International Journal of Smart Education and Urban Society
Volume 11 • Issue 4 • October-December 2020

Using Google Cardboard Compatible HMDs and Spherical Videos for Teaching History to High School Students

Emmanuel Fokides, University of the Aegean, Greece
https://orcid.org/0000-0003-3962-0314

Eleni Polydorou, University of the Aegean, Greece
https://orcid.org/0000-0003-4123-2871

Panos Mazarakis, University of the Aegean, Greece
https://orcid.org/0000-0002-4871-2547

ABSTRACT

The study presents the results from a project in which subjects related with history were taught to high school students using spherical videos, viewed by means of smartphones and Google Cardboard compatible HMDs. The target group was 105, 14-15 years old students, divided into three groups. The first used printed material, the second web pages, and the third the HMDs. The project lasted for 12 two-teaching-hours sessions (four for each tool), and data were collected using evaluation sheets and a questionnaire for recording student views and attitudes. The results suggested that students who used the HMDs outperformed students who used the other tools. All tools were considered equally effective and the participating students considered the web pages as easier to use. Then again, the combination of spherical videos, smartphones, and HMDs was more enjoyable and motivating. Though the findings highlighted the educational potential of spherical videos when viewed through HMDs, they also point to the need for finding innovative teaching methods/frameworks for better exploiting their potential.

KEYWORDS

Enjoyment, Google Cardboard, Head Mounted Displays, High School, History, Motivation, Spherical Videos

INTRODUCTION

The study of history is essential in a democracy, as it allows citizens to reach an understanding of the society they live in, of the human relations through the course of time, and of the reasons things do not remain static (Bradley Commission on History in the Schools, 1989). History education provides the context within which citizens, by drawing knowledge from the past, can shape their decisions for the present. To achieve that, certain skills and patterns of mind are required, such as (i) to perceive the events as they were experienced/perceived by the people of the time these events took place, (ii)

DOI: 10.4018/IJSEUS.2020100102

to be able to constructively question, debate upon, and interpret past texts and artifacts, and (iii) to understand that our views for historical events are constantly evolving depending on the available sources and their interpretations (National Council for History Education, n.d.). Then again, it seems that conventional teaching methods (e.g., lecturing) and tools (e.g., printed material), have failed to achieve the above. Students not only have trouble understanding the importance of historical events, but they also find the teaching of history boring and with little relevance to their interests (Angeli & Tsaggari, 2016; Barton & Levstik, 2004). Consequently, new teaching tools and methods are needed for raising students' interest in history and for achieving better learning outcomes.

Videos are widely used as entertaining media as well as educational tools. Much of their success is attributed to the fact that viewers get emotionally involved with what they see (Carr-Chellman & Duchastel, 2001). Then again, videos have certain limitations that do not allow them to become even more interesting or effective. One such is that viewers are confined to a single point-of-view; they cannot view the video content from a different angle/perspective. Yet, another form of videos, known as 360o or spherical videos (SVs), surpasses this limitation. SVs are recorded using panoramic cameras able to capture images from a whole sphere and not just from a limited field of view. They can then be displayed in computers, smartphones, or head-mounted displays (HMDs). In case of the two latter devices, the viewers can turn their heads in any direction they like and watch the portion of the SV corresponding to the direction they "see." The dynamic nature of SVs is further enhanced with the use of embedded hotspots that can trigger events/interactions (e.g., the display of images, text, and regular videos). Because of the realism and the innovative way the content is displayed, SVs are increasingly used in areas such as engineering and health sciences and for the presentation of cultural events, museums, and historical sites. They also found their way in education. In this case, the relevant research reported promising learning outcomes (e.g. Pham et al., 2018), a positive impact on motivation to learn, as well as elevated levels of enjoyment when learning (e.g., Lee et al., 2017; Xie et al., 2019).

In light of the above, it was considered interesting to examine whether the above positive effects resulting from the educational use of SVs can also be achieved when teaching history-related subjects. Thus, a project was implemented, having as an objective to comparatively examine the learning outcomes from the use of SVs, web pages, and printed material. Details for the project are presented in the coming sections.

HISTORY AS A LEARNING/TEACHING SUBJECT

The teaching of history, at all levels of education, is particularly important, as it allows students to understand contemporary national, political, social, religious, and economic issues (Zin et al., 2009). However, it is noted that, compared with other courses, history has always been considered uninteresting and boring. That is because it is usually conducted using conventional methods/means (i.e., lecturing and printed material) and few teaching aids (e.g., maps), putting emphasis on the memorization of an assortment of names, places, events, and chronological sequences (Angeli & Tsaggari, 2016). In contrast, far less emphasis is put on making connections between past events, between past events and the places they took place, and between past events and the present day. These result in historical data being perceived as uncorrelated (Barton & Levstik, 2004) and also cause a rift in the connection between reality and learning (Wong & Ghavifekr, 2018). Moreover, as the emphasis is on memorization, parroting already "processed" knowledge, and conducting standardized activities, neither critical thinking is encouraged, nor the formation of historical and/or cultural identity is nurtured.

The above also holds true for the Greek educational system (Angeli & Tsaggari, 2016). The problem is even more severe in the Greek history curriculum for secondary education. The syllabus is voluminous, fragmented into discrete/independent parts, each taught at a different high-school grade. In essence, there is no unified corpus that would allow students to critically examine it; students form the -wrong- impression that history is just a linear juxtaposition of disconnected periods/events (Vakaloudi & Dagdilelis, 2016).

Many historical sites have properties that can awe the observers as they come into contact with their colors, sounds, and size. As a result, the understanding of the site's history and importance is enhanced (Zin et al., 2009). The same applies to the emotions certain historical events can evoke to a person. In this respect, the intellectual and emotional embroilment historical sites and events can generate to students, if used during teaching, can probably increase their interest and their need to further explore them (Rasheed et al., 2015). In essence, what is suggested is that there is the need for an instructive premutation; from viewing history as a series of -mostly unconnected- events, to history teaching that is based on reflection and emotions. To the above, technology can play a decisive role as it has the potential to overturn the traditional narrative form of history. Indeed, ICTs contribute to history teaching by allowing direct access to (historical) sources, by providing collaborative learning environments, and by offering rich visualizations and experiences to students (e.g., through simulations) (Sutherland et al., 2004).

It seems that all the most common and widely accepted for their educational value technologies and ICT applications have been used -to a varying degree- for history teaching. In fact, there are numerous online resources available for school use that can be accessed through web pages and their use has been studied extensively (e.g., Lim et al., 2013; Klein, 2017). Quite common is the use of digital games (Nor Azan, 2013; Senrick, 2013; Watson et al., 2011), as well as serious games (e.g., Mortara et al. 2014). The relevant literature also reports the use of smartphones and augmented reality applications (e.g., Kysela and Štorková 2015; Magro et al. 2014), simulations, and virtual reality (e.g., Wright-Maley et al., 2018; Yildirim et al., 2018).

