

# The Hidden Heritage: Archaeology, Geophysics and GIS at the Service of Heritage Education in the Classrooms



Irene Ortiz Nieto-Márquez and Javier Vallés Iriso

**Abstract** Heritage is not always visible, particularly in archaeology, where much of it lies hidden underground. Often, archaeological remains are discovered accidentally and destructively, with governments sometimes overseeing their documentation. However, land surveying is crucial for proper documentation and interpretation. Using non-invasive or non-destructive techniques, as recommended by UNESCO, archaeologists can document hidden heritage. Geophysical surveys like ground-penetrating radar (GPR), alongside remote sensing and Geographic Information Systems (GIS), allow us to reveal entire buried cities, pipelines, defensive systems, and burial sites. Specialists and educators must document and share this historical heritage to ensure society values and preserve it. Teachers play a vital role in Heritage Education. Natural heritage, such as mines, and cultural heritage, like archaeological sites, can be used as educational resources in classrooms to teach History, Art History, and Geography. Incorporating archaeology encourages students to develop critical and reflective thinking. Current educational legislation and curriculum in Spain promote ICT tools, making GIS an ideal way to present hidden heritage through surveys and spatial analysis. By engaging students in archaeological research processes, they can explore new sites, solve historical questions, and develop teamwork and respect for heritage conservation.

**Keywords** Heritage · Archaeology · Geophysics · GIS · Active methodology · Critical thinking

---

I. O. Nieto-Márquez (✉)  
Faculty of Education, Complutense University of Madrid, Madrid, Spain  
e-mail: [ireort01@ucm.es](mailto:ireort01@ucm.es)

J. V. Iriso  
CAI of Archaeometry and Archaeological Analysis, Complutense University of Madrid, Madrid, Spain  
e-mail: [j.valles@ucm.es](mailto:j.valles@ucm.es)

© The Author(s) 2026  
R. de Miguel González and P. Rivero Gracia (eds.), *Geospatial Technologies for Heritage Education*, Key Challenges in Geography,  
[https://doi.org/10.1007/978-3-031-96372-8\\_9](https://doi.org/10.1007/978-3-031-96372-8_9)

## Introduction

Nowadays, new educational systems in Spain increasingly focus on competency-based learning. This means that students, beyond acquiring knowledge, must know how to apply it in everyday situations (LOMLOE 2020).

This goal is achieved by changing the classroom methodology, shifting from a one-way teaching system—where students play a passive role as mere recipients of the teacher’s knowledge—to a multidirectional learning system, where students actively participate in their own learning process, and the teacher acts as a guide and support.

Traditionally, experimental sciences and mathematics have been easier to apply in practical, everyday classroom situations. However, social sciences, often seen as more abstract and theoretical, have been relegated to traditional teaching methods, with lectures that are largely expository and reliant on memorization.

Within the realm of social sciences, we find Geography, History, Art History, Civic Education, and Heritage Education. These subjects are interconnected and can be studied in a transdisciplinary way. For example, we cannot study History without knowing where events took place (Geography), what was created during that period (Art History), what society was like at the time (Civic Education), and finally, how all of this can contribute to shaping us as critical and reflective citizens (Heritage Education).

Observing this, we must find a way to apply this knowledge to practical, everyday situations in which students can see themselves reflected and become active agents in their learning process, especially in the context of Heritage Education.

In this regard, Archaeology can be of great use to us. This is the science that studies past societies through the analysis and study of their material remains and artifacts (Renfrew and Bahn 1993). Archaeology is not only responsible for studying human history but also for making history, as the processes of surveying, excavation, and post-excavation analysis create narratives that reshape our understanding of past societies.

This inherently practical discipline, in addition to utilizing experimental sciences and mathematics, is fundamentally rooted in the social sciences (as well as geology). Therefore, we consider it a potential solution to bring social sciences to students in a practical and competency-based manner.

## Objectives

The main objective of this work is to present a teaching proposal to carry out heritage education in the classroom in a competency-based and practical way. To achieve this, we will use archaeology and non-invasive surveying processes to identify possible underlying remains, invisible to society, and their subsequent interpretation through Geographic Information Systems (GIS) in the classroom.

One of the key objectives of Heritage Education is to educate by, for, and through Heritage. As stated in Article 4 of UNESCO's "Convention Concerning the Protection of the World Cultural and Natural Heritage," (1972) it is recognized that "the duty of ensuring the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage..." lies with us. This excerpt highlights two important concepts:

- The identification, protection, and conservation of heritage through non-invasive and non-destructive documentation techniques.
- The transmission of heritage to future generations through Heritage Education.

Since the origin of the discipline, archaeology has always been linked to excavation activities as the only process for obtaining data about past societies and their material remains (Micó Pérez et al. 1998; Ruiz Zapatero 2013). These are destructive processes that directly interfere with archaeological remains and their contexts.

Thus, archaeological excavation is an invasive method of obtaining information, and considering that heritage is limited and not infinite, we must minimize these activities in favor of non-invasive and non-destructive techniques.

For this reason, we must move beyond the idea that excavation is the only way to obtain information, as today we have numerous non-invasive techniques dedicated to the discovery of archaeological sites (Dietz et al. 2011).

Non-invasive archaeology is based on the application of new techniques from geophysics and remote sensing to detect potential archaeological sites (Faltýnová et al. 2015). These techniques are interpretive, making multidisciplinary work essential for accurate data interpretation.

These non-destructive techniques are also key to passing heritage on to future generations. If excavation practices are the only way to obtain data, there will come a time when we have no heritage left to pass on.

The dissemination and success of non-invasive archaeology is closely tied to Heritage Education. If society is not aware of its heritage, it will not be possible to preserve, care for, and transmit it: "The educational perspective on heritage is essential for it to be known, understood, valued, and transmitted by the society that receives and inherits it" (Fontal Merillas 2006).

According to the author, education serves as a bridge capable of fostering awareness, promoting appreciation, and enabling the transmission of values, facilitating mediation between individuals and their heritage-based identities. Through heritage references, it is possible to enhance reflective knowledge of reality, regardless of whether the objective is heritage conservation and appreciation (Estepa Jiménez and Cuenca López 2006).

## Methodology

The proposed methodology to be used in the classroom will be **Problem-Based Learning (PBL)**, aimed at having students seek a solution using non-invasive surveying methods and GIS to document archaeological heritage without destroying it.

The application of this methodology in the classroom will follow the steps outlined by Eggen and Kauchak (2015). In the first stage, a question will be identified, presenting the central issue of the project: How can we document heritage without destroying it? In the second stage, students will generate hypotheses to solve the problem. Third, information will be gathered on non-destructive techniques in archaeology. Afterwards, students will evaluate the previously proposed hypotheses and conduct a practical application with the provided examples. To conclude the fifth stage, where the results obtained are generalized, and reflection on the process and evaluation takes place. In *Annex*, the instructional design of the project can be seen in more detail.

This methodology has been proposed because, as mentioned earlier, social sciences have traditionally been associated with passive teaching methods centred on memorization. PBL is ideal because it focuses on a real problem, organizing the content and skills students need to learn around it. Learning becomes student-centred, engaging both cognitive and affective processes to investigate and solve the problem. Students are asked to take responsibility for identifying learning objectives, planning the collection and processing of information, and reflecting on their understanding and learning. Collaborative work is essential, as is teacher scaffolding, whose role is to moderate and guide reasoning processes, information searches, and the formulation of relevant questions (Marra et al. 2014).

At the disciplinary level, to carry out this proposal, we have used Archaeology, Geophysics, and GIS to bring Heritage Education into the classroom.

The choice of **archaeology** as one of the disciplines to be implemented in this proposal is supported by the multiple empirical benefits it provides to both students and teachers.

