trying to learn was rather limited.

Having these in mind, we decided to implement a project to answer whether 360° videos have a measurable impact on primary school students' learning and whether the results are better (or worse) compared to printed material, which is the most commonly used educational tool. We also thought that it would be interesting to compare their impact with that of regular videos, so as to examine whether 360° videos have significant advantages over their less advanced predecessors. In addition, we considered it important to examine the learning experience they offer (again, in relation to other tools) more comprehensively, given that much of the research, although it explored similar issues, usually focused on one or two factors that shape one's learning experience. Thus, we addressed the following research questions:

- *RQ1. After controlling for the initial primary school students' knowledge level, are there any statistically significant differences in the learning outcomes produced from the use of printed material, regular videos, and 360^o videos? Does sex have an impact on the results?*
- *RQ2a-e. With regard to the above tools, are there any statistically significant differences on students' views and feelings for their (a) usefulness, (b) impact on motivation to learn, (c) easiness of use, (d) immersiveness, and (e) the enjoyment they offer while learning? Does sex have an impact on the results?*

Method

In previous studies, we used 360^o videos within a teaching framework (e.g., Fokides & Arvaniti, 2020; Fokides et al., 2020). In these studies, that were related to the teaching of environmental issues and historical events, we examined the impact of 360^o videos on students' performance, while comparing the learning outcomes to the ones produced by the use of other tools such as printed material and regular videos. The results indicated that the students who used 360^o videos were able to outperform the students who used conventional teaching tools. We also noted increased levels of immersion, motivation and enjoyment. These findings led us to theorize that the better learning outcomes of the 360^o videos, compared to other tools, can be attributed to the above factors. While the above-mentioned studies allowed us to test (and ultimately recommend) effective teaching strategiesthat utilize them, we were unable to discern to what extent the results were due to the teaching framework, the teachers, or the 360^o videos. Therefore, we decided that it was necessary to examine what is the exact impact of 360^o videos per se, without including other factors that might play a significant role. We elaborate further on this issue in the "Procedure" section.

We decided to follow a within-subjects research design with three conditions. This means that the same subjects/students used three different tools (i.e., printed material, regular videos, and 360^o videos) in order to be informed about subjects related to the environment (as presented in the "Materials and apparatus" section). We selected the within-subjects design over the between-subjects approach because literature suggested that it is efficient while requiring smaller sample sizes (Greenwald 1976; Keren 2014). Not only that, but the confounding effects of individual differences are not a cause of concern, as the same individuals participate in all treatments. Finally, group variances are not an issue, given that participants function as their own controls (Gravetter & Forzano, 2018). In addition, to address the disadvantages of this research design, we took a series of measures as discussed in sections "Materials and apparatus" and "Procedure."

Materials and apparatus

For this experiment, we used audiovisual and printed material developed (and tested) for the needs of previous studies in which we examined the use of 360^o videos in the context of environmental education (Figure 1). We decided to reuse it because of its information density and because the videos it included (regular and 360^o) were of high production quality. As in the aforementioned studies, the research design was an important consideration; we had to take into account that the same participants were going to use three different tools. This meant that the material could not be the same across tools, because with each subsequent tool students were going to learn a bit more, rendering the results invalid. On the other hand, if each tool presented different subjects, was also a threat, as they are incomparable. To overcome these problems, we followed the same set of measures we did in our previous studies. Firstly, we decided to conduct three sessions for each tool (nine in total), so as to increase the reliability of our data. Secondly, we rechecked whether the material, in terms of quality, quantity, cognitive load (e.g., number of terms/facts/figures/names/concepts and amount of text/narration), and difficulty level, was the same in all tools. Thirdly, the subjects included in one tool had matching subjects in the other two tools (Table 1). Lastly, we rechecked whether the presentation and organization of the material followed the same rules in all tools. As a sidenote, interactive hotspots (for displaying additional texts and images, and for transitions between scenes) were placed in both 360° and regular videos. In the printed material we used multiple screenshots taken from the corresponding videos.

Students in the condition of the 360° videos used Google cardboard compatible HMDs coupled with 6.39" smartphones running Android 10. Students wore headphones so as to have the best audio quality without any interference from background noises. Participants in the condition of the regular video used computers together with 27" full-HD monitors. As in the condition of the 360° videos, students wore headphones.

