

History and Interactive Learning Environments

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Abstract

Contemporary educational approaches to teaching and learning the subject of History lead to the use of interactive learning environments, whose design is based on the fundamental principles of Cognitive Psychology. In order to avoid cognitive overload caused by the complexity of digital interaction, it is proposed that the design and construction of these environments to be based on the principles of multimedia learning theory, which incorporates elements from the theories of dual coding and cognitive load. The purpose of this paper is to present the design and development, in a Geographic Information Systems environment, of the interactive environment GEO-HISTOR for the teaching/learning of History and the integration of pedagogical agents in it to enhance students' metacognition. Creatively utilizing the conclusions of previous relevant research, an attempt was made to transform the traditional expository historical text into an online version of an interactive learning environment. It took the form of the Story Map Journal, where the spatial background is utilized with the appropriate additions of photos and videos to visualize the information while avoiding cognitive overload. The use of the interactive learning environment GEO-HISTOR reframes the teaching of the subject of History and enables a personal approach to learning anywhere and anytime. The use of the GEO-HISTOR environment has shown that using data visualization enhances motivation and positively impacts learning outcomes and interest of secondary school students, thereby improving their cognitive performance compared to traditional teaching.

Keywords: interactive learning environment, multimedia learning, History, Geographical Information Systems

Introduction

Since the beginning of the 21st century, there has been a growing interest in the subject of History, with a particular focus on the role of History in several educational systems. This interest has been driven by the recognition that History is not merely a subject for passive memorization of information, but rather a discipline that encourages critical thinking and analysis of past events (Haydn & Harris, 2010). In recent years, there has been a significant focus on understanding students' attitudes and ideas about History, intending to inform teaching practices (Kokkinos & Nakou, 2016; VanSledright, 2004).

Additionally, the contemporary era has seen a shift in how historical knowledge is acquired and conveyed, a process that has unfolded in several interrelated ways. The advent of new technologies has facilitated access to historical information from multiple sources, and the concept of lifelong learning has become a prominent aspect of the contemporary

educational landscape. Furthermore, students may also gain historical knowledge through non-formal education, and appear to derive enjoyment from learning History from sources outside the classroom (Levesque, 2003). It is erroneous to assume that historical education solely depends on the textbook.

Students can consult a wide range of resources that provide illumination of historical eras in an accessible manner. The data can be divided into two categories: conventional sources (historical quotations, commercial books with historical background, photographic material, printed maps, testimonies of historical events, etc.) and new technologies (Cárdenas-Robledo & Peña-Ayala, 2018). The advent of new technology has created many opportunities, including integrating multimedia elements, producing documentaries, films, digital and interactive maps, augmented reality, and digital games, and establishing interactive learning environments. These new possibilities have the potential to revolutionize the way we engage with and learn about History.

1. Literature review

1.1. Learning History Today

In recent years, numerous studies have been conducted to assess the impact of Information and Communication Technologies (ICT) on the teaching and learning of History (De Sousa et al., 2017; Koutromanos et al., 2020). The results indicate that ICT can assist teachers in adopting new instruction approaches, as well as in providing students with additional support to enhance their learning (Shah & Khan, 2015). Furthermore, students benefit from ICT in that it becomes a source of help in the construction of new knowledge by stimulating motivation (Malik & Agarwal, 2012), facilitating concentration and recall of historical information (Tang & Intai, 2017), and promoting active learning and in-depth comprehension (De Sousa & Van Eeden, 2009).

The utilization of digital maps can facilitate a better comprehension of the material. In particular, the collaborative creation of digital maps can facilitate the learning process, as visualization encourages understanding (Mitchell & Elwood, 2012). Research findings indicate that, in general, interactive digital maps and Geographical Information Systems (GIS) offer modest learning benefits when compared to traditional printed maps. However, they are more beneficial for specific learning objectives and concept types (Baker & White, 2003; Taylor & Plewe, 2006).