Numerous publications have highlighted the advantages of using archaeological projects in classrooms, as they help develop educational values (Ayan Vilá et al. 2009; Castillo Lozano 2017; González Marcén 2010; Ruiz Zapatero 2010; Vicent et al. 2015) such as the management of sources, supporting the development of interdisciplinary and comprehensive teaching, promoting cooperative learning, instilling values such as respect and understanding of cultural diversity, and helping educate about the respect for cultural and natural heritage.

Additionally, as a scientific discipline, archaeology can foster scientific questioning, dialogue, and critical thinking, contributing to the scientific development of students (Montoya Martínez and Egea Vivancos 2021; Vicent et al. 2015). In this way, it allows an approach to scientific research methodology and helps overcome proposed problems, breaking away from purely memoristic and expository teaching methods in favor of a more active and meaningful one.

Finally, at a competency level, archaeology has proven to be a highly useful and applicable tool in classrooms, from early education to the university level. It involves multidisciplinary learning, opening up a wide range of competencies (basic, key, specific, etc.) (Egea and Arias 2013; Henson 2004; Ortiz Nieto-Márquez et al. 2024; Masriera Esquerria and Santacana i Mestre 2012).

As mentioned earlier, **archaeology** is a science that combines multiple disciplines to formulate hypotheses about past societies through the remains found. Therefore, we will adopt the first step of archaeological methodology in site investigation, which is surveying.

Archaeological surveying is an active search process for potential signs indicating the presence of buried remains (such as buildings, roads, necropolises, walls...) (Ruiz-Zapatero 2004). It can be done aerially, using remote sensing techniques (Chivueco 1995; Rejas and Burillo 2016), such as aerial photography, or on the ground, either by walking to search for surface indicators or using geophysical techniques (Goodman and Piro 2013). None of these techniques are destructive, as they aim to preserve heritage (Malfitana et al. 2015; Sarris et al. 2013).

*Aerial photography* is a commonly used technique in archaeology to locate new sites, particularly because it saves time and effort. In this type of survey, differential growth marks in vegetation are very useful, as plant growth is influenced by the type of substrate (Rouse et al. 1973). Where there is a stone structure, plant roots cannot penetrate as deeply, resulting in reduced plant growth above these areas. However, if negative elements (ditches, pits, trenches...) are present beneath the plants, they will grow more because they are rooted in a less compact, more nutrient-rich substrate with higher organic content (Bennett 2012; Webber et al. 2019).

To obtain these images, we use geographic viewers like IBERPIX or Google Earth, whose timeline tool allows us to observe the same location during different periods (different phases of plant growth). The use of these ICT tools in the classroom supports competency-based learning and enables students to handle their own sources and data (Sebastián-López and De Miguel-González 2017).

On the other hand, for ground surveying, we have turned to **Geophysics**. Geophysics, as a discipline that studies the physical properties of the Earth, is applicable in this proposal as a tool to address the proposed challenge within the project.

The application of this discipline in classrooms has been successfully tested, particularly in higher education levels (Boyd and Romig 1997; Stewart et al. 2010). However, considering its potential, it is highly interesting to explore its integration into other educational levels.

One of the educational values we can derive from geophysics is that its techniques, applied in archaeological surveys, allow for non-invasive and non-destructive heritage studies, aligning with one of the project's objectives (Rivero and López Benito 2013; Vallés et al. 2023; Bellón Ruiz et al. 2021; Rascón Marqués et al. 2023). This approach ensures the conservation and care of heritage remains for their transmission to future generations.

Furthermore, it supports the idea of multi-interdisciplinarity in classrooms. To understand the operation of these technologies and their outcomes in a simplified

manner, it is necessary to engage with various disciplines, including geology, physics, geography, mathematics, history, technology, and programming. Although no direct application has been carried out with primary school students, this proposal presents it as a challenge and an opportunity to broaden the range of adapted knowledge.

It is important to note that, depending on the educational level at which this proposal is applied, geophysical techniques may be somewhat complex. Therefore, we will introduce them by comparing them to something as familiar as certain medical tests (a common context for students).

A parallel can be drawn with the field of medicine, where techniques are used to view and interpret the interior of our bodies, such as X-rays or ultrasounds. These techniques rely on physical properties to create images and models that show bones or organs. In geology and archaeology, there are similar methods and techniques used to scan and document underground elements.

These techniques fall within the field of geophysics. Each material is different and possesses a set of chemical and physical characteristics that make it unique, like an ID. These characteristics and properties can be measured using high-precision and high-resolution equipment. Just like X-rays, images of the subsurface can be obtained, revealing the characteristics of each buried element and its position in depth, allowing us to know what lies beneath our feet. This is how petroleum, gold or silver, minerals and rocks, groundwater, archaeological structures, tombs, etc., can be located.

There are several data acquisition techniques based on different physical properties. In archaeology, methods are used that cover large areas in a short time and offer high resolution, allowing us to detect small objects (Goodman and Piro 2013). For these reasons, the most commonly used techniques are ground-penetrating radar (GPR), geomagnetism, and electromagnetism.

In our case, we will use *GPR*. It emits an electromagnetic pulse, a wave that penetrates the ground and receives the reflection or echo of the elements it encounters, producing graphics that show these reflections (Goodman et al. 2011; Zhao et al. 2013). This technique is widely used in non-invasive archaeological surveys because it is non-destructive, provides high-quality data (including depths of the remains), and is cost-effective.

Over the past few years, an increase in surveys using non-invasive techniques and their successful results can be documented (Bellón Ruiz et al. 2021; Colmenarejo García et al. 2023; Conyers 2015; Neubauer et al. 2002; Leucci et al. 2016; Piro and Campana 2012; Zhao et al. 2015, 2018).

Once the terrain has been analyzed and the results processed, they are visualized with **Geographic Information Systems (GIS)**. Burrough and McDonnell (1998) defined GIS in 1998 as “a powerful set of tools for collecting, storing, retrieving, transforming, and displaying geospatial data from the real world for a set.” However, most authors characterize GIS by its ability to model territory, its integrative potential for heterogeneous information sources, and its spatial analysis dimension, as well as the capability to perform geoprocessing operations based on the topological relationships of objects and the ability to generate new information and explain existing data (González et al. 2012).

The software chosen and used for this educational proposal is ESRI's ArcGIS, specifically ArcMap 10.8.1 and ArcScene 10.8.1. There is a wide variety of programs available, including free options such as QGIS, GRASS, and gvSIG. However, ArcGIS was selected because the university centre has a license, allowing us to work online with schools through ArcGIS Online.

Geographic Information Systems (GIS) are an educational tool with high potential for primary and secondary classrooms due to their ability to integrate multiple disciplines and foster active learning.

In primary education, GIS allows students to work with basic spatial concepts, promoting an understanding of their surroundings and the development of orientation and spatial analysis skills (Alibrandi and Goldstein 2015; Baker 2005).

In secondary education, their application expands to the analysis of complex geographic data, enabling students to explore topics such as climate change, natural resource distribution, or demographics, connecting geography with history, natural sciences, mathematics, and technology (Alibrandi and Goldstein 2015; Bednarz 2004; Milson et al. 2012).

Furthermore, GIS encourages critical thinking and problem-solving by addressing real-world issues through project-based learning and the use of innovative technological tools (Kerski 2008). This multidisciplinary nature makes GIS an ideal resource for developing digital, scientific, and civic competencies, preparing students to understand and tackle the challenges of today's world.