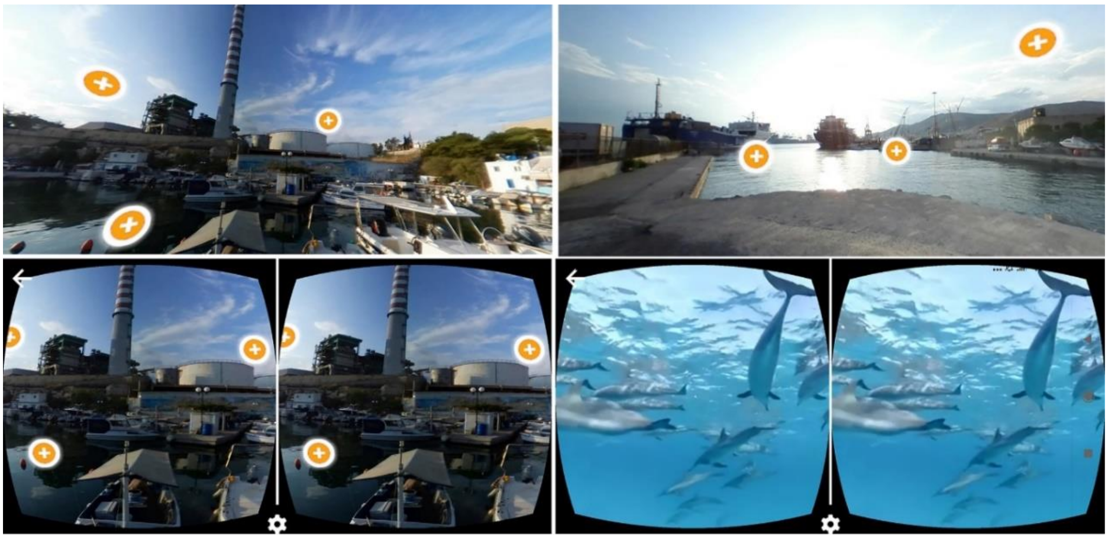

Figure 1. Screenshots from the apps

Table 1. Sessions' learning subjects

Unit	Printed material	Regular videos	360° videos
Greece's ecosystems	forest	freshwater	shoreside/sea
Pollutants and pollution prevention	land	air	water
Waste management and recycling	solid wastes	organic wastes	liquid wastes

Participants

An issue we had to resolve was related to the experiment's sample size. Our objective was the number of participants to allow us to detect even small effect sizes with more than enough power. For that matter, we performed a power analysis for sample size estimation using G*power (Faul et al., 2007). Following Cohen's (1969) guidelines, for $f_{\text{Cohen}} = .10$, $\alpha = .05$, power = 0.95, and a correlation between repeated measurements = .95, the projected sample size was at least forty-six participants.

Another decision we had to make was related to participants' age. We decided to target primary school students, as few studies had previously focused on them. Given that (i) Greece's program of study for primary schools presents/discusses issues related to the environment, for the first time, at the fourth grade (ages nine to ten) and (ii) the subjects discussed in the material we used were more advanced than those in the textbooks, we considered appropriate the sample to consist of slightly older students, aged ten to eleven (fifth grade). We contacted several fifth-grade teachers working in public primary schools in Athens, Greece. As a result, we selected forty-two boys and forty-two girls (significantly more than our initial intentions) who: (i) were never formally taught subjects similar to the ones in our study (ii) have never before used HMDs, and (iii) in terms of their academic performance they were equally divided into three categories (i.e., low, average, and high performance), and with an equal number of boys and girls in each group.

Because the experiment involved minors, we obtained ethical clearance from the University's ethical committee. In addition, we informed students' parents of the experiment's objectives and they granted their written consent for their children's participation.

We have to note that students were given a hearing and vision screening. We tested their hearing using the hearScreen app (https://www.hearxgroup.com/hearscreen/) running on Android smartphones together with high-quality pairs of headphones. We used the apps Peek Acuity (https://www.peekvision.org/en_GB/peek-solutions/peek-acuity/) and Ishihara Color Blindness Test (available in Play Store) to screen visual acuity and deficiencies in color perception. Finally, we used the iNSIGHT Depth Perception app (http://www.polyhedronlearning.com/) together with smartphones running Apple iOS for testing depth perception. None of the students had problems preventing their participation in the experiment.

Instruments

As we had nine sessions (three for each tool) and for recording what students were able to learn, we developed an equal number of evaluation tests. Each test had twenty multiple-choice questions derived from the learning material presented in a session and each question had five possible answers but only one correct. For determining what questions to include in these tests, we created an initial question pool and we asked five students (not included in the final sample) to answer them. This allowed us to remove questions that had a high number of incorrect responses, not significantly correlated with the total score. Participants received five points for every correct answer; to discourage guessing, their score was reduced by one point for an incorrect answer. We administered each evaluation test immediately after the end of its corresponding session. In addition, for establishing participants' prior knowledge/academic level on the subjects included in all sessions, we tested them using a pre-test (having a total of forty questions), that we administered a week before the beginning of the experiment.

Moreover, we used parts of a modular validated scale developed for recording users' experiences when dealing with digital educational tools (Fokides et al., 2019). Although it includes twelve factors, we selected five of them, one for each of the five research questions we sought to answer (RQ2a-e). The scale's items (twenty-three in total) were presented on a five-point Likert-type scale (from strongly disagree = 1 to strongly agree = 5). We present the questionnaire's items in the Appendix. We administered the questionnaire three times (during the last time one of the tools was used). We also included an open-ended question in which students could report problems when viewing the 360^{o} videos (e.g., discomfort, simulator sickness, and usability problems).

Procedure

To avoid usability issues and technical problems caused by the fact that students were inexperienced users of Google cardboard compatible HMDs and 360^{o} videos, we allowed them to familiarize themselves to both, during a session prior to the beginning of the experiment. For that matter, we installed on the smartphones a 360^{o} video the subject of which was not related to the other videos we used in the actual experiment. Because the sessions took place during school hours, we decided to conduct all of them on the same day of the week and at the same hour, in order to eliminate the influence of external factors such as students' loss of interest or tiredness due to previous lessons. Another measure we took, with the purpose of avoiding order effects, was to randomize the use of tools. Moreover, we did not inform students about which tool they were going to use each time.