Students frequently underestimate the value of historical knowledge and understanding, assuming that it offers little practical benefit in the context of their future careers (Cobbold & Oppong, 2010). The available evidence indicates that teaching techniques have a significant impact on students' attitudes (Boadu, 2015). Interest has been demonstrated to exert a significant impact on students' attitude, effort, and, ultimately, achievement in the field of History (Lee & Spratley, 2010). Nevertheless, the impact of interest on attitude remains a topic worthy of further investigation (Dan & Todd, 2014). In the contemporary era, attitude formation is influenced by multiple factors, with a significant contribution from extracurricular learning, diverse sources, and the integration of ICT.

1.2. Interactive Learning Environments

An interactive learning environment (ILE) is a computer-based environment designed with specific software and, on occasion, specialized hardware. Its purpose is to provide support for both teaching and learning, and it incorporates a range of learning resources, including text, audio, video, animations, simulations, graphics, hypertext, and more. According to recent research (Smaldino et al., 2019; Spantidakis 2010), the type of learning being supported influences the selection of features in the ILE. Interactive learning environments enable students to readily, effectively and enjoyably engage with the learning object. ILEs are a common practice in teaching multiple learning subjects and attract research interest internationally (Norbekova et al., 2019; Xeferis et al., 2018).

One of the challenges in the field of digital education is the creation of learning environments that are interactive, multi-sensory, student-centred, and oriented toward constructivist learning. However, a combination of text, images, graphics, audio, video and sometimes animation in learning environments is not as frequent among young children as among secondary school students (Abdulrahman et al, 2020). Among secondary students, this preference is mainly observed in those aged 15 and above (Gen & žahin, 2016) and students from disciplines in which combined information provision may be more legitimate and necessary (Blevins, 2018; Shah & Khan, 2015).

It is posited that the challenges encountered with new educational technologies, commonly referred to as ICT, are largely contingent upon the specific subject in question. Depending on the nature of a particular subject, the effectiveness of teaching approaches may be influenced in different ways (Harris, 2005). In the context of History, the discipline itself requires specific attention, rather than generalized technology use as a learning tool. Students should not simply meet the demands of creative utilization of technology, but rather adopt “innovative and imaginative applications” of functional interfaces between technology, educational content and abilities to create meaningful historical learning environments (Swan & Hicks, 2007).

However, to optimize the use of ICT in historical education, it has been suggested that clarification of the theoretical foundations of electronic applications is beneficial, as is the dissemination of research findings regarding their evaluation (Ioakeimidou, 2018). There is evidence that the use of ICT by students in historical education has a beneficial effect on learning (Sampson, 2000). Supported by computers learning environments are shaped by a theoretical background in specific epistemological, pedagogical, and teaching approaches. For instance, constructivism and sociocultural learning theories, are superior to earlier behavioural examples of software for simple practice, teaching, or skill acquisition (Tam, 2000). Nevertheless, the most contemporary pedagogical frameworks that facilitate historical education are designed to enrich students' historical literacy and critical thinking or to enhance their metacognitive skills and self-regulation (Poitras et al., 2012).

1.3. Interactive learning environments for teaching History

The utilization of learning environments that are specifically designed to facilitate the acquisition of historical knowledge and skills enables learners to develop the capacity to think in a historically informed manner, as well as to integrate the historical context in which a particular event occurred into their interpretations of that event (Lo et al., 2009). It is therefore evident that the scientific method, which relies on the repetition of

experiments, cannot be applied to the study of historical events. As it is impossible to recreate historical occurrences to analyze them in their original context, it is crucial to develop alternative approaches to representation and interpretation. This enables us to contextualize historical events within contemporary reality, thereby enhancing our understanding of past occurrences (Yilmaz, 2008), students' historical understanding and critical thinking (Van Drie & Van Boxtel, 2008).

The incorporation of technology into historical learning environments can facilitate the cognitive approach to complex historical topics (Brush & Saye, 2004; Saye & Brush, 2009). Furthermore, technology can be employed as metacognitive tools that facilitate self-regulation, thereby enhancing learning (Azevedo et al, 2009).