In terms of heritage, this tool is of utmost importance due to its capacity for managing and documenting heritage elements (Bru Castro et al. 2008; Farjas et al. 2009; Faustino Cordero and Álvarez 2017; Faustino Cordero Montero et al. 2020); its ability to create predictive models (Allen et al. 1990; Molina Martín 2009; Fernández-Fernández 2010, 2013; Fondevilla et al. 2021; Rascón Marqués et al. 2023); perform territorial analyses (Moreno Martín 2008; García Sanjuán et al. 2009; Ortiz et al. 2013; Ortiz Nieto-Márquez and Baena Preysler 2015; Ortiz Nieto-Márquez 2015), and even visibility and optimal route analyses (Zamora 2007, 2008, 2013; Orengo and Fiz 2008).

Additionally, GIS allows for the visualization of different data layers in an integrated way, with transparency, superimposed, or even modeled in 3D (Vallés-Iriso et al. 2019). This is the final solution for the dissemination, diffusion, and resources for Heritage Education in school classrooms, as well as for competency-based learning (Martín Vecino et al. 2016; Sánchez Cabiellas 2014).

## Practical Case

Based on the methodology and techniques described, a didactic proposal is suggested for application in a Primary/Secondary Education classroom, although it can always be adapted to higher or lower levels.

The Roman site of Caraca has been chosen as an example. This oppidum of the Carpetani tribe and Roman city is located at Cerro de la Virgen de la Muela (Driebes,

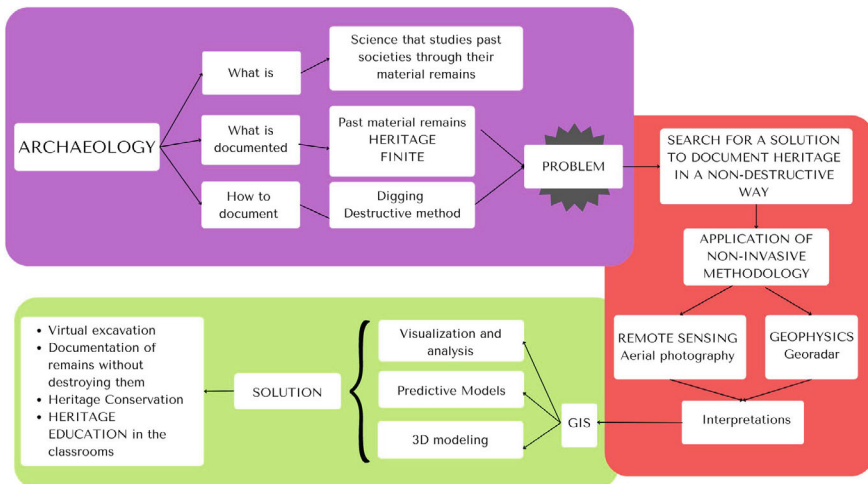
Guadalajara). The site was discovered in the twentieth century due to the discovery of silver remains on the hillside (Fernández and Gamo 2019). Thanks to subsequent prospecting campaigns and archaeological excavations, it has been confirmed that the hill has been occupied since the Paleolithic period, transitioning to a Carpetani oppidum upon which the Roman city was built. The city’s peak occurred between the first and second centuries AD, and it began to decline and be abandoned in the third century AD (Gamo Pazos et al. 2023).

Caraca is a high imperial Roman city organized around a forum, cardo, and decumanus, with approximately 27 blocks and covering nearly 8 hectares (Fernández and Gamo 2019). The interest in this city lies in the high quality of the information obtained through prospecting processes and the potential it holds for classroom presentation.

The **didactic proposal** is divided into three sections. It begins with conflicting concepts (Excavation vs. Conservation), moves on to finding solutions to this problem through the application of new prospecting techniques, and finally concludes with an investigation into Heritage using non-invasive methods (Fig. 1).

In the **first introductory section**, Archaeology is introduced by asking students what they know about the discipline, what comes to mind when they think of it, and if they have ever visited an archaeological site. After this introduction, the teacher explains what Archaeology is, what can be documented at archaeological sites, and how this documentation is carried out.

Following this initial approach, students can be shown a news story about looting or the destruction of archaeological remains, prompting them to reflect on whether such actions are right or wrong. In this context, it would be explained that everything



**Fig. 1** Schematic representation of the educational proposal based on PBL for Heritage Education. *Source* Own elaboration



**Fig. 2** Schematic representation of the problem as the central axis of the research process. *Source* Own elaboration

documented at archaeological sites is part of our cultural heritage, and as citizens, we must conserve and preserve it.

This is where students should become aware of the contradiction between the destructive methods of archaeological excavations and the obligation to preserve heritage as outlined by UNESCO (1972). This problem will be presented as the central focus of the project, prompting them to reflect, analyze the situation, and seek non-destructive methods to document archaeological sites (Fig. 2).

The **second block** will be organized around this real problem, where students must seek alternatives and create their hypotheses. They will be able to research in the classroom and present ideas as possible solutions. Later, examples of aerial prospections can be shown, featuring different buried but visible sites due to the differential growth of vegetation (Fig. 3). Based on these images, students can work directly with geographic viewers and infer what might be underground.

Similarly, examples of results from the interpretations of geophysical prospections of certain sites can be shown next, prompting students to think about what they are seeing and how the interpretations were made (Fig. 4). After this reflective process, geophysics will be introduced, explaining what it is and its applications, one of which is archaeology.

With these two techniques, archaeological data can be obtained without the need for excavation, thus preserving the heritage.

Finally, we begin the **third block**. To visualize and interact with the results of the prospections, Geographic Information Systems (GIS) will be used. Aerial photographs can be overlaid with georadar interpretations (Fig. 5). This step allows for the comparison of the prospection techniques and determines which one yields better results or if they can be used in conjunction.

Once the results of the ground and aerial prospections are georeferenced, a map of the interpretations is obtained. This map displays the urban layout of the city, which adapts to the morphology of the hill. At this stage, students can visualize what the city would look like without the need to excavate or even visit the site (Fig. 6).



**Fig. 3** Aerial photograph of the hill where the Caraca archaeological site is located (Driebes, Guadalajara). Images taken from Google Earth; the one on the left is from 2015, and the one on the right is from 2024. Differential growth of vegetation can be observed. *Source* Own elaboration

They can document the most important parts of the city, such as the forum, the baths, the circulation routes, large blocks that could represent the villas of wealthy families, irregular layouts, and smaller structures to the south...

Thanks to the various tools provided by GIS, it is possible to answer some questions that may arise after visualizing the results. In this case, the absence/presence of remains in certain areas of the hill is striking, leading to the following question: What could have happened? (Fig. 7).

By examining the GPR alteration map (Fig. 6), we can identify areas with greater clarity and depth, as well as areas with fainter anomalies and lesser thickness, alongside zones with a complete absence of anomalies, where continuity should exist.

The Digital Terrain Model (DTM) of the hill shows that in the highest areas, structures are thinner, and the soil is more heterogeneous, indicating that these regions have experienced greater abrasion due to human actions or higher erosion due to their elevation. Conversely, in the peripheral areas of this elevated zone, the structures are more distinct (showing greater contrast between the structures and their surroundings, which suggests a more homogeneous soil), indicating better preservation.