SPHERICAL VIDEOS

The most basic devices for viewing SVs are smartphones. However, Google Cardboard offered an extremely low-cost solution for experiencing SVs more immersively. It is an HMD-like device made out of Cardboard or plastic with just two lenses contained within the enclosure, in which a smartphone is inserted (because it does not have its own displays as the standard HMDs have). The built-in gyroscope of the smartphone tracks the user head movements, displaying, in turn, the portion of the SV corresponding to the orientation of the device. Given that smartphones have limited processing power, the quality of the video is inferior to that of standard HMDs. For triggering interactions and for navigating, users have to focus on hotspots embedded in the scene and hold that position for about two seconds. Although users do not have trouble using this interaction mode, some raised usability concerns, as they supported that hand tracking devices allowed for a more natural interaction (Miller & Bugnariu, 2016). Probably the most significant issue of HMDs, but mostly of devices similar to Google Cardboard, is simulator sickness. As the viewer is static but the SV depicts moving objects or even the camera is moving, this results in sensorimotor contingencies (the eyes and the body provide conflicting information to the brain), affecting the vestibular system (the system responsible for the sense of balance, motion, and spatial orientation), which, in turn, causes nausea and/or vomiting (Lawson, 2014). Understandably, this situation severely impairs one's cognitive abilities and learning experience (Rupp et al., 2019).

Quite reasonably, SVs attracted the interest of researchers and professionals from a variety of disciplines. For example, they are used for virtual tours to museums and sites of cultural and historical interest (e.g., Argyriou et al., 2017; Minocha et al., 2017), as well as for the demonstration of lab experiments (e.g., Ardisara & Fung, 2018), or surgical procedures (e.g., Pulijala et al., 2018). SVs are also used for the teaching of courses/subjects at all levels of education, such as science, Geography (e.g., Minocha et al., 2017; Wu et al., 2019), first and second language (e.g., Blyth 2018; Xie et al. 2019), for construction-safety (e.g., Pham et al. 2018) or healthcare education (Ulrich et al., 2019), and for delivering university lectures (McKenzie et al., 2019).

Notwithstanding the broad scope of applications, research regarding the educational uses of SVs is still at its infant stage. Consequently, there are research gaps and contradictory results. In general, users/students found that SVs offered them enjoying (Lee et al., 2017) and interesting (Xie et al., 2019) experiences that motivated them to learn (Karageorgakis & Nisiforou, 2018) and engaged them with the learning content (Broeck et al., 2017). While most reported positive learning outcomes (e.g., Karageorgakis & Nisiforou, 2018; Pham et al., 2018), noting benefits even for students of poor performance (e.g., Wu et al., 2019), others reported no significant differences (e.g., Lee et al. 2017) or even worst learning outcomes compared with traditional teaching (Ulrich et al., 2019). The lack of a well-developed pedagogical framework for their use was also noted (Sultan et al., 2019). Disorientation, distraction, and lack of focus are still unresolved issues. For example, presence, the feeling of being/living inside the virtual environment (Falah et al., 2014), was found to be strong in SVs (Rupp et al., 2016,2019). Then again, this led to less information recall, as users were overwhelmed by the novelty of the experience and got distracted (Rupp et al., 2016). Besides users being easily disorientated (Ardisara & Fung, 2018), it is not easy to draw their attention and keep them focused on what is important; they might be interesting to a certain part of the scene while something important takes place at a different part.

STATEMENT OF THE PROBLEM AND HYPOTHESES FORMATION

The brief literature review presented above highlighted certain important issues. First, students have difficulties in history related learning subjects. Second, there are many uncertainties regarding the impact of SVs on learning, as they constitute an emerging study field, not yet systemized. Also, methodological issues (e.g., small sample sizes and few interventions) are not uncommon. Although SVs can be viewed on computers as well, very few studies contrasted their impact of this medium and HMDs. Most importantly, the use of SVs for history teaching remains outside the main concern of research; to the best of the authors' knowledge, there are no relevant studies. Therefore, the objective of the paper is to draw attention to the possibilities that SVs offer in this field, by testing the following hypotheses:

H1: When teaching subjects related to history to high school students, the use of smartphones and HMDs similar to Google Cardboard for viewing SVs yields better learning outcomes compared with other teaching tools, such as printed material or web pages.

H2a-d: Compared with printed material and web pages, high school students consider the use of smartphones and HMDs similar to Google Cardboard for viewing SVs as (a) more enjoyable, (b) more useful, (c) easier to use, and (d) more motivating.

METHOD

For testing the above hypotheses, a between-subjects experimental design with one experimental (SVs, viewed using HMDs similar to Google Cardboard) and two control groups (printed material and web pages) was applied, Details for the project are presented in the coming sections.

Participants and Duration

The Greek program of study for the teaching of history in high school includes subjects related to ancient Greece (first grade), the Byzantine Empire (second grade), and the main historical events between the late fifteenth century until today (third grade). Out of these subjects, the latter period was considered as being the closest to students' interests. Thus, the study's target group was third-grade high school students (ages fourteen to fifteen).

In line with the recommendations for achieving an ordinary/typical sample (Creswell & Poth, 2017) the following selection criteria were applied for forming the study sample: (i) students to attend urban public high schools, (ii) to have never before been taught subjects similar to the ones in the project, (iii) to have never before used HMDs, and (iv) their spread of ability and the ratio of boys and girls not to be far off of a typical Greek third high school grade. Several history teachers working in high schools in Athens, Greece were conducted and interviewed for determining whether their students met the above criteria. As a result, six classes were selected, having a total of 117 students. In order to comply with rules for conducting research with minors: (i) a research approval was granted from the University's ethical committee and (ii) students' parents provided their written consent.

It was decided sessions to last for two teaching-hours each. Several reasons lead to this decision; the teaching procedure (presented in a later section) -by default- requires a lot of time given that students work in groups, additional activities are included, and their active participation is encouraged through the exchange of ideas and discussions. Moreover, it was essential to making provisions for extra time, as some delays and technical issues are -in most cases- expected when students use ICT tools. Four sessions for each group were considered enough to form a rather comprehensive idea on the impact of each tool in student knowledge. Therefore, the project lasted for a total of twelve sessions, from mid-October to mid-November 2019.