Twenty minutes were allocated for each session. We estimated that this time was enough for an average ten-to-eleven-year old student to either thoroughly read the printed material, or carefully watch the regular/360^{o} videos. We instructed students that their goal was to try to learn as much as they could about the subjects presented to them. The sessions were conducted on an individualized basis in offices available to students' schools. For watching the 360^{o} videos, students sat in a swivel office chair and had enough space to move and turn around. A desk and an office chair were used for watching the regular videos or for studying the printed material. For the evaluation tests, that immediately followed, students had fifteen minutes at their disposal. Finally, in cases of simulator sickness or discomfort, students were allowed to stay for about ten minutes for the symptoms to abate.

To remove bias, the researcher who was present for the duration of each session did not provide any help to students related to what they were learning or did not intervene for any reason other than for providing technical assistance if needed.

As none of the participants was absent in any of the nine sessions, we included in the analysis that followed data coming from all of them. We calculated three variables representing students' mean scores per tool. We also checked the questionnaires for missing or unengaged responses (none were found). We assessed the questionnaires' factors as well as their overall internal consistency. In all cases, we found that Cronbach's alpha was above the .700 threshold which is considered acceptable (Taber, 2018). Following that, we calculated fifteen variables, representing the items' means per factor (three questionnaires X five factors).

For examining the learning outcomes, we deemed that a Mixed Model Analysis of Covariance (ANCOVA) was the appropriate statistical method for determining whether significant differences exist in the learning outcomes, between boys and girls, after controlling for students' prior knowledge (as recorded in the Pre-test). The following tests examined whether the data were fit for this type of statistical analysis: (i) we assessed the assumption of normality using Q-Q scatterplots (DeCarlo, 1997); (ii) we plotted the residuals against the predicted values for evaluating homoscedasticity (Field, 2013); (iii) we assessed the assumption of sphericity using Mauchly's test (Mauchly, 1940); (iv) we calculated Mahalanobis distances and compared them to a χ^2 distribution for identifying influential points in the residuals, (Newton & Rudestam, 2012); (v) we rerun the mixed model ANCOVA by including interaction terms between each independent variable and the covariate, for assessing the assumption for homogeneity of regression slopes (Field 2013); and (vi) we conducted an ANOVA for each covariate-independent variable pair, to assess covariate-independent variable independence (Field 2013). Out of the above, only the sphericity assumption was violated [$\chi^2(2) = 26.90$, $p < .001$]. To address this issue, we used the Greenhouse-Geisser correction when calculating the p-values for the within-subjects factor and its interactions with either the between-subjects factor or the covariate (Greenhouse & Geisser, 1959).

We were to conduct a total of five Mixed Model ANOVAs with one within-subjects factor (students' mean scores in the questionnaires' factors for each tool) and one between-subjects factor (sex) to determine whether significant differences exist in students' views and opinions regarding the use of the three tools (as recorded by the questionnaires' five factors) and between boys and girls. While the assumption of homoscedasticity was not violated and there were no multivariate outliers, in three cases (i.e., immersion, enjoyment, and subjective usefulness) we found that the data were approximately normally distributed. Given that ANOVA is rather robust to moderate deviations from normality and that the sample size was more than thirty subjects, this violation did not raise any major concerns (Tiku, 1971). The sphericity assumption was violated in all cases except in the factor labeled "Immersion." For that matter, as in the ANCOVA, we used the Greenhouse-Geisser correction.

Results

We imputed the resulting data in SPSS 26 for further analysis. Table 2 presents descriptive statistics for all the study's variables.

Table 2. Means and standard deviations for the study's variables

Variable	**Boys** (n = 42)		**Girls** (n = 42)	
	M	*SD*	*M*	*SD*
Pre-test	33.07	8.46	34.93	7.68
Printed material evaluation tests	50.20	12.25	54.77	11.46
Regular videos evaluation tests	53.33	12.62	57.99	11.49

360º videos evaluation tests	53.95	12.44	58.61	11.46
Immersion-Printed material	3.46	0.91	3.18	0.92
Immersion-Regular videos	3.73	0.89	3.42	1.02
Immersion-360º videos	4.00	0.85	4.07	0.87
Enjoyment-Printed material	3.64	0.83	3.53	0.92
Enjoyment-Regular videos	4.24	0.59	4.15	0.66
Enjoyment-360º videos	4.56	0.46	4.40	0.66
Subjective usefulness-Printed material	4.10	0.60	4.05	0.59
Subjective usefulness-Regular videos	4.20	0.63	4.21	0.66
Subjective usefulness-360º videos	4.19	0.74	4.31	0.73
Ease of use-Printed material	4.32	0.53	4.31	0.45
Ease of use-Regular videos	3.81	0.67	3.81	0.64
Ease of use-360º videos	3.24	0.68	3.25	0.62
Motivation-Printed material	3.59	0.73	3.49	0.72
Motivation-Regular videos	3.87	0.67	4.01	0.60
Motivation-360º videos	4.51	0.47	4.64	0.43