It is now widely accepted that incorporating geographical information into the teaching and learning of History is essential (Academic Sinica, 2005; Lo, 2004). Indeed, the study of History is inherently spatial and the use of interactive History learning environments allows the incorporation of Geographic Information Systems (GIS) (Lo et al., 2009). Firstly, GIS provide a suitable digital environment for integrating spatial information. It is evident that, in addition to the efficient collection, storage, processing, management, analysis and presentation of spatial information (maps with different levels of resolution), GIS can successfully integrate various other types of digital information and data of verbal and non-verbal (visual and audio) types. It is important to integrate the information appropriately to enhance comprehension (Coohill, 2006). This can be achieved by ensuring a balance between the volume of information and the cognitive load it places on the learner.

In the case of History, the integration of GIS with constructivist learning techniques has been demonstrated to facilitate a positive attitude towards this subject among students who previously regarded it as tedious and irrelevant when it was taught in the traditional teacher-centred approach (Lo et al., 2009; Yilmaz, 2008).

1.4. Design and development of an interactive learning environment

The main steps in the design and full development of an ILE for the teaching and learning of a specific subject are as follows: preliminary stage; design of the environment; construction of structural elements; implementation of the environment as a whole; pilot application for the refinement and formative evaluation; implementation of the environment in a classroom setting; final evaluation of its effectiveness.

The preliminary stage entails actions that establish fundamental prerequisites for the construction of a technically complete and cognitively adequate result for the specified cognitive object. Furthermore, a general literature review is conducted, and a search and selection process for audiovisual material suitable for integration into the interactive environment is carried out. Specifically, the needs of the students are explored by recording their questions, difficulties and requests, during fieldwork in a regular classroom with the specific subject being integrated into the interactive environment. The objective of this phase is twofold. It aims firstly to identify any challenges that may arise in constructing the environment, and secondly to suggest the specific tools that can be used to address these challenges effectively.

At the designing stage, it is important to take into account the principles of multimedia learning to ensure its effectiveness (Mayer, 2014b). For instance, in the selection of the

teaching material to be integrated into the final environment, the principle of minimum cognitive load must be taken into account. This is achieved mainly by adhering to appropriate specifications in the multimedia material, such as audio recordings of expository texts, the creation of videos of pedagogical agents, directly related photographic material, short documentary clips, and so forth. Additionally, option buttons must be placed in appropriate positions so that the materials presented selectively and not simultaneously and en masse.

The principal platform that will serve as the foundation for the construction of the ILE is of crucial importance. Once the possibilities offered by the existing platforms for attaining the educational objectives have been explored, the selection will be made. Subsequently, the platform will be enriched with additional elements that follow. For instance, a particularly beneficial platform for courses in History might be a geographic information system (GIS) (Antoniou et al., 2018). The basic expository text can be presented in an audiovisual format and can be accessible to students with specific learning difficulties and disabilities. The additional teaching material may consist of on-screen expository texts, audiovisual material, multimedia material, photographs, maps, external websites, and so forth. It is of the utmost importance that the software to be used for the production of new and/or the editing of existing teaching material before its integration is carefully chosen. This software should include, for example, recording software and video editing software. Furthermore, the platforms for archiving the additional teaching material must be interconnected through the main platform to complete the environment. Finally, the mechanisms of the user's interaction with the interface, for example, menu buttons and web page links, must be considered. The mechanisms to guide the learner, for example, pop-ups with additional explanatory material and pedagogical agents, should be considered. Tools to collect a variety of useful data, for example, questionnaires in Google Forms format and a notebook for recording objectives or summaries, should also be included. Psychometric and possibly other assessment tools, for example, rating scales for various characteristics and assessment criteria based on the formal school system, should also be considered.

The endeavor to surmount the absence of a human element in multimedia learning led, through several intermediary stages, to the design and utilization of Animated Pedagogical Agents (APA). One of the key benefits of agents is that they can create the illusion of a traditional classroom learning environment in an impersonal computer setting (Mayer & DaPra, 2012; Mavrogianni et al., 2023). In contrast, one of the primary advantages of animated pedagogical agents is that they can motivate and entertain students to a greater extent than any other learning environment, encouraging them to exert greater effort in understanding the learning material (Choi & Clark, 2006). In contrast to students who tend to avoid interacting with the learning environment, pedagogical agents are designed to encourage students to consider themselves as friends and to engage actively with the learning process (Liew et al., 2017; Mavrogianni et al., 2023).