Materials

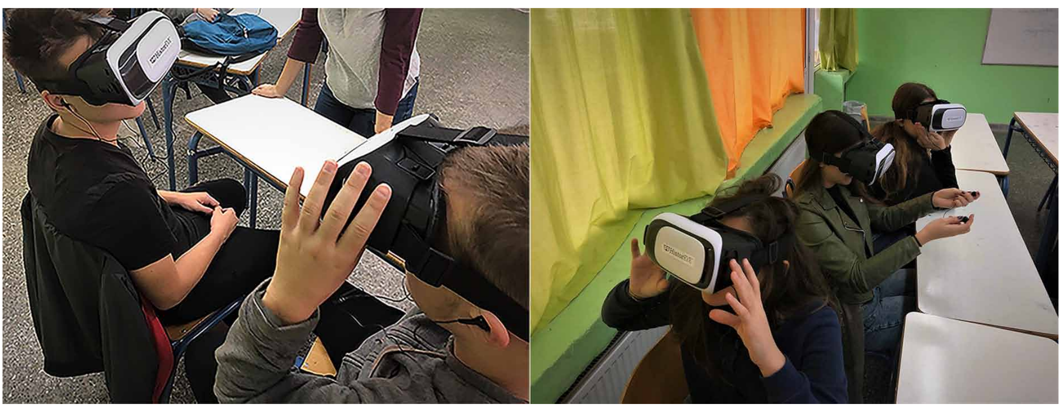
An important concern was the learning material to discuss/present subjects suitable for filming. While a number of units included in the third grade's history textbook met this criterion, very few were -even remotely- related to each other; thus, it was very hard to form a coherent learning material to be used in a sequence of interventions. After reflecting on the mater, it was decided to select different parts of the textbook, but all to revolve around a central theme, namely the history of the Palamidi fortress, in Nafplio, Greece. It is a typical baroque fortress, built during the second occupation of the city by the Venetians (1686-1715). It was captured by the Ottomans in 1715 and part of it was destroyed. In fact, Lasalle (one of the engineers who designed the fortress) helped them during its siege. Palamidi remained under Ottoman control until 1822. During the uprising of Greeks against the Ottoman Empire, it was captured by Staikopoulos (a Greek hero) and his men. In 1834, Kolokotronis (probably the most prominent figure of the Greek uprising) was accused of high treason and he was imprisoned for eleven months in Palamidi, before being pardoned. According to the local legend, his cell (which nowadays attracts a significant number of visitors) was a hole in one of the fortress's bastions, occupying a space of no more than 1.05 X 0.69 meters. In later years, until 1926, Palamidi became an infamous prison for long-term convicts.

The above four distinct periods of the fortress's history became the basis for an equal number of teaching units. A low-cost 360o camera was used for recording the necessary SVs and 360o photos. Several editing stages followed, including video stabilization (using CyberLink's PowerDirector 17), narration recording, video-music-narration synchronization, and exporting the resulting videos in 4K resolution. Following that, four guided virtual tours (one for each teaching unit) were developed using Unity. In these tours, interactive hotspots were embedded which allowed the transitions between videos and the presentation of information in the form of texts, photos, and simple videos (in addition to the narration). The hotspots were triggered using the gazing system, meaning that users had to center their view to a hotspot and hold still for at least two seconds. For reasons further elaborated in the "Procedure" section, each tour consisted of two parts, one which presented the main learning material and one presenting the additional one. Finally, the virtual tours were exported as Android apps (Figure. 1). The participating students viewed the apps using smartphones and HMDs similar to Google Cardboard (one for each student), provided by the project (Figure. 2).

A booklet was written and Google sites were used for the development of a web site. Although sequences of photos replaced the videos in the booklet, both the booklet and the web site presented

Figure 1. Screenshots from the SVs

Figure 2. Screenshots from the lessons



the exact same learning material included in the virtual tours and were also split into two parts. Finally, a series of worksheets were written, including in-classroom activities, tasks, and exercises.

Instruments

Four evaluation sheets/tests together with a pre- and a delayed post-test were devised for assessing the learning outcomes. Each evaluation sheet was administered right after the end of a session, the pre-test was administered a week prior to the beginning of the project, and the delayed post-test was administered three weeks after its end. Around a third of the questions included in these tests examined the acquisition of declarative knowledge (e.g., facts, dates, figures, definitions of terms/concepts). The remaining two-thirds examined the acquisition of procedural and conditional knowledge. Indeed, these questions were rather “difficult;” they required critical thinking, attention to detail, and making connections with different pieces of knowledge. For example, students were asked to make concept maps, analyze the relationship between key players in the Greek uprising, give their own explanations for the outcome of certain events, and make educated guesses on what the outcomes might have been if the conditions were different. An initial pool of questions was suggested by both the authors and the teachers, followed by the assembly of draft evaluation sheets. In a series of face-to-face meetings, the drafts were assessed, revisions were made, and the final versions were established.

A modular scale designed for examining digital educational applications (Fokides et al., 2019) was used for examining H2a-d. Four of its factors were selected, namely, ease of use (six items), motivation (three items), subjective usefulness (six items), and fun/enjoyment (six items). All items were presented on a five-point Likert-type scale (ranging from 1 = strongly disagree to 5 = strongly agree). At the end of the questionnaire, there was also an open-ended question prompting students to report cases of simulator sickness or any kind of discomfort when using the HMDs.

Procedure

A rather important concern was the teaching procedure, described below, to be accurately followed in all groups. For that matter, during a meeting, it was demonstrated to the participating teachers who were then asked to strictly follow it. Except when wearing the HMDs, students worked in groups of four, following the suggestions for constructivist learning (Boyle, 1977; Bruner, 1966). Although Bybee et al.'s (2006) 5Es is a teaching framework most commonly used in science-related subjects, it was decided that, with minor adaptations, it could suit the study's needs. Thus:

- The purpose of the Engage stage is to excite students' interest in the learning subject. Following a short introduction outlining the main topic, the teachers prompted students to discuss among themselves what they already knew about it (e.g., relationships between key players and facts related to the subject);
- The Explore stage, as its name implies, allows students to explore the learning subject. Depending on the group that students belonged to, they studied the material included in the first part of the booklet/ web pages/virtual tours. Following that, they recorded their views and opinions in the unit's corresponding worksheet;
- The Explain stage allows students to communicate, with the rest of the class, the ideas and opinions they recorded during the previous stage. The objective of the discussions that followed was to reach a common consensus. If necessary, the groups revised their worksheets;
- The purpose of the Extend stage is to allow students to further explore ideas, facts, and issues presented during the Explore stage. The participating students studied/viewed the second part of the booklet/web pages/virtual tours. Once again, the worksheets were used for recording their views and opinions, followed by their presentation and another round of discussions with the other groups;
- During the Evaluation stage, in order for teachers to evaluate how much their students learned, they initiated a last round of discussions. These discussions focused, mainly, on the impact of the historical events presented in the lesson, on the present state of political/economical/social affairs in Greece and on Greece's relationship (or problems) with other countries. The reason for not asking/discussing topics directly connected to the lesson's subject matter was to avoid an impact on the results of the evaluation sheets that were administered right after the end of this stage.