Analysis of the evaluation tests

We examined the results in the evaluation tests using an alpha of .05. As it is evident in Table 3, the main effect for sex was not significant [$F(1, 81) = 2.71$, $p = .103$], indicating that the results for girls and boys were all similar after controlling for students' prior knowledge. As expected, the covariate (students' prior knowledge, Pre-test), was significantly related to the results in the evaluation tests of all tools [$F(1, 81) = 185.65$, $p < .001$]. The main effect of the within-subjects factor was significant [$F(1.56, 126.02) = 4.25$, $p = .025$], indicating significant differences between the learning outcomes of the three tools. The effect size was small ($\eta_p^2 = 0.05$). The interaction effect between students' sex and the within-subjects factor was not significant [$F(1.56, 126.02) = 0.02$, $p = .960$], indicating that the strength of the relationship between the outcome and the interaction of sex did not change significantly (for all combinations of the within-subjects factor and sex). The same applied for the interaction effect of the Pre-test [$F(1.56, 126.02) = 0.13$, $p = .828$].

Table 3. Mixed Model ANCOVA results

Source	***df***	***SS***	***MS***	***F***	***p***	η_p^2
Between-Subjects						
Sex	1	347.90	347.90	2.71	.103	0.03
Pre-test	1	23819.48	23819.48	185.65	< .001	0.70
Residuals	81	10392.41	128.30			
Within-Subjects						
Evaluation tests	1.56	53.37	33.63	4.25	.025	0.05
Sex*Evaluation tests	1.56	0.23	0.15	0.02	.960	0.00
Pre-test*Evaluation tests	1.56	1.58	1.02	0.13	.828	0.00
Residuals	126.02	998.27	7.92			

The pairwise contrasts revealed that the results in the evaluation tests assessing the outcomes from the use of the printed material were significantly less than in regular videos [$t(81) = -5.50$, p < .001 for boys and $t(81) = -5.39$, $p < .001$ for girls], as well as in 360º videos [$t(81) = -5.81$, $p < .001$ for boys and $t(81) = -6.32$, $p < .001$ for girls]. On the other hand, the results in the evaluation tests assessing the impact of regular videos were, statistically speaking, not different from the results in 360º videos [$t(81) = -1.71$, $p = .094$ for boys and $t(81) = -1.63$, $p = .110$ for girls] (Table 4). The effect sizes, when comparing the printed material with either regular videos or 360º videos, were very large (d_{Cohen} ranging from 0.80 to 1.06). On the other hand, the effect sizes when comparing the regular videos with 360º videos were rather small ($d_{Cohen} = 0.16$ for boys and 0.17 for girls). Thus, for answering RQ1, we can support that, after controlling for the initial students' knowledge level and regardless of participants' sex, 360º videos produced better learning outcomes compared to printed material but not better compared to regular videos.

Table 4. Pairwise contrasts for the Mixed Model ANCOVA (Tukey comparisons)

Contrast	Difference	*SE*	*df*	*t*	*p*	d_{Cohen}
Boys						
Printed material-Regular videos	-3.13	0.57	41	-5.50	< .001	-0.80
Printed material-360º videos	-3.75	0.65	41	-5.81	< .001	-0.96
Regular videos-360º videos	-0.62	0.36	41	-1.71	.094	-0.16
Girls						
Printed material-Regular videos	-3.22	0.60	41	-5.39	< .001	-0.89
Printed material-360º videos	-3.84	0.61	41	-6.32	< .001	-1.06
Regular videos-360º videos	-0.63	0.38	41	-1.63	.110	-0.17

Analysis of the questionnaires

Coming to the questionnaires, the main effect for Sex was not significant in all cases [$F(1, 82) = 1.22$, $p = .272$ for Immersion; $F(1, 82) = 0.84$, $p = .361$ for Enjoyment; $F(1, 82) = 0.06$, $p = .809$ for Subjective usefulness; $F(1, 82) = 0.00$, $p = .978$ for Ease of use; and $F(1, 82) = 0.26$, $p = .609$ for Motivation], indicating that the results for girls and boys were similar. The main effect for the within-subjects factor was significant in all cases except in Subjective usefulness [$F(2, 164) = 23.74$, $p < .001$ for Immersion; $F(1.59, 130.55) = 81.04$, $p < .001$ for Enjoyment; $F(1.17, 140.40) = 2.55$, $p = .090$ for Subjective usefulness; $F(1.80, 147.81) = 187.23$, $p < .001$ for Ease of use; and $F(1.83, 150.14) = 136.97$, $p < .001$ for Motivation]. The interaction effect between the within-subjects factor and sex was not significant in all cases [$F(2, 164) = 2.06$, $p = .130$ for Immersion; $F(1.59, 130.55) = 0.11$, $p = .847$ for Enjoyment; $F(1.17, 140.40) = 0.61$, $p = .606$ for Subjective usefulness; $F(1.80, 147.81) = 0.01$, $p = .984$ for Ease of use; and $F(1.83, 150.14) = 2.45$, $p = .094$ for Motivation]. Table 5 presents the Mixed Model ANOVA results.