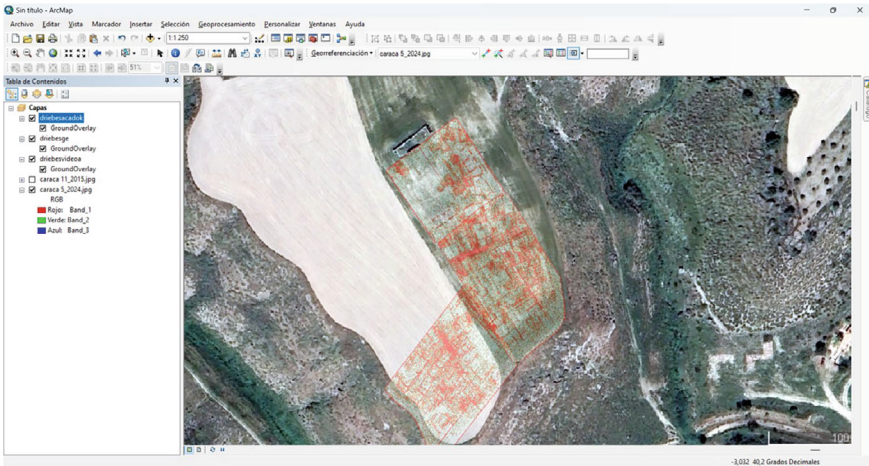
Through hydrological analysis, the heads of the small streams or gullies on the hill have been located, which have been altered by current plowing practices that tend to flatten cultivated surfaces. It can be seen that these heads coincide with the areas of absence of remains on the anomaly map, suggesting that the site has been



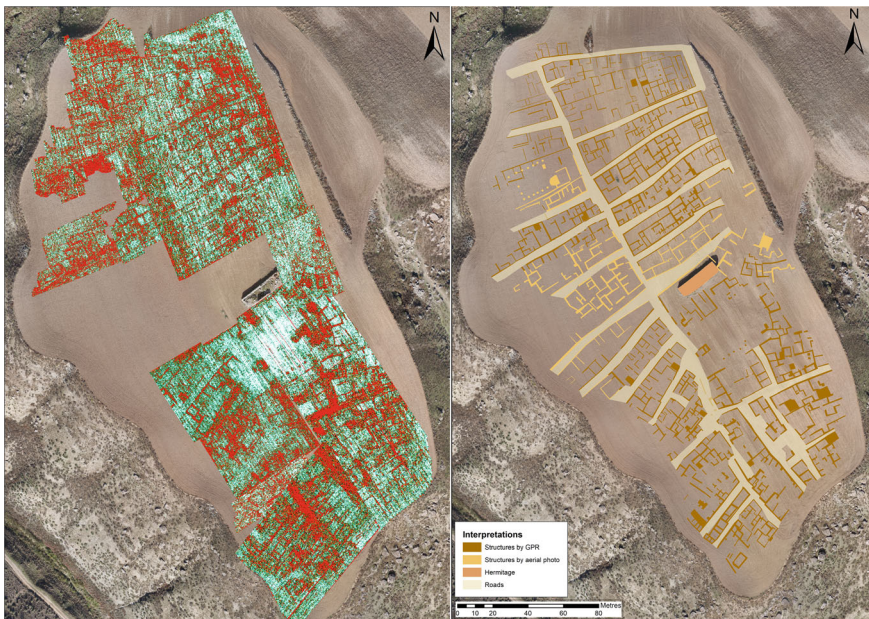
**Fig. 4** Example of results from geophysical surveys with ground-penetrating radar in archaeological sites. Software: ArcMap 10.8.1. *Source* Own elaboration

affected, potentially disappearing due to erosive actions before agricultural use of the hill (Fig. 7).

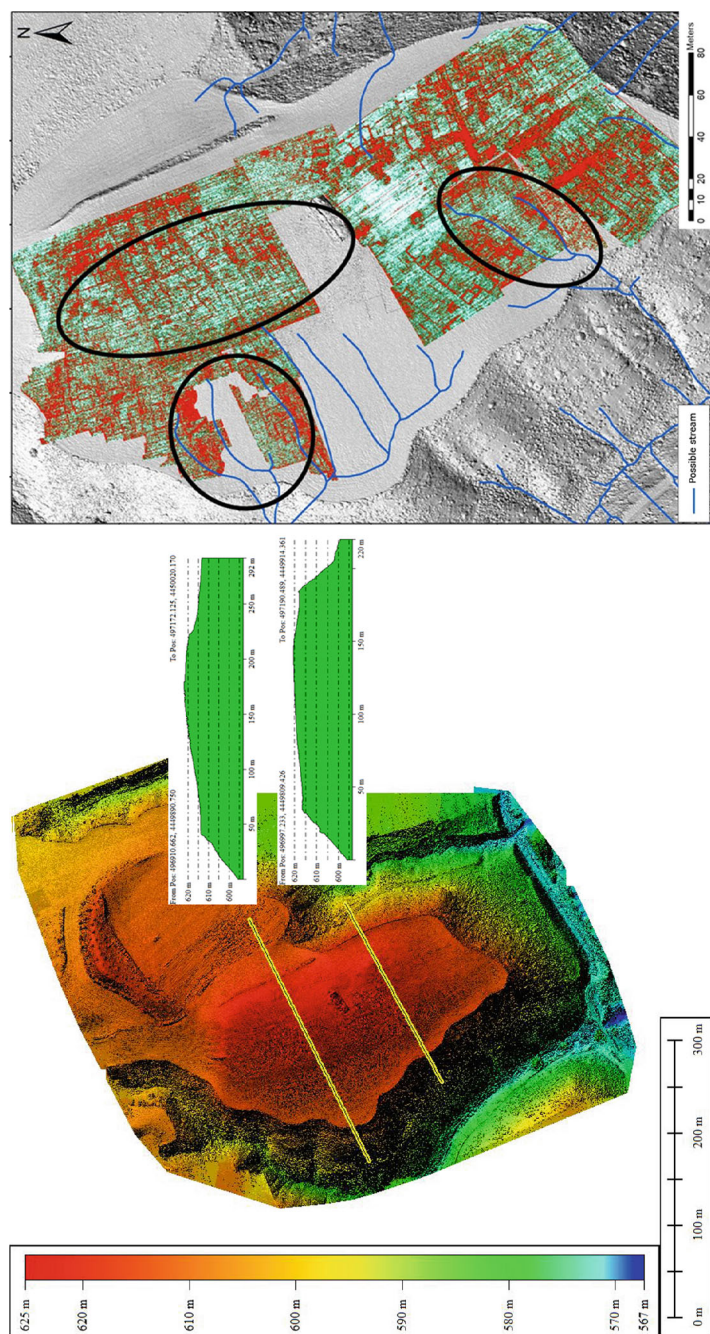
These issues address post-depositional processes that directly affect our heritage. The fact that archaeological sites are exposed to the elements, as is the case with most sites, means that weather phenomena and human activities impact the condition and conservation of these assets.



**Fig. 5** ArcGIS interface with the overlay of the photograph showing differential vegetation growth and the results of the ground-penetrating radar. Software: ArcMap 10.8.1. *Source* Own elaboration



**Fig. 6** Comparison of the results obtained from the GPR and their interpretation. Software: ArcMap 10.8.1. *Source* Own elaboration



**Fig. 7** Use of the Digital Terrain Model (DTM) of the hill to create cross-sections and observe its topography, allowing for comparison with the absence/presence of remains, along with the influence of hydrological processes. Software: ArcMap 10.8.1. *Source* Own elaboration



**Fig. 8** 3D modeling of the interpretations of non-invasive prospections. Software: ArcScene 10.8.1.  
*Source* Own elaboration

In this instance, the site was affected by water runoff caused by rainfall, which led to the deterioration of certain areas of the urban landscape. Subsequently, with the change in land use to agricultural, farming activities have also impacted its preservation. Considering this dilemma between socio-economic advancement and heritage conservation, a debate can be initiated in the classroom.

Finally, thanks to ArcGIS's capability to work with 3D elements in ArcScene, a model can be created using the DTM of the site as a base for heights, onto which the interpretations from the surveys are overlaid, with extrusions to reach the desired height (Fig. 8).

It is with this tool that students get a more realistic view of what the city of Caraca could have been. This is the final moment of generalization, where the final solutions (aerial photography, use of geophysics, etc.) are proposed, and students can evaluate the process they followed.