In the case of narrative pedagogical agents, they are designed to emulate the characteristics of a human being and engage with students through the construction of dialogues (Mavrogianni et al., 2019). The agent provides feedback to the students in many ways, including dialogues, facial expressions, hand movements, and specific behaviours (Dinçer & Doğanay, 2017). The objective is to enable the agent to function as a kind of "scaffold" (Zheng, 2016) to assist the learner.

In general, scaffolds may comprise tools, strategies, prompts, metacognitive comments, or guides designed to facilitate the learner's attainment of a more advanced understanding or proficiency beyond their current abilities (Bendou et al., 2017; ter Beek et al., 2018). To fulfil a scaffolding function, the texts recorded by the pedagogical agent must incorporate the most suitable strategies for the students involved.

In the construction of narratives by agents or dialogues between narrative agents, it is necessary to consider methods for enhancing truthfulness (Figure 1). This can be achieved by simulating real human communication conditions, incorporating humour, or other similar techniques (Mavrogianni et al., 2023). Images of the figures in question have been created or procured and entered into appropriate software to synchronize the voices with the facial expressions of each figure. These techniques result in a realistic impression, whereby the figures appear to narrate the text in a life like manner. A final video file is generated, containing the audio recording and the requisite graphic components of the agent's figure in a background setting serving the anthropomorphism. This may include simulating social media environments familiar to adolescents, such as Instagram. Once the process has been concluded, a comprehensive organizational framework is required to archive the multimedia material in accounts on available platforms. This encompasses the final formatted text, audio, image and video files.