Table 5. Mixed Model ANOVA results

Factor	Source	*df*	*SS*	*MS*	*F*	*p*	η_p^2
Immersion	Between-Subjects						
	Sex	1	1.92	1.92	1.22	.272	0.01
	Residuals	82	128.63	1.57			
	Within-Subjects						
	Within factor	2	22.00	11.00	23.74	< .001	0.22
	Sex*Within factor	2	1.91	0.96	2.06	.130	0.02
	Residuals	164	76.00	0.46			
Enjoyment	Between-Subjects						
	Sex	1	0.89	0.89	0.84	.361	0.01
	Residuals	82	86.03	1.05			
	Within-Subjects						
	Within factor	1.59	34.77	21.84	81.04	< .001	0.50
	Sex*Within factor	1.59	0.05	0.03	0.11	.847	0.00
	Residuals	130.55	35.18	0.27			
Subjective usefulness	Between-Subjects						
	Sex	1	0.04	0.04	0.06	.809	0.00
	Residuals	82	61.85	0.75			
	Within-Subjects						
	Within factor	1.17	1.40	0.70	2.55	.090	0.03
	Sex*Within factor	1.17	0.33	0.17	0.61	.606	0.01
	Residuals	140.40	45.15	0.28			
Ease of use	Between-Subjects						
	Sex	1	0.00	0.00	0.00	.978	0.00
	Residuals	82	68.03	0.83			
	Within-Subjects						
	Within factor	1.80	48.36	26.83	187.23	< .001	0.70

	Sex*Within factor	1.80	0.00	0.00	0.01	.984	0.00
	Residuals	147.81	21.18	0.14			
Motivation	Between-Subjects						
	Sex	1	0.21	0.21	0.26	.609	0.00
	Residuals	82	65.53	0.80			
	Within-Subjects						
	Within factor	1.83	45.68	24.94	136.97	< .001	0.63
	Sex*Within factor	1.83	0.82	0.45	2.45	.094	0.03
	Residuals	150.14	27.35	0.18			

The pairwise contrasts (Table 6) revealed that:

- While immersion in the printed material was similar to that in regular videos [$t(41) = -1.65$, $p = .108$ for boys and $t(41) = -1.83$, $p = .074$ for girls], it was significantly less than in 360° videos [$t(41) = -3.36$, $p = .002$ for boys and $t(41) = -6.22$, $p < .001$ for girls]. Interestingly, girls considered 360° videos as being more immersive than regular videos, while boys considered them as being equally immersive [$t(41) = -1.81$, $p = .074$ for boys and $t(41) = -4.56$, $p < .001$ for girls].
- Boys and girls enjoyed the use of printed material less than regular videos [$t(41) = -5.71$, $p < .001$ for boys and $t(41) = -6.10$, $p < .001$ for girls] and 360° videos [$t(41) = -7.69$, $p < .001$ for boys and $t(41) = -7.11$, $p < .001$ for girls]. They also enjoyed the use of regular videos less than 360° videos [$t(41) = -4.66$, $p < .001$ for boys and $t(41) = -3.09$, $p = .004$ for girls].
- As we already stated, there were no statistically significant differences regarding the tools' subjective usefulness.
- The printed material was considered as being easier to use than regular videos [$t(41) = 7.99$, $p < .001$ for boys and $t(41) = 7.23$, $p < .001$ for girls] and 360° videos [$t(41) = 11.65$, $p < .001$ for boys and $t(41) = 12.51$, $p < .001$ for girls]. Also, regular videos were considered as being easier to use than 360° videos [$t(41) = 7.02$, $p < .001$ for boys and $t(41) = 7.57$, $p < .001$ for girls].
- The participating students found the use of the printed material as being less motivating than regular videos [$t(41) = -3.23$, $p = .002$ for boys and $t(41) = -5.27$, $p < .001$ for girls] and 360° videos [$t(41) = -9.55$, $p < .001$ for boys and $t(41) = -11.25$, $p < .001$ for girls]. It was also found that the use of regular videos was less motivating than the use of 360° videos [$t(41) = -7.83$, $p < .001$ for boys and $t(41) = -9.35$, $p < .001$ for girls].

Table 6. Pairwise contrasts for the Mixed Model ANOVA (Tukey comparisons)

Factor	**Contrast**	**Difference**	***SE***	***df***	***t***	***p***	d_{Cohen}
Immersion	Boys						
	Printed material-Regular videos	-0.27	.16	41	-1.65	.108	0.25
	Printed material-360° videos	-0.54	.16	41	-3.36	.002	0.51
	Regular videos-360° videos	-0.27	.15	41	-1.81	.077	0.28
	Girls						
	Printed material-Regular videos	-0.24	.13	41	-1.83	.074	0.30
	Printed material-360° videos	-0.89	.14	41	-6.22	< .001	0.93
	Regular videos-360° videos	-0.65	.14	41	-4.56	< .001	0.66
Enjoyment	Boys						
	Printed material-Regular videos	-0.60	.10	41	-5.71	< .001	0.80
	Printed material-360° videos	-0.91	.12	41	-7.69	< .001	1.01
	Regular videos-360° videos	-0.32	.068	41	-4.66	< .001	0.67
	Girls						
	Printed material-Regular videos	-0.62	.10	41	-6.10	< .001	0.87
	Printed material-360° videos	-0.87	.12	41	-7.11	< .001	0.99
	Regular videos-360° videos	-0.25	.081	41	-3.09	.004	0.48
Ease of use	Boys						
	Printed material-Regular videos	0.51	.063	41	7.99	< .001	1.49
	Printed material-360° videos	1.08	.09	41	11.65	< .001	2.10
	Regular videos-360° videos	0.57	.08	41	7.02	< .001	1.08
	Girls						
	Printed material-Regular videos	0.50	.07	41	7.23	< .001	1.46
	Printed material-360° videos	1.06	.09	41	12.51	< .001	2.36
	Regular videos-360° videos	0.57	.07	41	7.57	< .001	1.14