During all stages, the teachers avoided direct lecturing. Instead, they acted as coordinators of student discussions and facilitated the whole process. When students were in need of some guidance, it was provided indirectly through hints or by drawing their attention to important aspects of what they were learning.

RESULTS

Although the initial sample size was 117 students, twelve were removed from the subsequent data analysis as they were absent in one or more sessions. As a result, Group1 (printed material) had 34 students, Group 2 (web pages) had 36, and Group3 (SVs) had 35. The evaluation sheets, as well as the pre- and delayed post-tests were graded on a 1-100 scale and the resulting data were imputed into SPSS 25 for further analysis. Table 1 presents the mean scores per group and per test.

Table 1. Tests means and standard deviations

Tests	Group1 $n = 34$		Group2 $n = 36$		Group3 $n = 35$	
	M	*SD*	*M*	*SD*	*M*	*SD*
Pre-test	26.65	13.14	24.28	13.42	25.03	12.32
ES1	52.62	12.38	60.78	13.03	68.09	11.82
ES2	58.88	14.11	62.50	13.06	70.40	8.28
ES3	56.94	14.07	64.03	14.81	66.97	14.62
ES4	60.26	17.26	69.53	14.48	78.37	12.92
Delayed post-test	46.38	11.54	49.19	11.52	57.34	12.50

Note. ES = evaluation sheet

Prior to conducting a series of one-way ANOVA tests for examining H1, the data were checked for violations of the assumptions for this type of test. No issues were found, as the data were normally distributed, there were no outliers, and the assumption for the homogeneity of variance was not violated. Although the three groups did not have equal sample sizes, this was considered a rather minor deviation, given that their sizes were not that different and one-way ANOVA is robust is such cases (Keppel & Wickens, 2004). The results of these tests indicated that there were no statistically significant differences in the pre-test [$F(2,102) = 0.30$, $p = .739$]. On the other hand, there were statistically significant differences in the (i) evaluation sheet 1 [$F(2,102) = 11.00$, $p < .001$], (ii) evaluation sheet 2 [$F(2,102) = 8.25$, $p < .001$], (iii) evaluation sheet 3 [$F(2,102) = 4.35$, $p = .0.15$], (iv) evaluation sheet 4 [$F(2,102) = 12.23$, $p < .001$], and (v) delayed post-test [$F(2,102) = 7.80$, $p = .001$].

As series of post-hoc comparisons followed on all pairwise contrasts, in order to examine the differences between pairs of groups. The results are presented in Table 2. From this table the following can be inferred:

- **Evaluation Sheet 1:** Group3 ($M = 68.09$, $SD = 11.82$) outperformed both Group1 ($M = 52.62$, $SD = 12.38$, $p < .001$, $d = 1.28$) and Group2 ($M = 60.78$, $SD = 13.03$, $p = .039$, $d = 0.59$). Also, Group2 outperformed Group1 ($p = .019$, $d = 0.64$);
- **Evaluation Sheet 2:** Students in Group3 ($M = 70.40$, $SD = 8.28$) achieved better results compared with students in Group1 ($M = 58.88$, $SD = 14.11$, $p < .001$, $d = 1.39$) and Group2 ($M = 62.50$, $SD = 13.06$, $p = .019$, $d = 0.72$). There were no differences between Group2 and Group1 ($p = .425$);
- **Evaluation Sheet 3:** Group3 ($M =66.97$, $SD = 14.62$) outperformed Group1 ($M = 56.94$, $SD = 14.07$, $p = .014$, $d = 0.70$) but not Group2 ($M = 64.03$, $SD = 14.81$, $p = 670$). Also, there were no differences between Group2 and Group1 ($p = .107$);
- **Evaluation Sheet 4:** Group3 ($M = 78.37$, $SD = 12.92$) had better results compared with both Group1 ($M = 60.26$, $SD = 17.26$, $p < .001$, $d = 1.19$) and Group2 ($M = 69.53$, $SD = 14.48$, $p = .038$, $d = 0.64$). Also, Group2 outperformed Group1 ($p = .029$, $d = 0.58$);

Table 2. Post-hoc pairwise comparisons

Evaluation Sheet	Group (x)	Group (y)	Mean Difference (x-y)	Std. Error	*p*	*d*	95% Confidence Interval for Difference	
							Lower Bound	Upper Bound
ES1	Group1	Group2	-8.160	2.972	.019	0.64 (medium)	-15.23	-1.09
		Group3	-15.468	2.992	< .001	1.28 (very large)	-22.58	-8.35
	Group2	Group3	-7.308	2.950	.039	0.59 (medium)	-14.32	-.29
ES2	Group1	Group2	-3.62	2.887	.425	-	-10.48	3.25
		Group3	-11.52	2.907	< .001	1.39 (very large)	-18.43	-4.60
	Group2	Group3	-7.90	2.866	.019	0.72 (medium)	-14.72	-1.08
ES3	Group1	Group2	-7.09	3.470	.107	-	-15.34	1.17
		Group3	-10.03	3.494	.014	0.70 (medium)	-18.34	-1.72
	Group2	Group3	-2.94	3.444	.670	-	-11.14	5.25
ES4	Group1	Group2	-9.26	3.579	.029	0.58 (medium)	-17.77	-.75
		Group3	-18.11	3.603	< .001	1.19 (very large)	-26.68	-9.54
	Group2	Group3	-8.84	3.552	.038	0.64 (medium)	-17.29	-.40
Post-test	Group1	Group2	-2.81	2.836	.584	-	-9.56	3.93
		Group3	-10.96	2.856	.001	0.91 (large)	-17.75	-4.17
	Group2	Group3	-8.15	2.815	.013	0.68 (medium)	-14.84	-1.45

Notes. - = not applicable; d = effect size, Cohen's d

- **Delayed Post-Test:** Students in Group3 ($M = 57.34$, $SD = 12.50$) achieved better results compared with students in Group1 ($M = 46.38$, $SD = 11.54$, $p = .001$, $d = 0.91$) and Group2 ($M = 49.19$, $SD = 11.52$, $p = .013$, $d = 0.68$). There were no differences between Group2 and Group1 ($p = .584$).