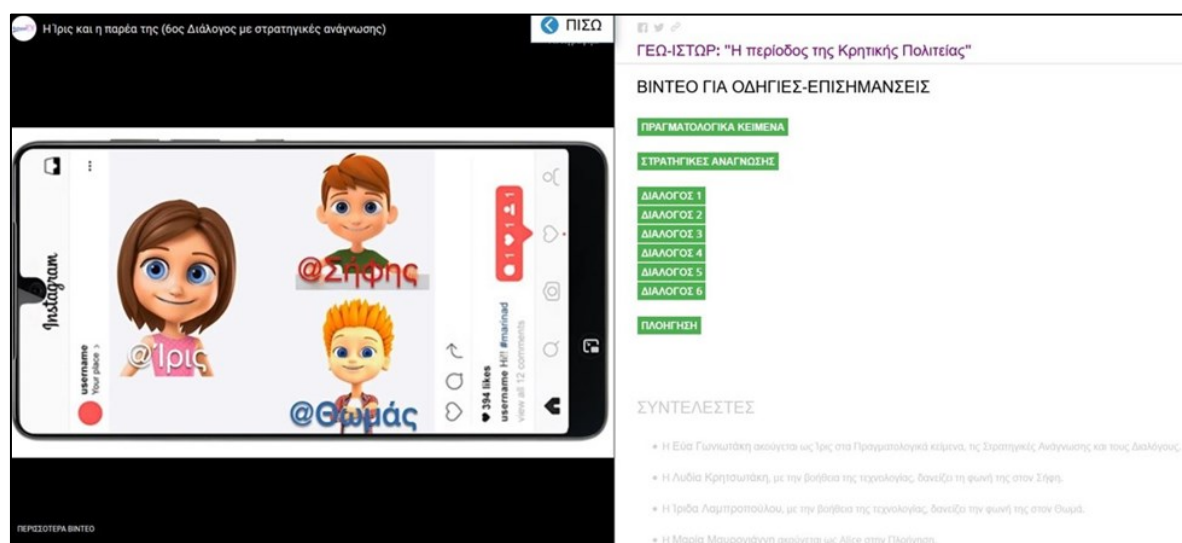


Figure 1: Narrative Pedagogical Agents in the GEO-HISTOR environment

At the final phase of integration, the final interactive learning environment is constructed using a selected basic platform as the foundation, to enable users to execute it via the internet. It is structured to function as a single entity, integrating and synthesizing all the elements from the individual platforms where they were archived. This integration is designed following the functional requirements. The pilot implementation phase of the developed learning environment is designed for formative evaluation and refinement, to identify potential weaknesses that can be eliminated through feedback from previous steps. The environment is piloted with small groups of students, and evaluated (Kleftodimos & Evangelidis, 2016). In the final stage, the interactive environment is ready to be implemented in the classroom for a final evaluation of its effectiveness before its

generalized use. The fundamental criteria for evaluating the interactive environment are whether and to what extent it effectively achieves the objectives for which it was created and whether it is superior to traditional teaching or other existing technological tools.

Evaluation is undertaken to determine whether the intended learning outcomes or other desired outcomes have been achieved. These might include changes in students' attitudes towards the subject in question, the extent to which students have gained knowledge and metacognition through their use of the interactive environment, and other relevant factors. It should be noted that, as part of the evaluation process, statistical analyses, often of considerable complexity, are employed. These can be external, employing appropriate software such as SPSS, Statistica, R, STATA or SAS, to analyze stored data (Kleftodimos & Evangelidis, 2016). Alternatively, they can be internal, embedded within the system, and automated (Mavrogianni, 2023).

2. Methodology

2.1. Preliminary fieldwork

To develop the interactive learning environment, preliminary fieldwork was required to ascertain the material that would be integrated. This was conducted over one academic year with two groups of students (N=47) from the first general high school. It was implemented as a research project course, which, following the curriculum, employs the group-collaborative project method and allows for substantial autonomy for both students and teachers.

In particular, the fieldwork was conducted to record the students' needs, questions and difficulties, as well as gather relevant primary and secondary material, based on the analyses of the expository texts to be integrated into the learning environment. Given that the expository texts pertained to the Cretan State period (1898-1913), we proposed a series of topics related to this historical era for the students to select from. Ultimately, the topics selected by two sections (N=47 students) of the first grade of the 2nd High School of Heraklion were as follows: (a) "The autonomy of Crete: myths and truths" and (b) "The period of Cretan autonomy in the digital environment of Geographical Information Systems". Since the School Counsellor had approved these topics, the educational process commenced. Priority was accorded to the experiential approach to knowledge, with particular emphasis on active learning methods, including group-cooperative and exploratory techniques.

Subsequently, the students were divided into research groups according to their specific interests, and the roles and research tools of each member were defined. In the initial phase, the students were introduced to the expository texts that were to be integrated into the learning environment. This was done to record their needs, questions and difficulties, to take them into account when developing the learning environment. In a subsequent phase, the group project method was employed as a research strategy to facilitate the acquisition of supplementary historical knowledge about the Cretan State period (1898-1913) for the students. At the outset, the students were provided with guidance and assistance to enable them to effectively explore the school library, as well as training on the rules of safe and effective navigation and research on the internet. Subsequently, the aforementioned data was augmented with primary verbal and audio-visual material

(documentary clips, historical photographs, cartoons, pictures, quotations) collected by the students with procedural facilitation by the teacher through teaching visits to the Vikelaia Municipal Library, the Historical Archive and the Historical Museum of Heraklion. A portion of this material was employed to enhance the preliminary construction of the digital educational environment.

Following the collection of the material and reading of the expository texts, the students attempted to synthesize the historical knowledge they had gained with the information in the quotations. This resulted in the identification of points that required further investigation. The students were divided into groups of three or four and tasked with processing the material collected either through classroom visits or through research on the Internet. They were then required to answer the research questions of each group. In the final phase, the research results of all the groups were presented in both pilot sections (A and B) in the form of PowerPoint. This presentation was made at the plenary of the section, after which the students received feedback from their classmates and the teacher.