Motivation	Boys						
	Printed material-Regular videos	-0.27	.08	41	-3.23	.002	0.50
	Printed material-360º videos	-0.91	.10	41	-9.55	< .001	1.31
	Regular videos-360º videos	-0.64	.08	41	-7.83	< .001	1.08
	Girls						
	Printed material-Regular videos	-0.52	.10	41	-5.27	< .001	0.75
	Printed material-360º videos	-1.15	.10	41	-11.25	< .001	1.49
	Regular videos-360º videos	-0.64	.07	41	-9.35	< .001	1.34

On the basis of the above results and for answering RQ2a-e, we can conclude that students viewed all tools as being equally useful and that the 360º videos were considered the least easy to use, followed by regular videos. On the other hand, the 360º videos were the most enjoyable and motivating tool among the three tools considered in this study. Finally, although the 360º videos offered the most immersive experience compared to printed material, there was an inconsistency in the results when compared to regular videos; girls considered 360º videos as being more immersive than regular videos, while boys considered both tools as being equally immersive.

As for the open-ended question, students reported usability issues related to the 360º videos and HMDs (n = 16 and n = 13 respectively). For example, the most common problem was that students did not properly adjust the HMDs' straps so as to fit their heads. There were also cases in which the smartphones had to be restarted because of overheating. Some students could not properly trigger the hotspots (n = 9). Most of the above problems were eliminated after the first session in which the HMDs were used. Discomfort caused by the use of HMDs was also an issue (n = 11). Finally, some cases of -mild- simulator sickness were reported (n = 8).

Additional analysis

Given that the 360º videos proved to be the most enjoyable, motivating, and immersive tool among the ones we tested, we decided to conduct an additional analysis, in order to gather insights for the impact of the above factors on the learning outcomes when viewing 360º videos. For that matter, we run a two-step hierarchical multiple regression analysis. The dependent variable was students' mean scores in the 360º videos' tests, while the independent variables were Sex (entered during the first step of the regression, for controlling its effects) and the mean scores of the five factors in the questionnaire for 360º videos. We have to note that our sample size was below the minimum threshold the relevant literature recommends for this type of analysis. We acknowledge this limitation and we advise caution when interpreting our results. Nevertheless, the results (Table 7) demonstrated that immersion, enjoyment, and motivation had a significant positive impact on students' learning when viewing the 360º videos (t = 4.15, p < .001; t = 3.92, p < .001; and t = 2.94, p = .004 respectively).

Table 7. Results of the multiple regression analysis

Step 1 model summary	$F(1, 82) = 3.19, p = .078, R = .193, R^2 = .037$				
Step 2 model summary	$F(5, 77) = 13.74, p < .001, R = .701, R^2 = .491$				
Strep 1 IV	***b***	**SE B**	***β***	***t***	***p***
Sex	4.66	2.61	.19	11.95	.078
Step 2 IVs					
Sex	3.26	2.00	.14	1.63	.108
Immersion	5.04	1.21	.36	4.15	< .001
Enjoyment	7.29	1.86	.34	3.92	< .001
Subjective usefulness	1.74	1.37	.11	1.27	.208
Ease of use	1.33	1.57	.07	0.84	.402
Motivation	6.54	2.22	.24	2.94	.004

Notes. b = unstandardized beta coefficients, SE B = standard errors for b, β = standardized error coefficients, t = t test statistic, p = probability value

Discussion

For every new digital tool, it is imperative to validate its impact on learning, so as all involved in education to be able to make informed decisions about whether it can be adopted or not (Grover et al., 1996). That being said, the analysis of students' scores in the evaluation tests we presented in the preceding section, demonstrated that 360° videos have statistically significant advantages in terms of knowledge gains compared to printed material but not compared to regular videos. Also, the analysis of the questionnaires brought to light some findings regarding the five factors we examined, worthy of further discussion.

An interesting observation is made by comparing the pre-test scores and the scores in the evaluation tests for the three tools (see Table 2). In short, the comparison reveals that we can expect an improvement of around 51.5% in students' prior knowledge with the use of printed material, around 60% with regular videos, and around 63.5% with 360° videos. While these results cannot be generalized to learning subjects other than the ones included in our study (i.e., subjects related to environmental education), they provide a -rather general- idea about the impact on learning that is expected from the use of the above tools.