## Conclusions

When conflicting cases arise in the classroom, such as the current one where documenting heritage remains would require excavating and destroying them, while legislation advocates for conservation, students tend to reflect on the dilemma, presenting them with a real problem they must confront.

This is one of the primary objectives of Heritage Education (educating from, by, and for heritage): to make society part of the heritage, to feel it as their own, and at the same time to understand that they can generate it for future generations. By analyzing the issues presented in the classroom, students must become aware of the

importance of the remains, as they form part of cultural heritage and history. When certain heritage elements are controversial or generate debate, they can contribute the most to Heritage Education. These actions ensure that students actively participate in their learning through their critical and reflective abilities (Cuenca López 2023).

They must analyze the situation, determine whether it is correct or not based on social values, and take action. This is why heritage education in classrooms is so important. In this case, it has been linked to archaeology and non-invasive techniques, but many other disciplines can be addressed if we analyze the conservation and restoration of heritage elements, or if we deal with the conflict or integration of leisure and tourism related to heritage.

Pedagogically, this problem-based learning (PBL) proposal fits perfectly with the treatment of heritage education in the classroom, especially focused on controversial heritage. One should not fall into the temptation of viewing the problem as Heritage itself; rather, the issue lies in the damage and destruction it suffers, which must be avoided.

This learning approach, which combines PBL and Heritage Education, stimulates students' critical thinking as they investigate to propose solutions. Its application allows for effective evaluation of the knowledge acquired. Additionally, it promotes cognitive development by encouraging comparison and exchange of ideas with others, and fosters active participation in problem-solving (Cuenca López 2013; Eggen and Kauchak 2015; Estepa Jiménez and Cuenca López 2006; Monfort 2007).

The use of new technologies in the classroom, such as GIS, cartographic viewers, and the presentation of data obtained through new non-invasive prospecting techniques, reinforces the role of ICT in the learning processes (LOMLOE), while strengthening the students' relationship with heritage.

GIS plays a crucial role in acquiring geographic, historical, artistic, and heritage competencies and knowledge.

As can be seen in the Table 1, the proposed approach is fully immersed in competency acquisition. Key competencies, as well as specific ones, are achieved whether implemented in Primary or Secondary Education (LOMLOE).

Finally, it can be concluded that the proposed approach combines new technologies (cartographic viewers and GIS) with disciplines such as archaeology, geophysics, and remote sensing to serve heritage, its conservation, and its dissemination and promotion in society (in this case, the classrooms). This work demonstrates how Heritage Education can be conducted in classrooms in an active, participatory, and immersive manner, where students are part of their learning by seeking solutions to a real problem that affects the conservation and legacy of the remains (archaeological in this case).

**Table 1** Competency application of the applied disciplines in the proposal

<b>DISCIPLINES</b>	<b>KEY COMPETENCIES</b>	<b>Operational Descriptor</b>
<b>HERITAGE EDUCATION</b>	Citizenship Competence	CC1, CC2 & CC4
	Cultural Awareness and Expression Competence	CCEC1, CCEC2 & CCEC 4
<b>ARCHAEOLOGY</b>	Digital Competence	CD1, CD2, CD3 & CD5
	Cultural Awareness and Expression Competence	CCEC1 & CCEC2
	Citizenship Competence	CC1, CC2, CC3 & CC4
	Mathematical and Scientific Competence in Engineering	STEM2, STEM4 & STEM5
<b>GEOPHYSICS</b>	Mathematical and Scientific Competence in Engineering	STEM2, STEM4 & STEM5
	Digital Competence	CD1, CD2, CD3 & CD5
	Digital Competence	CD1, CD2, CD3 & CD5
	Entrepreneurial Competence	CE1
	Mathematical and Scientific Competence in Engineering	STEM2, STEM4 & STEM5
<b>PRIMARY SPECIFIC COMPETENCIES</b>	<b>SECONDARY SPECIFIC COMPETENCIES</b>	
Knowledge of the Natural, Social, and Cultural Environment: CE1, CE2, CE3, CE5, CE6 & CE7	Geography and History: CE1, CE2, CE3, CE4, CE5 & CE7	

Source Own elaboration

**Acknowledgements** We would like to thank the research team at the Caraca site (Driebes, Guadalajara) for their generous collaboration. Their contribution has been essential for the development and enrichment of this work.

## Annex

INSTRUCTIONAL DESIGN FOR PBL		
	PRIMARY EDUCATION (5th and 6th grades - ages 10–12)	SECONDARY EDUCATION (3rd and 4th grades of ESO - ages 14–16)
<b>1. PLANNING</b> <b>LEARNING OBJECTIVES</b>	<ol style="list-style-type: none"> <li>Understand what archaeological heritage is and its importance.</li> <li>Become familiar with basic concepts of ground-penetrating radar (GPR) and remote sensing.</li> <li>Develop observation and data recording skills.</li> <li>Use simple ICT tools to interpret maps.</li> </ol>	<ol style="list-style-type: none"> <li>Analyze non-invasive documentation technologies (GPR, remote sensing). Interpret data obtained using Geographic Information System (GIS) tools.</li> <li>Propose solutions for the conservation of archaeological heritage based on findings.</li> <li>Reflect on the importance of heritage conservation for cultural identity.</li> </ol>
<b>1. PLANNING</b> <b>KEY COMPETENCES</b>	<ol style="list-style-type: none"> <li>Competence in cultural awareness and expression.</li> <li>Digital competence.</li> <li>Mathematical competence and basic competences in science and technology.</li> <li>Competence in learning to learn.</li> <li>Social and civic competences.</li> </ol>	<ol style="list-style-type: none"> <li>Competence in cultural awareness and expression.</li> <li>Digital competence.</li> <li>Mathematical competence and basic competences in science and technology.</li> <li>Competence in linguistic communication.</li> <li>Competence in learning to learn.</li> <li>Social and civic competences.</li> </ol>
<b>1. PLANNING</b> <b>TRANSVERSAL COMPETENCES</b>	<ul style="list-style-type: none"> <li>Teamwork and collaboration</li> <li>Problem-solving</li> <li>Environmental awareness</li> <li>Critical thinking</li> </ul>	
<b>1. PLANNING</b> <b>PROBLEM</b>	<p>How can we discover and protect an archaeological site without damaging it?</p> <p>A team of archaeologists has found evidence of an important archaeological site near your community. However, they cannot excavate directly because the site is protected by environmental laws and is located in a nature reserve. They need your help to document and study the site using non-invasive methods such as ground-penetrating radar (GPR) and remote sensing. Additionally, you will propose solutions to protect the site and share it with the public without causing harm.</p>	
<b>1. PLANNING</b>	6 SESSIONS OF 1 HOUR	
<b>2. GROUP ORGANIZATION</b>	25 students: 5 groups of 5 students	30 students: 6 groups of 5 students
<b>3. BRAINSTORMING</b>	Students share their knowledge about Archaeology. There is no debate, and everything is noted down.	
<b>4. PROBLEM PRESENTATION</b>	The problem is presented, and terms are clarified. Present the case to the students and address any questions. Specify the time available and the evaluation criteria.	
<b>5. PROBLEM DEFINITION</b>	Students analyze the case and identify the problem. They must express it in a single question or statement	
<b>6. RESPONSE AND HYPOTHESIS FORMULATION</b>	Students must explore alternatives and create their hypotheses. They can also conduct research in the classroom and present ideas as possible solutions.	