2.2. Designing the GEO-HISTOR Interactive Learning Environment

The theoretical framework for the design and construction of the GEO-HISTOR learning environment was informed by three main theoretical perspectives: the theory of dual coding, the theory of cognitive load and the theory of multimedia learning. The theory of dual coding (Paivio, 1991) states that individuals can process information using two distinct coding systems, one verbal and one visual. This concept was applied in the design of the learning environment, to enhance the learning experience. According to the theory of cognitive load (Sweller, 2011; Paas & Sweller, 2014), it is suggested that individuals may become overwhelmed by excessive cognitive load, leading to a decline in their learning abilities. This theory informed the design of the GEO-HISTOR learning environment, with the aim of reducing cognitive load and improving learning outcomes. According to the theory of multimedia learning (Mayer, 2014a), the interactive learning environment is suggested to be designed based on some principles.

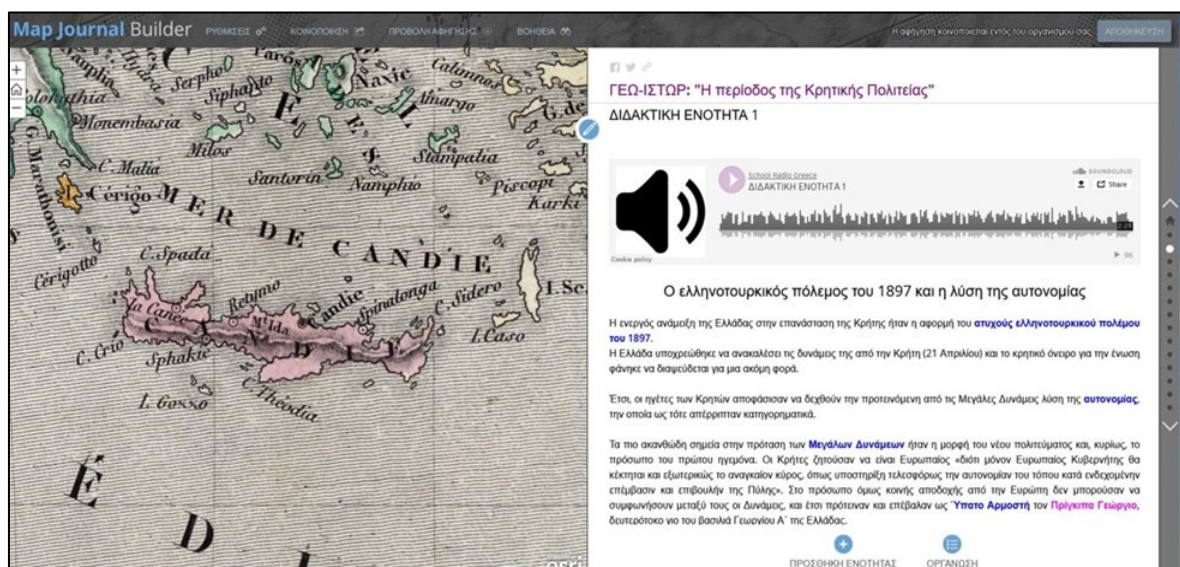


Figure 2: The GEO-HISTOR environment in the form of the Story Map Journal

The GEO-HISTOR environment is structured in the form of a narrative map, specifically in the Story Map Journal application of ArcGIS by Esri (Figure 2). It comprises various forms of digital media, including expository texts (in both digital and audio formats), digital maps, photographs (static and interactive), documentaries, narrative pedagogical agents, websites offering supplementary information, and digital evaluation forms (Figure 3). The objective of these forms is to evaluate students' historical knowledge, metacognition, and attitude towards History. To complete the construction of the GEO-HISTOR learning environment, accounts were created within the digital platforms CrazyTalk Animator, YouTube, Flickr, and SoundCloud and linked to the Story Map Journal application through these platforms (Mavrogianni, 2023).