There are two opposing interpretations of the outcomes, that reflect the ongoing and unsettled debate concerning all educational tools (regardless if they are ICT related or not). Some might suggest that the distance between the results of the printed material on one hand and both types of videos on the other, is not that great (although, statistically speaking, it is). Moreover, considering the time and effort needed for the development of 360° videos and the cost of obtaining the necessary technological apparatus, this technology might not be so appealing as it was initially considered. The questionnaires' results regarding the tools' subjective usefulness give partial and indirect support to such claims. Indeed, students expressed the view that all tools were equally effective in facilitating their learning, despite the fact that they liked 360° videos more (as it is evident in the results concerning other factors). Yet, others, including us, might argue that education is not about how much better are the learning outcomes of a tool compared to others, but whether they are better or not. That is because, in education, small differences do count and accumulate into larger differences through the course of time. In this respect, even the 3.5% difference that we found between regular and 360° videos, though not statistically significant, might be important. Not only that, but we have to emphasize that, in this study, we examined the effects of 360° videos without embedding them (or the other tools) in a teaching framework. On the basis of the results of our previous studies in which we did exactly that and given that we used the same learning material, we can theorize that better results can be expected, as the use of 360° videos seems to be well-aligned with contemporary teaching methods.

Nevertheless, our findings confirm the existing literature reporting that 360° videos are able to produce positive learning outcomes (e.g., Chang et al., 2019; Fokides & Arvaniti, 2020; Wu et al., 2019). Thus, what we have to discuss is the "why" these outcomes were observed. In line with past research, we found that the feeling of immersion was strong in 360° videos (e.g., Berns et al., 2018; Elmezeny et al., 2018; Fokides & Kefalinou, 2020; Higuera-Trujillo et al., 2019). Furthermore, in our additional analysis, we confirmed the positive impact of this factor on the learning outcomes. Therefore, immersion offers a quite strong explanation for the outcomes, as it allows a better understanding of concepts and processes (e.g., Chang et al., 2019; Dawson et al., 2018; Fokides & Arvaniti, 2020). In addition, we found that students were more motivated to learn when viewing 360° videos and we noted motivation's positive impact on students' learning. More or less we expected this finding, as motivation to learn seems to be one of the 360° videos' key-advantages (Fokides & Arvaniti, 2020; King-Thompson, 2017; Xie et al., 2019).

Learning satisfaction is important for determining the effectiveness of a tool. Research in learning satisfaction when regular videos are used, even in its early stages, has demonstrated that they offer a quite satisfying experience (Ritchie & Newby, 1989). As 360° videos are more advanced in terms of the presentation of the visual content, we expected higher levels of satisfaction, as others suggested (e.g., Huang et al., 2019; Violante et al., 2019). We examined two aspects of learning satisfaction: (i) how valuable/useful users consider the tools in relation to their learning; this factor has been widely used for measuring the impact of technologies such as augmented reality (e.g., Akçayır & Akçayır,

2017) and (ii) the fun/enjoyment students had when using these tools. As we already mentioned in a previous paragraph and interestingly enough, we did not find any differences in the tools' subjective usefulness (see Table 5). Then again, we have to stress that students considered all three tools highly useful (see Table 2). Moreover, of the three tools considered, students' enjoyment was higher in 360º videos (see Table 6). Thus, we can conclude that learning satisfaction was higher in 360º videos. What is also of interest, is that although enjoyment was very high, we found that it was positively correlated with the learning outcomes (see Table 7). Researchers suggested that the novelty of the experience intensifies enjoyment, which, in turn, can lead to increased knowledge gains (Lin et al., 2019). Yet, others suggested that overexcitement might lead to distraction and a subsequent decrease in knowledge gains (Rupp et al., 2016). While we acknowledge that the latter case is probable, we are more inclined towards the former one, because of our study's results.

Our results suggest that 360º videos are -by far- the least easy-to-use tool (see Table 2 and Table 6). This comes as a bit of surprise since we provided students enough time (at least in our view) to familiarize themselves with the HMDs and how to navigate in 360º videos; probably we had to allocate more time. Although we did not find a negative impact on the learning outcomes due to this issue, it is possible that it is related to low-tech HMDs (as were the ones we used in our study), as navigation is implemented in a somehow "unnatural" method, namely by keep looking towards the direction of a hotspot for a few seconds rather than with the use of hand-held controllers (Fokides et al., 2020). Finally, students reported some cases of discomfort and mild simulator sickness. Although there is literature suggesting that simulator sickness can be a significant problem (Rupp et al., 2019) negatively impacting learning (Lackner, 2014), we conclude that even the low-tech HMDs can be well-tolerated by young students, at least when they are used for a limited amount of time (around twenty minutes).