<p><b>7. FORMULATION OF LEARNING OBJECTIVES</b></p>	<p><b>Cognitive Objectives</b></p> <ul style="list-style-type: none"> <li>-Understand what archaeological heritage is and why it is important to protect it.</li> <li>-Learn what non-invasive technological tools (ground-penetrating radar, remote sensing) are and how they work in a basic and engaging way.</li> <li>-Identify basic cultural and historical elements in the context of the fictional site (structures, objects).</li> </ul> <p><b>Procedural Objectives</b></p> <ul style="list-style-type: none"> <li>-Use a simple ground-penetrating radar simulator to detect patterns or shapes in the terrain.</li> <li>-Record data in a field journal, organizing the information clearly.</li> <li>-Create an illustrated map of the fictional site with their findings and explain its significance to a non-specialized audience.</li> </ul> <p><b>Attitudinal Objectives</b></p> <ul style="list-style-type: none"> <li>-Foster curiosity and interest in the conservation of cultural heritage.</li> <li>-Collaborate in teams, respecting the ideas of peers.</li> <li>-Appreciate the importance of preserving the past for future generations</li> </ul>	<p><b>Cognitive Objectives</b></p> <ul style="list-style-type: none"> <li>-Analyze in depth what archaeological heritage is and how it relates to cultural identity.</li> <li>-Understand the technical functioning of tools like ground-penetrating radar (GPR) and remote sensing systems.</li> <li>-Introduce basic concepts for interpreting geospatial data using Geographic Information Systems (GIS).</li> </ul> <p>-Recognize the environmental, social, and cultural risks that threaten heritage conservation.</p> <p><b>Procedural Objectives</b></p> <ul style="list-style-type: none"> <li>-Use GIS software to load, analyze, and represent data obtained through non-invasive technology.</li> <li>-Design conservation proposals for the site, considering social and environmental factors.</li> </ul> <p>-Prepare and present a well-argued report that integrates historical, technological, and strategic analyses.</p> <p><b>Attitudinal Objectives</b></p> <ul style="list-style-type: none"> <li>-Develop a critical attitude towards the relationship between technology, sustainability, and heritage.</li> <li>-Appreciate interdisciplinary work and the importance of collaboration in complex projects.</li> <li>-Reflect on individual and collective responsibility in the protection of cultural heritage.</li> </ul>
<p><b>8. RESEARCH</b></p>	<p>To visualize and interact with the results of the surveys, GIS tools will be used.</p>	
<p><b>9. SYNTHESIS AND PRESENTATION</b></p>	<p>Synthesis: Creative and visual (illustrated maps, posters).</p> <p>Presentation Level: Playful and narrative to engage the audience.</p> <p>Simulated Audience: School or family community.</p>	<p>Synthesis: Analytical and technical (digital maps, reports).</p> <p>Presentation Level: Formal presentation with reasoning and concrete data.</p> <p>Simulated Audience: Technical or institutional committee.</p>
<p><b>10. EVALUATION AND SELF-ASSESSMENT</b></p>	<p><b>Cognitive Evaluation</b></p> <ul style="list-style-type: none"> <li>-Questionnaires or Basic Knowledge Rubrics (self-assessment and peer assessment).</li> </ul> <p><b>Procedural Evaluation</b></p> <ul style="list-style-type: none"> <li>-Direct observation.</li> <li>-Visual Production Rubric.</li> <li>-Simple field report.</li> </ul> <p><b>Attitudinal Evaluation</b></p> <ul style="list-style-type: none"> <li>-Rubric for collaboration and group attitude (peer assessment).</li> <li>-Self-assessment.</li> </ul>	<p><b>Cognitive Evaluation</b></p> <ul style="list-style-type: none"> <li>-Short test.</li> <li>-Open-ended questions.</li> </ul> <p><b>Procedural Evaluation</b></p> <ul style="list-style-type: none"> <li>-Rubric for the technical report and digital presentation.</li> <li>-Evaluation of the technical quality of the GIS map.</li> <li>-Presentation of the conservation proposal.</li> </ul> <p><b>Attitudinal Evaluation</b></p> <ul style="list-style-type: none"> <li>-Group evaluation rubric.</li> <li>-Group self-assessment.</li> </ul>

## References

- Alibrandi M, Goldstein D (2015) Integrating GIS and other geospatial technologies in middle schools. In: *Geospatial technology and geography education in a changing world: a critical reader*. Springer, pp 91–104. [https://doi.org/10.1007/978-4-431-55519-3\\_5](https://doi.org/10.1007/978-4-431-55519-3_5)
- Allen K, Green S, Zubrow E (eds) (1990) *Interpreting space: GIS and archaeology*. Taylor and Francis, London
- Ayán Vila XM, Criado Boado F, González Veiga M, Otero Vilarriño C (2009) Cultura científica en arqueología y patrimonio: Los valores educativos de lo invisible. En: *V Congreso Internacional Musealización de Yacimientos Arqueológicos, Cartagena 2008*, pp 115–124. ISBN 978-84-96728-18-9
- Baker TR (2005) Internet-based GIS mapping in support of K-12 education. *Prof Geogr* 57(1):44–50
- Bednarz SW (2004) Geographic information systems: a tool to support geography and environmental education? *GeoJournal* 60(2):191–199
- Bellón Ruiz JP, Lechuga Chica MÁ, Rueda Galán C, Moreno Padilla MI, Quesada Sanz F, Molinos Molinos M, Ruiz Rodríguez A, García-Bellido MP, Nieto-Márquez IO, Vallés Iriso J (2021) De situ Iiturgi, análisis arqueológico de su asedio en el contexto de la segunda guerra púnica. *Archivo Español de Arqueología* 94:e15. <https://doi.org/10.3989/aespa.094.021.15>
- Bennett R et al (2012) The application of vegetation indices for the prospection of archaeological features in grass-dominated environments. *Archaeol Prospect* 19(3):209–218. <https://doi.org/10.1002/arp.1429>
- Boyd TM, Romig PR (1997) Cross-disciplinary education: the use of interactive case studies to teach geophysical exploration. *Comput Geosci* 23(5):593–599. [https://doi.org/10.1016/S0098-3004\(97\)00028-9](https://doi.org/10.1016/S0098-3004(97)00028-9)
- Bru Castro MA, López Quiroga J, Farjas Abadía M, Zancajo Jimeno JJ, Martínez Tejera AM (2008) Cultural resource management medieval team. Projects and applications in the Iberian Peninsula. In: *On the road to reconstructing the past, computer applications and quantitative methods in archaeology conference, program and abstracts CAA 2008*. Archaeolingua Foundation, Budapest, pp 155–156
- Burrough PA, McDonnell RA (1998) *Principles of geographical information system*. Oxford University Press, USA
- Castillo Lozano JÁ (2017) La importancia de la arqueología en las aulas: La recreación de una excavación arqueológica como actividad innovadora en la educación del alumnado de la E.S.O. *Revista Otarq* 2:411–428. <https://doi.org/10.23914/otarq.v0i2.125>
- Chivueco E (1995) *Fundamentos de la teledetección espacial*. Ediciones RIALP S.A.
- Colmenarejo García F, de Andres Santos M, Vallés Iriso J, Ortiz Nieto-Márquez I, Herranz Rodrigo D (2023) Historiografía y nuevas perspectivas de la Necrópolis de Fuente del Moro (Colmenar Viejo), a partir de las prospecciones geofísicas mediante georradar 3D. *Estudios de Historia y Patrimonio* 1:17–43
- Conyers LB (2015) Analysis and interpretation of GPR datasets for integrated archaeological mapping. *Near Surf Geophys* 13(6):645–651. <https://doi.org/10.3997/1873-0604.2015018>
- Cordero F, Álvarez LA (2017) APP CÁ CERES VIEW. La IDE local al servicio del usuario. *Revista Mapping* 26:20–26. <http://ide.caceres.es>
- Cordero Montero F et al (2020) Arqueología del planeamiento urbano de Cáceres. *Revista Mapping* 29:22–28
- Cuenca López JM (2013) El papel del patrimonio en los centros educativos: hacia la socialización patrimonial. *Tejuelo* 19:76–96
- Cuenca López JM (2023) Preliminares: Los patrimonios desde la perspectiva del conflicto. Los problemas controversiales a través de la educación patrimonial. *REIDICS* 12:6–12. <https://doi.org/10.17398/2531-0968.12.01>
- Dietz C, Catanzariti G, de la Presa P, Jimeno A (2011) Técnicas no invasivas para el registro del patrimonio arqueológico. *Jornadas Sobre Documentación Gráfica Del Patrimonio Histórico. Presente y Futuro*, pp 118–129