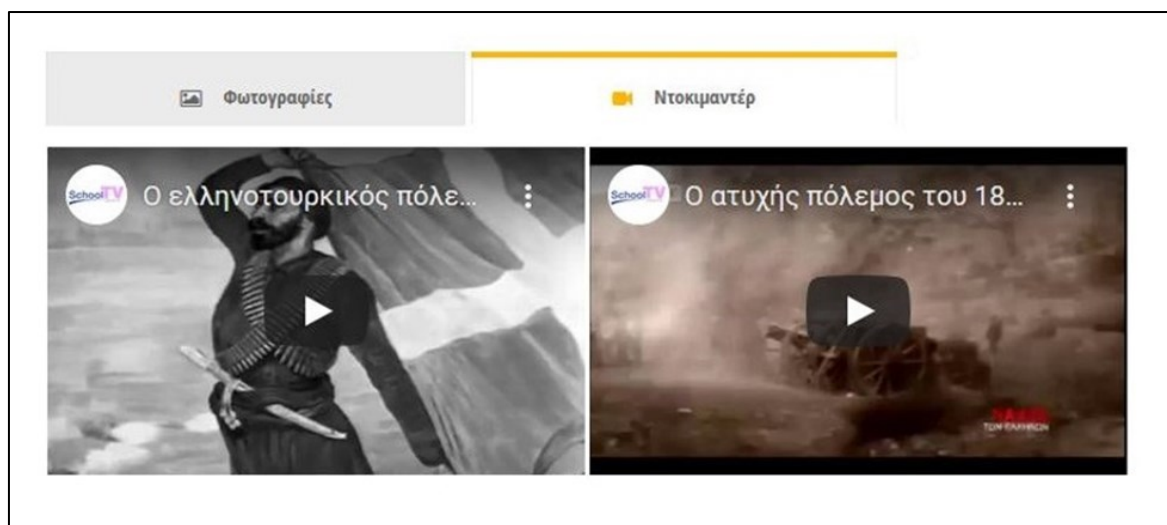


Figure 3: Photographs and small documentaries at the end of each unit in the GEO-HISTOR environment

The construction of the GEO-HISTOR environment was informed by several considerations, including the limitations of available resources, the absence of requisite specialized knowledge and digital skills among students, as well as the constraints posed by the high maintenance costs and the limited duration of usage in a traditional educational setting (Al-Ajmi & Aljazzaf, 2020; Putra, 2018). Consequently, it was designed to be accessible online to students utilizing personal computers, tablets or mobile devices with internet access, facilitating the acquisition of knowledge in a flexible manner that aligns with the contemporary learning preferences of students.

3. Conclusion

The dynamics of the use of interactive learning environments became apparent both during the preliminary fieldwork stage, which led to conclusions for structuring the GEO-HISTOR learning environment, and from the use of this particular learning environment itself.

On the one hand, the fieldwork with the pilot research through qualitative analyses of the students' interviews and the researcher's observation diary, played a decisive role in designing

the GEO-HISTOR environment. The findings of the researcher's observations in real school environments, as recorded in the researcher's observation diary, indicate that the use of the interactive environment GEO-HISTOR has resulted in notable changes in the classroom dynamic and interactions between students and teachers, in addition to the students' attitude towards History (Mavrogianni, 2023). This finding was also corroborated by the deployment of the GEO-HISTOR environment, which demonstrated that the judicious use of ICT in the learning and teaching processes can effectively transform traditional teacher-centered pedagogical approaches into learner-centered ones. In this new model of instruction, teachers are no longer mere transmitters of knowledge but become facilitators and cognitive partners of their students. This shift in role has been documented in numerous studies (Coleman et al., 2016; Guan et al., 2018; Spantidakis, 2010).

In light of the aforementioned evidence, it is clear that our research is in line with the view that multimedia tools have a profound impact on education. The impact of multimedia tools in education has been demonstrated in numerous studies across diverse subjects and age groups (Milovanovic et al., 2013). These tools enhance interactivity and improve the quality of learning (Zin et al., 2013). Furthermore, multimedia tools facilitate cognitive performance in students (Al-Hariri & Al-Hattami, 2017; Barzegar et al., 2012; Jian-Hua, 2012) and are an effective approach to increasing student engagement and motivation and modifying their attitudes towards the subject (Haydn & Stephen, 2021; Shah & Khan, 2015).