Given that students in Group3 outperformed (i) students in Group1 in all the evaluation sheets and in the delayed post-test and (ii) students in Group2 in three out of four evaluation sheets and in the delayed post-test, H1 is confirmed; when teaching subjects related to history to high school students, the use of SVs, yields better learning outcomes compared with other teaching tools, such as printed material or web pages.

Coming to the questionnaire, its overall internal consistency, as well as the reliability of the four factors, were assessed using Cronbach's alpha. In all cases, α was found to be very good as it was well above the recommended value of .70 (DeVellis, 2003) (ranging from $\alpha = .805$ to .821 for the factors and $\alpha_{overall} = .808$). For examining H2a-d, eleven variables were calculated, representing the averages of students' responses in each factor (three factors X three groups, plus one factor X two groups because for Group1 the factor labeled as "Ease of use" was not applicable). Descriptive statists for the questionnaire's factors are presented in Table 3. As with the evaluation sheets, a series of one-way ANOVA tests were to be conducted for examining the differences among groups. Given that in almost all cases the data were not normally distributed and the homogeneity of variances was violated, it was decided to proceed using Kruskal-Wallis H test (the non-parametric equivalent of one-way ANOVA test). No statistically significant differences were observed in subjective usefulness [$H(2) = 1.23$, $p = .540$]. Thus, H2b is rejected; high school students consider printed material, web pages, and SVs, as equally useful.

Table 3. Factor means and standard deviations

Factor	Group1 $n = 34$		Group2 $n = 36$		Group3 $n = 35$	
	M	*SD*	*M*	*SD*	*M*	*SD*
Enjoyment	3.32	1.04	3.98	0.86	4.56	0.48
Motivation	3.34	1.05	3.48	0.83	4.18	0.54
Ease of use	-	-	4.35	0.58	3.41	0.90
Subjective usefulness	3.50	1.10	3.83	0.86	3.75	0.67

Note. - = not applicable

In all the other factors there was strong evidence of a difference between the mean ranks (at least in one pair of groups) [$H(2)_{\text{enjoyment}} = 28.54$, $p < .001$; $H(2)_{\text{motivation}} = 17.68$, $p < .001$; and $H(1)_{\text{ease of use}} = 20.10$, $p < .001$]. A series of Dunn's (1964) pairwise post-hoc tests were carried out for examining the differences between groups (Table 4). Note that Bonferroni adjusted *p*-values are reported, which conservatively adjust the significance level depending on the number of repeated analyses being conducted (Bland & Altman, 1995).

From the results in Table 4, it can be concluded that:

- **Enjoyment:** Students considered SVs as being more enjoyable than the printed material ($p < .001$, $d = 1.57$) and web pages ($p = .011$, $d = 0.80$). In addition, students enjoyed the use of web pages more than the use of the printed material ($p = .039$, $d = 0.67$). Thus, H2a is confirmed;
- **Ease of Use:** According to the participating students, the web pages were easier to use compared with SVs ($p < .001$, $d = 1.27$). Given that, H2c is rejected;
- **Motivation:** When contrasting the results of groups 1 and 2 no statistically significant differences were found ($p = 1.000$). Then again, the SVs were more motivating than both the printed material ($p < .001$, $d = 0.91$) and web pages ($p < .001$, $d = 1.01$). Therefore, H2d is confirmed.

Table 4. Factor post-hoc comparisons

Factor	Pair	Std. Test Statistic	Mean Ranks Group A, B		*p*	*d*
Enjoyment	1-2	-2.48	28.90	41.74	.039	0.67 (medium)
	1-3	-5.35	22.46	47.19	< .001	1.57 (very large)
	2-3	-2.91	28.60	43.61	.011	0.80 (large)
Motivation	1-2	-0.291	34.12	36.81	1.000	-
	1-3	-3.76	26.49	43.27	.001	0.91 (large)
	2-3	-3.52	26.92	45.34	.001	1.01 (large)
Ease of use	1-2	-	-	-	-	-
	1-3	-	-	-	-	-
	2-3	20.10	46.79	24.90	< .001	1.27 (very large)

Notes. - = not applicable; p = Bonferroni adjusted significance level (when using this correction, it is possible to obtain p values equal to or greater than 1.000); d = Cohen's d

As for the open-ended question, the majority of students in Group3 ($n = 20$) reported simulator sickness (ranging from light to severe). In addition, around a third of them ($n = 13$) reported some discomfort (e.g., facial skin irritation and eyestrain). While students stated that simulator sickness manifested after a couple of minutes of viewing the videos, the problems related to discomfort were noted when the HMDs were used for an extended period of time (about twenty minutes or more).

DISCUSSION

Student's prior knowledge about the history subjects included in the project was rather limited, given that, regardless of the group they belonged to, they were able to answer correctly just a quarter of the questions in the pre-test. In the delayed post-test, although the percentage of the correct answers remained somehow low (around 46% to 57%), there was a significant positive change in students' performance (74% for the printed material, 103% for the web pages, and 129% for the SVs). Whether the learning outcomes each tool was able to produce are satisfactory or not is debatable. However, there are some facts that have to be accounted for. First, one has to keep in mind that the evaluation sheets, as well as the pre- and post-tests, were rather difficult (see "Instruments" section). Consequently, low scores were to be expected. Second, as all tools had a significant positive impact, they can all be considered effective. This logical assumption is consistent with the views of the participating students. Indeed, because there were no statistically significant difference in subjective usefulness, this means that they considered all tools as equally useful; to their view, they all helped them to learn. Third, it is true that the development of the virtual tours was significantly more time consuming compared with the development of the web pages (or the printed material for that matter). Given that, a skeptic might argue that considering the trouble for developing such apps on one hand and their added value (in terms of their impact on learning) on the other, their introduction into everyday teaching is not essential. Yet, equally valid is the argument that even small advantages that a teaching tool might have over other tools are crucial if we want to ensure that we deliver high-quality education to students. These arguments and counterarguments reflect the broader debate for the role of ICTs in education and it is not among the ones that can be easily settled. Nevertheless, on the basis of the results and strictly statistically speaking, significant differences between the three tools were noted. Further analysis revealed that the SVs surpassed the other tools in most cases, pointing to the valid conclusion that they were more effective. This finding is, more or less, consistent with previous research which suggested that SVs had a positive impact on learning (e.g., Karageorgakis & Nisiforou, 2018; Pham et al., 2018; Wu et al., 2019). Not only that but also the effect sizes were found to be mostly very large when the SVs were compared with printed material and medium when compared with web pages, reinforcing the validity of this conclusion.