- Egea A, Arias L (2013) IES Arqueológico: La arqueología como recurso para trabajar las competencias básicas en la educación secundaria. *Clío: History and History Teaching*, 39
- Eggen P, Kauchak D (2015) Estrategias docentes. Enseñanza de contenidos curriculares y desarrollo de habilidades de pensamiento. Fondo de Cultura Económica, México
- Estepa Jiménez J, Cuenca López JM (2006) La mirada de los maestros, profesores y gestores del Patrimonio. Investigación sobre concepciones acerca del Patrimonio y su didáctica. In Calaf R, Fontal O (eds) *Miradas al Patrimonio*. TREA, pp 51–72
- Faltýnová M et al (2015) Complex archaeological prospection using combination of non-destructive techniques. *Int Arch Photogramm Remote Sens Spat Inf Sci XL-5/W7*:141–146. <https://doi.org/10.5194/isprsarchives-XL-5-W7-141-2015>
- Farjas M, García-Lázaro FJ, Zancajo J, Mostaza T (2009) Automatic point-cloud Surveys in prehistoric site documentation and modelling. In: Fischer L, Frischer B, Wells S (eds) *Making history interactive, 37th computer applications and quantitative methods in archaeology CAA 2009*, online proceedings. Williamsburg, Virginia. [http://www.caa2009.org/articles/Farjas\\_Contribucion163\\_a.pdf](http://www.caa2009.org/articles/Farjas_Contribucion163_a.pdf)
- Faustino Cordero Montero LA, Álvarez Llorente AJ, Gómez González AJ, Sánchez Franco C (2020) Arqueología del planeamiento urbano de Cáceres. *Revista Mapping* 29:22–28. ISSN: 1131-9100
- Faustino Cordero LA (2017) APP CÁCERES VIEW. La IDE local al servicio del usuario. *Revista Mapping* 26:20–26. ISSN: 1131-9100
- Fernández Fernández J (2010) Modelos predictivos y SIG: algunos ejemplos de su aplicación en Arqueología: los asentamientos fortificados del Valle del Trubia (Asturias, España). *Mapp Sci Remote Sens*
- Fernández Fernández J (2013) ‘Arqueología, SIG y modelos predictivos basados en redes neuronales artificiales Un caso de Estudio. *Mapping* 160:30–36
- Fernández J, Gamó E (2019) Hallazgo de un tesoro de plata en época de Felipe II en Driebes (Guadalajara). In Gamó E, Fernández J, Álvarez D (eds) *En ningún lugar... Caraca y la romanización de la Hispania interior*. Guadalajara, pp 189–218.
- Fondevilla JJ, Rivera Jiménez T, Ampliato Briones AL (2021) Implementación SIG de modelos analíticos predictivos del sistema castramental dispuesto por el concejo de Sevilla en torno a la Vía de la Plata en la Baja Edad Media. *Arqueología De La Arquitectura* 18:e111. <https://doi.org/10.3989/arq.arqt.2021.003>
- Fontal Merillas O (2006) Introducción. El Patrimonio mirado desde diferentes ópticas. In Calaf R, Fontal O (eds) *Miradas al Patrimonio*, Ediciones Trea, pp 17–19
- Gamo Pazos E, Fernández Ortea J, Bustamante Álvarez M, Marín González S, Domínguez Solera SD, González Blas A (2023) Un Ustrinum romano en Caraca (Driebes, Guadalajara). *ANAS* 36:259–284
- García Sanjuán L, Wheatley D, Márquez Pérez J (2009) Los SIG y el análisis espacial en arqueología: aplicaciones en la prehistoria reciente del sur de España. In Cau Ontiveros MA, Nieto Prieto FX (eds) *Arqueología náutica mediterránea*. Centre d’Arqueologia Subacuàtica de Catalunya, Girona, pp 163–180
- González Marcén P (2010) La dimensión educativa de la arqueología. In: *La tutela del patrimonio prehistórico*. Congreso Memorial Siret. Antequera. Disponible en: <http://bit.ly/1nK8jLS>
- González IDB, Freire CF, Morente LM-F, Asensio EP (2012) Los Sistemas de Información Geográfica y la investigación en ciencias humanas y sociales. In: *Apuntes de Ciencias Instrumentales y Técnicas de Investigación*, 3. CCHS-CSIC, Madrid
- Goodman D, Novo A, Morelli G, Piro S, Kutrubes D, Lorenzo H (2011) Advances in GPR imaging with multi-channel radar systems from engineering to archaeology. *SAGEEP*, 416–422. <https://doi.org/10.4133/1.3614128>
- Goodman D, Piro S (2013) *GPR remote sensing in archaeology*. SPRINGER-VERLAG BERLIN AN, Geotechnology and Environment
- Henson D (2004) Archaeology and education, an exercise in constructing the past. *Treballs d’Arqueologia* 10:5–16