It has been demonstrated that interactive learning environments, including the GEO-HISTOR environment, enhance the motivation and interest of secondary school pupils, thereby improving their cognitive performance. This is evidenced by studies conducted by Akinoso (2018), Haydn and Stephen (2021) and Ilhan and Oruc (2016), as well as the positive impact observed by Shah and Khan (2015) on the attitudes of students towards their cognitive subjects.

Furthermore, our research findings corroborate those of Burd (2020), who demonstrated that using data visualization and mapping (ArcGIS Online) as active learning methodologies is conducive to motivation and positively impacts learning outcomes. Furthermore, Burd's study and our research corroborate the view already espoused by many researchers (Bonds, 2014; Locke, 2017; Jakacki & Faull, 2016). They posit that digital tools offer the potential to diversify and modernize the curriculum and expand the avenues for engaging students with these subjects.

4. Limitations of the present study

Due to the constraints of conducting the study within the actual classroom setting, the following limitations must be considered:

- The findings may not be generalizable to students of other educational levels or learning contexts.
- Due to its nature, the present research was limited in scope to expository texts and thus does not provide conclusions for different textual genres.
- The sample size was, in effect, limited as it reflected the number of students in two school sections.

- As the survey sample was randomly selected from an already alphabetically divided student body, the survey's general validity cannot be assumed.

5. Proposed future project

In the wake of the global pandemic and the subsequent shift towards distance education necessitated by health concerns, there has been a notable surge in research interest into the perceptions of students at every level of education regarding their learning experiences and satisfaction with digital distance learning, in comparison to traditional face-to-face instruction (Baker & Unni, 2018; Barnes, 2017; Guest et al., 2018; Tratnik et al., 2019). The learning process can be subjected to various forms of investigation, contingent upon the specific teaching methodology employed. For instance, when the learning environment is entirely distance-based, or when it follows the mixed model approach, which entails a combination of remote learning and face-to-face instruction, as well as the incorporation of digital technology in the hands of the instructor. Additionally, a return to traditional learning without any technological intervention is also represented (Hilton et al., 2020).

As this interactive learning environment was designed with personalized computer-based learning in mind, it should be noted that it can only be utilized in a dedicated computer laboratory setting. Furthermore, its lack of a collaborative approach to teaching is a notable limitation. To extend its use to the classroom and enhance its socio-cultural dimension, the interactive white board could be used to test its potential for classroom-based learning. The utilization of interactive white boards is enhanced when appropriate learning resources are selected. Therefore, teachers can follow a series of steps when using these resources, including: identifying the learning objective; designing and creating the resources; evaluating their effectiveness; modifying and revising the resources as needed; and sharing the resources (Bannister, 2010).

An approach that incorporates the utilization of pertinent methodologies, including brainstorming, conceptual mapping, multimedia analysis, digital literacy activities, peer teaching, collaborative writing and problem-solving activities, and the analyses of multimodal discourse features, has been found to foster enhanced interactions between software, teachers, and students, as well as providing valuable opportunities for dialogue and motivating reflective learning (Becta, 2003).

A novel approach could be implemented by augmenting the GEO-HISTOR environment with historical sources and investigating the capacity to develop historical reasoning within the context of each source. The following elements of historical reasoning should be given due consideration as key components: (a) establishing a connection between historical events and contemporary circumstances; (b) employing contrasting historical sources to facilitate a more impartial analysis of historical events; and (c) framing historical inquiries pertinent to students (Mamoura, 2016).

Furthermore, future research could be oriented towards the integration of cognitive assessment criteria, self-report questionnaires on students' attitudes and acquired metacognition, and embedded assessment of their performance in challenging tasks into the digital assessment process. This would allow for the enhancement of the digital assessment process by integrating these elements into the learning environment.

The expansion of procedures employed to evaluate learning, beyond self-report assessments, could incorporate the analysis of data derived from neuroimaging methods during the learning process, such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). It could also include the recording and assessment of other behaviours, such as eye-tracking.

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