Thus, what remains to be discussed is why the SVs had a larger positive impact on student knowledge. The results in the questionnaire indicated that students considered the SVs a fun experience. There was also strong evidence that students in the SVs group were highly motivated to learn. Both findings concur with the conclusions of past research suggesting that enjoyment when learning and motivation to learn, are key advantages of SVs (e.g., Broeck et al., 2017; Karageorgakis & Nisiforou, 2018; Lee et al., 2017; Xie et al., 2019). As both are linked with higher academic performance (Fokides et al., 2019), they provide a solid explanation for the better learning outcomes of the SVs group. There is another interesting conclusion that can be drawn by examining the results in enjoyment side-by-side with the learning outcomes. Several researchers advised caution about the role of enjoyment resulting from the novelty of the experience when students learn with SVs, suggesting that it can distract them from what they are supposed to learn (e.g., Ardisara & Fung, 2018; Rupp et al., 2016). Yet, in this study, although enjoyment was significantly higher in the SVs group (and the effect sizes were noteworthy), at the same time the performance of this group was better. It seems that the "wow" effect did not have a negative impact noted by others. The teaching framework, namely Bybee et al.'s 5Es (2006), might offer a creditable explanation for this outcome. It has to be stressed that, by itself, the teaching framework cannot explain the learning outcomes in the SVs group. That is because the same framework was applied to all groups; therefore, it is a probable explanation for the positive results in all of them. Then again, it can be assumed, that by engaging students with other meaningful in-classroom activities, directly connected with the content of the SVs, it allowed the SVs to be better integrated into teaching. Students knew beforehand that they had to be focused on what they were watching, because, at a later stage, they were going to discuss and draw conclusions on issues related to what they watched.

Besides the factors that might have had a positive impact, there are factors that might have had a negative one. Indeed, there were some cases of students in the SVs group that reported minor discomfort caused by the use of the HMDs. Not only that, but students also reported several cases of simulator sickness (some of which were severe). Although the SVs in this study were mostly recorded while the camera was fixed on a tripod, there were certain scenes recorded with the camera following the narrator. According to students' comments, the latter scenes were the ones causing most of the problems. As Rupp et al. (2019) suggested, simulator sickness has a strong negative impact on the learning experience and, quite reasonably, on the learning outcomes. Moreover, students considered the web pages as being easier to use and the effect size was very large. Usability is a factor that also affects the quality of the learning experience. An easy to use system does not disturb the flow of the learning experience, allowing users to be more focused on what they are trying to learn (Fokides & Atsikpasi, 2018). In contrast, a hard to use system forces users to allocate valuable cognitive resources in trying to master it. Given that despite the above problems, the group of students that used the SVs had better results compared with the other groups, it is probable that the outcomes would have been even better if these issues were resolved.

Implications for Research and Practice

The study at hand contributes to the relevant literature provided that (i) the use of SVs and HMDs is rather uncommon in history teaching and (ii) the impact of the above tools was quantified and comparatively examined with the impact of two other tools. The study's findings might be useful to software developers. Not only in SVs but also in other ICT related teaching tools, the increased fun/enjoyment positively impacts motivation to learn, and, in turn, this has a positive impact on the learning outcomes (Fokides & Atsikpasi, 2018). As the study results demonstrated that enjoyment and motivation are indeed important factors, developers should consider methods to increase both even further. A method to achieve that is to add game-like features, an advise applicable to all ICT related teaching tools (e.g., Faiola et al., 2013). The web pages proved to be easier to use than the HMDs, probably because, to the latter, navigation and triggering of interactions were done by focusing on the embedded hotspots. In this respect, an alternative and more natural way of interacting is through hand-tracking devices as Miller and Bugnariu (2016) suggested (although this adds to the total cost for the end-user).

Given the results, it can be recommended educators to integrate SVs and HMDs into their teaching. On the other hand, this suggestion has to be considered with some caution. The presentation of the learning content through SVs and HMDs does not necessarily mean that positive learning outcomes are to be expected; the context in which they are used is equally important. In this respect, for any teaching subject, educators have to make sure that the SVs are suitable and that their advantages over other teaching tools are strong. A well-defined teaching framework is also a prerequisite as noted by others (Sultan et al., 2019). That is because in-classroom meaningful and engaging activities might help to avoid the derailment of the learning process due to the novelty of the technology used. On the basis of the results, the teaching framework suggested in this study can provide a good starting point. Third, a familiarization period is advised when students use technology tools (Fernández-López et al., 2013). It has to be reminded that students found the use of web pages easier that the use of HMDs. This might not have been the case if students were more adept in the use of the navigation/triggering system. Finally, all the above require time that is not always available. Although two-teaching-hours per session proved to be enough, it was rather hard to fit them in the existing school timetable. Education policymakers should consider revisions to the program of study and to the teaching hours allocated for each subject, that will encourage innovative, technology-based teaching.

Limitations and Future Work

Even though the results were encouraging, the study is not without certain limitations that bear mentioning. While the sample size was adequate for statistical analysis, a larger one would have allowed for more confidence in the study's conclusions. The target group could have been more diverse; for example, other age groups could have been considered. Given that there are a lot of events associated with the historical period that was examined, one might argue that the number of sessions was rather limited. Therefore, concerns for the result generalizability are not totally unjustified. A significant limitation of the study is that it did not examine the impact of presence. Then again, presence is limited (if not non-existent) in web pages and printed material. Thus, it would have been unwise to compare the effects of these tools with the effects of HMDs and SVs. In addition, one has to take into account the study's exploratory nature; as the literature is both limited and spread across diverse disciplines, the most important goal was to shape a general idea on the pros and cons of HMDs and SVs in the context of history teaching. On the basis of the conclusions drawn by this study, future research can target students of all ages (ranging from primary school to university students). Other historical periods can be considered as well. Another interesting research path is to examine teachers' views and their willingness to integrate SVs and HMDs into their everyday teaching. Long-term interventions and the use of qualitative research tools could also be of help.

CONCLUSION

In the context of history teaching, high school students used smartphones and Google Cardboard compatible HMDs for viewing SVs. The learning outcomes were compared with that of printed material and web pages. On the basis of the results, it can be supported that the use of HMDs together with SVs proved to be effective tools for promoting high school students' knowledge about history. Their effectiveness can be attributed to fun and enjoyment, as well as to their positive impact on student motivation to learn. The instructional framework which was proposed and tested might have also contributed. On the other hand, more research is needed on what features to include in applications utilizing SVs and how to integrate them into teaching, that would allow researchers and educators alike to fully exploit their potential.