Implications for research and practice

Our study extends the existing literature regarding the impact 360º videos have on learning as it: (i) quantified and contrasted their learning outcomes with that of other tools commonly used in educational settings, (ii) explored students' views and feelings regarding their use, and (iii) quantified (with limitations) the impact of certain factors (i.e., enjoyment, motivation, and immersion). Due to the above, we can suggest a number of interesting implications for all involved in the educational uses of 360º videos. For example, we noted elevated levels of enjoyment and motivation when students explored the educational material using this technology. Although this is not uncommon in educational ICTs, software developers can explore pathways for increasing them even more. The addition of game-like features is among the most common approaches for achieving this (Fokides et al., 2019). On the other hand, we think that it is advisable to balance fun and learning, given that students' overexcitement, because the novelty of the experience 360º videos offer is already a distraction factor (Rupp et al., 2016). The addition of game-like features might intensify distraction's negative effects. We also found that students considered 360º videos the least easy tool to use. As we theorized in the previous section, the way navigation was implemented was a probable cause. Given that, we advise the use of hand-held controllers or even hand-tracking devices, since navigation using them is more natural (Miller & Bugnariu, 2016). Then again, the trade-off is the additional cost of these devices and the relatively harder implementation (in terms of programming/software development). Moreover, as we used low-tech HMDs, this might have had a negative impact on immersion and, in turn, on the learning outcomes as others suggested (Rupp et al., 2019). Therefore, we underline the need for studies comparing different types of HMDs, offering different levels of immersion, in order to examine its exact impact on learning.

As for education, on the basis of our results, it seems that 360º videos offer an appealing path for presenting the learning material. Although they were as effective as regular videos, their more positive impact on motivation cannot be overlooked. Yet, some constraints regarding their integration in everyday teaching cannot be ignored. We consider the lack of reliable educational content to be the most significant one. Even though millions of 360º videos are available, most of them for free, far less are suitable for educational use, as their vast majority was recorded for recreational purposes. Initiatives for delivering educational content with the use of 360º videos are scarce (e.g., Google Expeditions). Furthermore, it is questionable whether educators are willing to dedicate the amount of time needed for recording and editing such videos by themselves. To make things worse, the infrastructure required, even for low-tech HMDs and smartphones, is not always present, although the cost is not considerable. Thus, we believe that steps should be taken in order to convince education administrators and policymakers to take action.

Limitations and future work

Although our data suggest that 360° videos have a positive impact on learning, we have to acknowledge certain limitations of our study. Although our sample size was more than satisfactory, we targeted a rather narrow age-range (ten-to eleven years old); thus, we are not able to offer valuable insights about what the impact of 360° videos might be on younger or older students. The learning subject of the videos might also raise some concerns. That is because environmental issues are rather difficult to grasp and the cognitive load might not have been that well-suited for students of the aforementioned age. As we already mentioned in the last section of our data analysis, the results regarding the impact of certain factors on the effectiveness of 360° videos have to be viewed with caution, as the sample size was not ideal for multiple regression analysis. All the above limitations can serve as guiding principles for future research projects. In addition, it would be interesting to analyze educators' views about the introduction of this technology to their teaching. Longitudinal studies are also needed for assessing the effectiveness of 360° videos when the novelty effect wears out. Finally, we think that comparisons with other available or emerging technologies (e.g., augmented reality and fully immersive VR using high-tech HMDs) are needed, so as to understand the pros and cons of this technology.

Conclusion

An ever-growing number of either conventional or ICT related tools are utilized with the objective to improve students' learning. One such tool is 360° videos. Although the general consensus is that they are effective, the existing literature does not give definite answers regarding their exact educational potential. This was the driving force of our study. By comparing the results with the ones coming from the use of regular videos and conventional printed material, we tried to determine whether they constitute an attractive, and, at the same time, effective alternative solution for presenting the learning material. Eighty-four ten-to-eleven-year-old students participated in our experiment. On the basis of the results, we can conclude that while 360° videos produced better learning gains than printed material, they did not offer significant advantages compared to regular videos. We have to note that the above results display what the tools per se can achieve, as we did not examine them in the context of a teaching framework. Moreover, we concluded that motivation, enjoyment, and immersion play a significant role in 360° videos' effectiveness. On the negative side, we found that usability issues are a concern, as 360° videos were the least easy to use tool. In conclusion, our study adds more evidence to the body of research supporting that 360° videos have an interesting educational potential and that educators can consider using them in their daily practices.

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Appendix

The questionnaire's items

Factor	Item
Enjoyment	I think the tool* I used was fun
	I felt bored while using this tool**
	I enjoyed using this tool
	I really enjoyed studying with this tool
	I felt frustrated**
Subjective usefulness	I felt that this tool can ease the way I learn
	This tool was a much easier way to learn compared with the usual teaching
	This tool made my learning more interesting
	I felt that this tool helped me to increase my knowledge
	I felt that I caught the basics of what I was taught with this tool
Ease of use	I think it was easy to learn how to use this tool
	I found this tool unnecessarily complex**
	I think that most people will learn to use this tool very quickly
	I needed to learn a lot of things before I could get going with this tool**
	I felt that I needed help from someone else in order to use this tool because It was not easy for me to understand how to use it**
	It was easy for me to become skillful at using this tool
Immersion	I was deeply concentrated when using the tool
	If someone was talking to me, I couldn't hear him
	I forgot about time passing while using the tool
	I felt detached from the outside world while using the tool
Motivation	This tool did not hold my attention**
	When using this tool, I did not have the impulse to learn more about the learning subject**
	The tool did not motivate me to learn**

Notes. * = the word "tool" was replaced by "printed material", "regular videos", and "360° videos", depending on the tool students used; ** = item for which its scoring was reversed; all items were presented in a five-point Likert type scale