REFERENCES

Angeli, C., & Tsaggari, A. (2016). Examining the effects of learning in dyads with computer-based multimedia on third-grade students' performance in history. *Computers & Education*, *92*, 171–180. doi:10.1016/j.compedu.2015.10.015

Ardisara, A., & Fung, F. M. (2018). Integrating 360° videos in an undergraduate chemistry laboratory course. *Journal of Chemical Education*, *1881-1884*(10), 1881–1884. Advance online publication. doi:10.1021/acs.jchemed.8b00143

Argyriou, L., Economou, D., & Bouki, V. (2017). 360-degree interactive video application for Cultural Heritage Education. In *Proceedings of the 3rd Annual International Conference of the Immersive Learning Research Network*, (pp. 297-304). Verlag der Technischen Universität Graz.

Barton, K. C., & Levstik, L. S. (2004). *Teaching history for the common good*. Lawrence Erlbaum., doi:10.4324/9781410610508

Bland, J. M., & Altman, D. G. (1995). Multiple significance tests: The Bonferroni method. *British Medical Journal*, *310*(6973), 170–171. doi:10.1136/bmj.310.6973.170 PMID:7833759

Blyth, C. (2018). Immersive technologies and language learning. *Foreign Language Annals*, *51*(1), 225–232. doi:10.1111/flan.12327

Boyle, T. (1997). *Design for multimedia learning*. Prentice Hall.

Bradley Commission on History in the Schools. (1989). Building a history curriculum: Guidelines for teaching history in schools. In P. Gagnon (Ed.), *Historical literacy: The case for history in American education* (pp. 16–47). Macmillan.

Broeck, M. V. D., Kawsar, F., & Schöning, J. (2017). It's all around you: Exploring 360 video viewing experiences on mobile devices. In *Proceedings of the 25th ACM International Conference on Multimedia*, (pp. 762-768). ACM. doi:10.1145/3123266.3123347

Bruner, J. S. (1966). *Toward a theory of instruction* (Vol. 59). Harvard University Press.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness (Vol. 5). Colorado Springs, CO: BSCS.

Carr-Chellman, A., & Duchastel, P. (2000). The ideal online course. *British Journal of Educational Technology*, *31*(3), 229–241. doi:10.1111/1467-8535.00154

Creswell, J. W., & Poth, C. N. (2017). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

DeVellis, R. F. (2003). *Scale development: Theory and applications* (2nd ed.). SAGE Publications.

Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, *6*(3), 241–252. doi:10.1080/00401706.1964.10490181

Faiola, A., Newlon, C., Pfaf, M., & Smyslova, O. (2013). Correlating the effects of flow and telepresence in virtual worlds: Enhancing our understanding of user behavior in game-based learning. *Computers in Human Behavior*, *29*(3), 1113–1121. doi:10.1016/j.chb.2012.10.003

Falah, J., Khan, S., Alfalah, T., Alfalah, S. F. M., Chan, W., Harrison, D. K., & Charissis, V. (2014). Virtual reality medical training system for anatomy education. In *Proceedings of the 2014 Science and Information Conference*, (pp. 752-758). IEEE. doi:10.1109/SAI.2014.6918271

Fernández-López, Á., Rodríguez-Fórtiz, M. J., Rodríguez-Almendros, M. L., & Martínez-Segura, M. J. (2013). Mobile learning technology based on iOS devices to support students with special education needs. *Computers & Education*, *61*, 77–90. doi:10.1016/j.compedu.2012.09.014

Fokides, E., & Atsikpasi, P. (2018). Development of a model for explaining the learning outcomes when using 3D virtual environments in informal learning settings. *Education and Information Technologies*, *25*(3), 2265–2287. doi:10.1007/s10639-018-9719-1

Fokides, E., Atsikpasi, P., Kaimara, P., & Deliyannis, I. (2019). Let players evaluate serious games. Design and validation of the Serious Games Evaluation Scale. *International Computer Games Association Journal*, *41*(3), 116–137. doi:10.3233/ICG-190111

Karageorgakis, T., & Nisiforou, E. A. (2018). Virtual reality in the EFL classroom. *The Cyprus Review*, *30*(1), 381–396.

Keppel, G., & Wickens, T. D. (2004). *Design and analysis: A researcher's handbook*. Pearson Prentice Hall.

Klein, S. (2017). Educational websites on the memory of slavery in Europe: The ongoing challenge of history teaching. In *Palgrave handbook of research in historical culture and education* (pp. 717–733). Palgrave Macmillan., doi:10.1057/978-1-137-52908-4_37

Kysela, J., & Štorková, P. (2015). Using augmented reality as a medium for teaching history and tourism. *Procedia: Social and Behavioral Sciences*, *174*, 926–931. doi:10.1016/j.sbspro.2015.01.713

Lawson, B. D. (2014). Motion sickness symptomatology and origins. In *Handbook of virtual environment: Design, implementation, and applications* (2nd ed., pp. 532–587). CRC Press., doi:10.1201/b17360-29

Lee, S. H., Sergueeva, K., Catangui, M., & Kandaurova, M. (2017). Assessing Google Cardboard virtual reality as a content delivery system in business classrooms. *Journal of Education for Business*, *92*(4), 153–160. doi:10.1080/08832323.2017.1308308

Lim, H. L., Chin, H. L., & Nabeel, A. (2013). Using Weblog in cooperative learning to improve the achievement of history learning. *The Malaysian Online Journal of Educational Technology*, *1*(3), 30–43.

Magro, G., De Carvalho, J. R., & Marcelino, M. J. (2014). Improving history learning through cultural heritage, local history and technology. In *Proceedings of the 10th International Conference Mobile Learning 2014*, (pp. 34-40). International Association for the Development of the Information Society.

McKenzie, S., Rough, J., Spence, A., & Patterson, N. (2019). Virtually there: The potential, process and problems of using 360 video in the classroom. *Issues in Informing Science and Information Technology*, *16*, 211–219. doi:10.28945/4318

Miller, H. L., & Bugnariu, N. L. (2016). Level of immersion in virtual environments impacts the ability to assess and teach social skills in autism spectrum disorder. *Cyberpsychology, Behavior, and Social Networking*, *19*(4), 246–256. doi:10.1089/cyber.2014.0682 PMID:26919157

Minocha, S., Tudor, A. D., & Tilling, S. (2017). *Affordances of mobile virtual reality and their role in learning and teaching*. <ALIGNMENT.qj></ALIGNMENT>10.14236/ewic/HCI2017.44

Mortara, M., Catalano, C. E., Bellotti, F., Fiucci, G., Houry-Panchetti, M., & Petridis, P. (2014). Learning cultural heritage by serious game. *Journal of Cultural Heritage*, *15*(3), 318–325. doi:10.1016/j.culher.2013.04.004

National Council for History Education. (n.d.). *History's habits of mind*. Retrieved 27 February 2020, from https://www.nche.net/habitsofmind

Nor Azan, M. Z., & Wong, S. Y. (2013). Design and evaluation of history digital game based learning (DGBL) software. *Journal of Next Generation Information Technology, 4*(4), 9–24. https://doi.org<ALIGNMENT.qj></ALIGNMENT>10.4156/jnit.vol4.issue4.2

Pham, H. C., Dao, N., Pedro, A., Le, Q. T., Hussain, R., Cho, S., & Park, C. S. I. K. (2018). Virtual field trip for mobile construction safety education using 360-degree panoramic virtual reality. *International Journal of Engineering Education*, *34*, 1174–1191.

Pulijala, Y., Ma, M., Pears, M., Peebles, D., & Ayoub, A. (2018). Effectiveness of immersive virtual reality in surgical training—A randomized control trial. *Journal of Oral and Maxillofacial Surgery*, *76*(5), 1065–1072. doi:10.1016/j.joms.2017.10.002 PMID:29104028

Rasheed, F., Onkar, P., & Narula, M. (2015). Immersive virtual reality to enhance the spatial awareness of students. *Proceedings of the 7th International Conference on HCI, IndiaHCI 2015-IndiaHCI15*, 154-160. doi:10.1145/2835966.2836288

Rupp, M. A., Kozachuk, J., Michaelis, J. R., Odette, K. L., Smither, J. A., & McConnell, D. S. (2016). The effects of immersiveness and future VR expectations on subjective-experiences during an educational 360 video. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 60, No. 1, pp. 2108-2112). Los Angeles, CA: SAGE Publications. doi:10.1177/1541931213601477

Rupp, M. A., Odette, K. L., Kozachuk, J., Michaelis, J. R., Smither, J. A., & McConnell, D. S. (2019). Investigating learning outcomes and subjective experiences in 360-degree videos. *Computers & Education*, *128*, 256–268. doi:10.1016/j.compedu.2018.09.015

Senrick, S. (2013). Civilization IV in 7th grade social studies: Motivating and enriching student learning with constructivism, content standards, and 21st century skills. In Y. Baek & N. Whitton (Eds.), *Cases on digital game-based learning: Methods, models, and strategies* (pp. 82–96). IGI Global. doi:10.4018/978-1-4666-2848-9.ch005

Sultan, L., Abuznadah, W., Al-Jifree, H., Khan, M. A., Alsaywid, B., & Ashour, F. (2019). An experimental study on usefulness of virtual reality 360 in undergraduate medical education. *Advances in Medical Education and Practice*, *10*, 907–916. doi:10.2147/AMEP.S219344 PMID:31802964

Sutherland, R., Armstrong, V., Barnes, S., Brawn, R., Breeze, N., Gall, M., Matthewman, S., Olivero, F., Taylor, A., Triggs, P., Wishart, J., & John, P. (2004). Transforming teaching and learning: Embedding ICT into everyday classroom practices. *Journal of Computer Assisted Learning*, *20*(6), 413–425. doi:10.1111/j.1365-2729.2004.00104.x

Ulrich, F., Helms, N. H., Frandsen, U. P., & Rafn, A. V. (2019). Learning effectiveness of 360° video: Experiences from a controlled experiment in healthcare education. *Interactive Learning Environments*, 1–14. doi:10.1080/10494820.2019.1579234

Vakaloudi, A. D., & Dagdilelis, V. (2016). The Transformation of history teaching methods in secondary education through the use of information and communication technology (ICT). *History Education Research Journal*, *13*(2), 150–174. doi:10.18546/HERJ.13.2.15

Watson, W. R., Mong, C. J., & Harris, C. A. (2011). A case study of the in-class use of a video game for teaching high school history. *Computers & Education*, *56*(2), 466–474. doi:10.1016/j.compedu.2010.09.007

Wong, S. Y., & Ghavifekr, S. (2018). User experience design of history game: An analysis review and evaluation study for Malaysia context. *International Journal of Distance Education Technologies*, *16*(3), 46–63. doi:10.4018/IJDET.2018070103

Wright-Maley, C., Lee, J. K., & Friedman, A. (2018). Digital simulations and games in history education. In S. A. Metzger & L. M. Harris (Eds.), *The Wiley international handbook of history teaching and learning* (pp. 603–629). doi:10.1002/9781119100812.ch23

Wu, J., Guo, R., Wang, Z., & Zeng, R. (2019). Integrating spherical video-based virtual reality into elementary school students' scientific inquiry instruction: Effects on their problem-solving performance. *Interactive Learning Environments*, 1–14. doi:10.1080/10494820.2019.1587469

Xie, Y., Ryder, L., & Chen, Y. (2019). Using interactive virtual reality tools in an advanced Chinese language class: A case study. *TechTrends*, *63*(3), 1–9. doi:10.1007/s11528-019-00389-z

Yildirim, G., Elban, M., & Yildirim, S. (2018). Analysis of use of virtual reality technologies in history education: A case study. *Asian Journal of Education and Training*, *4*(2), 62–69. doi:10.20448/journal.522.2018.42.62.69

Zin, N. A. M., Jaafar, A., & Yue, W. S. (2009). Digital game-based learning (DGBL) model and development methodology for teaching history. *WSEAS Transactions on Computers*, *8*(2), 322–333.

Emmanuel Fokides (PhD) is an Assistant Professor in the Department of Primary School Education, University of the Aegean, Greece. His courses focus on the educational uses of emerging technologies, virtual reality, digital storytelling, augmented reality, and serious games. Since 1994, he is involved in a number of research projects regarding distance and lifelong learning and the educational uses of virtual and augmented reality. His work is published in several conference proceedings, chapters in edited books, and journals. He is also the co-author of two books.

Eleni Polydorou is a researcher at University of the Aegean, Greece. She holds a Bachelor's degree from the Department of Cultural Technology and Communication and an MSc degree from the Department of Primary Education, both from the same university. She is experienced at creating multimedia content for educational applications such as serious games, websites and virtual reality. Her work is published in conference proceedings and educational websites. Her interests include 3D modeling, animation and programming educational websites and games in Unity. Her main research interests focus on the promotion of cultural heritage through technology.

Panos Mazarakis is an MSc Student at the Department of Cultural Technology and Communication, University of the Aegean, holding a Bachelor's degree from the same department. He is experienced in web design and full-stack development, having worked for clients in Greece and the UK. His interests include privacy-focused web applications, UI/UX design, the Internet of Things and Virtual Reality. He currently works as a .NET (C#) Engineer. He also prototypes electronics and IoT devices, utilizing 3D Printer, and is also involved in the creation of digital media art.