- Kerski JJ (2008) The role of GIS in digital earth education. *Int J Digit Earth* 1(4):326–346
- Leucci G, de Giorgi L, di Giacomo G, Ditaranto I, Miccoli I, Scardozzi G (2016) 3D GPR survey for the archaeological characterization of the ancient Messapian necropolis in Lecce, South Italy. *J Archaeol Sci Rep* 7:290–302. <https://doi.org/10.1016/j.jasrep.2016.05.027>
- Malfitana D et al (2015) The potential of integrated GPR survey and aerial photographic analysis of historic urban areas: a case study and digital reconstruction of a Late Roman villa in Durrës (Albania). *J Archaeol Sci Rep* 4:276–284. <https://doi.org/10.1016/j.jasrep.2015.09.018>
- Marra R, Jonassen DH, Palmer B, Luft S (2014) Why problem-based learning works: theoretical foundations. *J Excel CollE Teach* 25(3–4):221–238
- Martín Vecino JM, Nieto Masot A, Buzo Isaac (2016) Los SIG aplicados a la enseñanza de la geografía en 1º de educación secundaria obligatoria. In: *TECNOLOGÍAS DE LA INFORMACIÓN GEOGRÁFICA EN EL ANÁLISIS ESPACIAL*. Aplicaciones en los Sectores Público, Empresarial y Universitario, pp. 141–160. Grupo de Investigación en Desarrollo Sostenible y Planificación Territorial de la Universidad de Extremadura Grupo de Investigación Geomática de la Universidad de Extremadura. <https://www.researchgate.net/publication/312054015>
- Masriera Esquerria C, Santacana i Mestre, J (2012) La arqueología reconstructiva y el factor didáctico. *Biblioteconomía y Administración Cultural* - 241, 1 ed., Gijón
- Micó Pérez R, Benito López JE, Ruiz Zapatero G, Rodríguez Ariza MO, Cotino Villa F, Burillo Mozota F, Molinos Molinos M, Picazo Millán JV (1998) Metodología para la recuperación del dato arqueológico. *Arqueología espacial* 18:45–56
- Milson AJ, Demirci A, Kerski JJ (eds) (2012) *International perspectives on teaching and learning with GIS in secondary schools*. Springer. <https://doi.org/10.1007/978-94-007-2120-3>
- Molina Martín O (2009) Aplicación de los SIG para el desarrollo de modelos predictivos en la prospección y búsqueda de contextos arqueológicos. *Boletín Antropológico* 27(76):219–236
- Monfort NG (2007) El valor educativo y uso didáctico del Patrimonio Cultural. *Universitat Autònoma de Barcelona, España*
- Montoya Martínez FJ, Egea Vivancos A (2021) La arqueología experimental como estrategia educativa: realidad y posibilidades. *Investigación en la Escuela* 103:139–152. <https://doi.org/10.12795/IE.2021.i103.10>
- Moreno Martín A (2008) Using GIS to Deconstruct Iberian Iron Age Landscapes: The Territory of Kelin Between 6th–5th Centuries BC (La Plana d’Utiel, València). In: Huggett J (ed) *Layers of perception*. Proceedings of the 35th computer applications and quantitative methods in archaeology CAA 2007. Archaeopress, Oxford, pp 87–92
- Neubauer W, Eder-Hinterleitner A, Seren S, Melichar P (2002) Georadar in the Roman civil town Carnuntum, Austria: an approach for archaeological interpretation of GPR data. *Archaeol Prospect* 9(3):135–156. <https://doi.org/10.1002/arp.183>
- Orengo HA, Fiz I (2008) The application of 3D reconstruction techniques in the analysis of ancient Tarraco’s urban topography. In: Posluschny A, Lambers K, Herzog I (eds) *Layers of perception*. Proceedings of the 35th international conference on computer applications and quantitative methods in archaeology (CAA), Berlin, Germany, April 2–6, 2007, *Kolloquien zur Vor- und Frühgeschichte*, vol. 10. Dr. Rudolf Habelt GmbH, Bonn
- Ortiz Nieto-Márquez I, Baena Preysler J (2015) ¿Acciones antrópicas o naturales en los hogares neandertales? Arqueología experimental y análisis intra-site. In: Maximiano Castillejo AM, Cerrillo Cuenca E (eds) *Arqueología y tecnologías de información espacial: una perspectiva ibero-americana*, pp 168–190. ISBN 978-1-78491-318-2
- Ortiz Nieto-Márquez I, Baena Preysler J, Chacón MG (2013) GIS spatial distribution analysis in raw material quarrying sites: the example of El Cañaveral (Madrid, Spain). In: García Moreno A, García Sánchez J, Maximiano Castillejo AM (eds) *Debating spatial archaeology: proceedings of the international workshop on landscape and spatial analysis in archaeology*, Santander, June 8–9, 2012, pp 199–211. ISBN 978-84-697-0213-0
- Ortiz Nieto-Márquez I, Muñoz García G, Jiménez Pablo E (2024) Arqueología en las aulas de Educación Infantil para maestros/as en formación: propuestas y recursos didácticos a partir de

- La Casa de Hippolytus (Complutum, Alcalá de Henares). *Revista UNES. Universidad, Escuela Y Sociedad* 18:161–179. <https://doi.org/10.30827/unes.i18.31163>
- Ortiz Nieto-Márquez I (2015) Acercamiento a las conductas neandertales a través del análisis espacial: Remontajes y SIG. Universidad Autónoma de Madrid, Tesis Doctoral
- Piro S, Campana S (2012) GPR investigation in different archaeological sites in Tuscany (Italy): analysis and comparison of the obtained results. *Near Surf Geophys* 10(1):47–56. <https://doi.org/10.3997/1873-0604.2011047>
- Rascón Marqués S, Vallés Iriso J, Sánchez Montes AL, Ortiz Nieto-Márquez I, Herranz Rodrigo D (2023) Nueva información sobre el urbanismo de la ciudad romana de “Complutum” a partir de los últimos estudios geofísicos: las prospecciones de 2020 y 2021. *Anas* 36:145–165
- Rejas JG, Burillo F (2016) Teledetección aplicada a la arqueología. In Mínguez García MC, Capdevila Montes E (eds) *Manual de tecnologías de la información geográfica aplicadas a la arqueología*, pp 241–270. Comunidad de Madrid: Museo Arqueológico Regional ; Ilustre Colegio Oficial de Doctores y Licenciados en Filosofía y Letras y en Ciencias de la Comunidad de Madrid
- Renfrew C, Bahn PG (1993) *Arqueología: teorías, métodos y práctica*. Ediciones Akal
- Rivero V, López Benito V (2013) Virtual archaeology as an instructional tool. In: *Virtual archaeology: nondestructive methods of prospections, modeling, reconstructions*. Proceedings of the first international conference (The State Hermitage Museum 4–6 June 2012). San Petersburgo, pp 295–302
- Rouse JW, Haas RH, Schell JA, Deering DW (1973) Monitoring vegetation systems in the great plains with ERTS. In: *Third ETRS symposium*, pp 309–317
- Ruiz Zapatero G (2013) La excavación arqueológica. In: García Diez M, Zapata Peña L (Coords) *Métodos y técnicas de análisis y estudio en arqueología prehistórica: De lo técnico a la reconstrucción de los grupos humanos*. Universidad del País Vasco, pp 39–72
- Ruiz Zapatero G (2010) Los valores educativos de la prehistoria en la enseñanza obligatoria. *MARQ, Arqueología y Museos* 04:161–179
- Ruiz-Zapatero G (2004) La prospección arqueológica en los inicios del siglo XXI. *Arqueología Espacial* 24–25:17–32
- Sánchez Cabiellés P (2014) TIC y didáctica de la Geografía: el papel del SIG en la educación secundaria. Universidad de Cantabria, Tesis de Máster
- Sarris A et al (2013) Integration of geophysical surveys, ground hyperspectral measurements, aerial and satellite imagery for archaeological prospection of prehistoric sites: the case study of Vészto-Mágor Tell, Hungary. *J Archaeol Sci* 40(3):1454–1470. <https://doi.org/10.1016/j.jas.2012.11.001>
- Sebastián-López M, de Miguel-González R (2017) Educación Geográfica 2020: IBERPIX y Collector for ArcGIS como recursos didácticos para el aprendizaje del espacio. *Didáctica Geográfica* 18:231–246
- Stewart RR, Khan S, Hall S, Liner C, Wong J (2010) Geophysics field education: better learning by doing. *Lead Edge* 29:546–550. <https://doi.org/10.1190/tle29050546.1>
- Vallés J, Ortiz Nieto-Márquez I, Herranz-Rodrigo D, Yravedra J, Martínez-Pagán P, Segura MA, Bellón Ruiz JP, Lechuga MÁ, Díaz A, 2023. Más allá de los muros: Estructuras negativas y “falsos positivos”. La alianza entre la arqueología y la geofísica. En: *10.ª Asamblea Hispano-Portuguesa de Geodesia y Geofísica*, pp 1070–1080. Catálogo de publicaciones de la Administración General del Estado. Disponible en: <https://cpage.mpr.gob.es>
- Vallés-Iriso J, Ortiz Nieto-Márquez I, Chapa-Brunet MT, Barderas Manchado G, Yravedra Sainz de los Terreros J, Turégano-Botija M (2019) Una mirada al subsuelo: estudio del yacimiento romano del Cerro de la Virgen de la Muela (Driebes, Guadalajara) mediante georradar multicanal. In Gamon Pazos E, Fernández Ortea J, Álvarez Jiménez D (eds) *En ningún lugar... Caraca y la romanización de la Hispania interior*. Diputación provincial de Guadalajara, Guadalajara, pp 237–250
- Vicent N, Rivero Gracia MP, Feliu Torruella M (2015) Arqueología y tecnologías digitales en Educación Patrimonial. *Educatio Siglo XXI* 33(1):83–102. <https://doi.org/10.6018/j/222511>

- Webber H, Heyd V, Horton M, Bell M, Matthews W, Chadburn A (2019) Precision farming and archaeology. *Archaeol Anthropol Sci* 11(2):727–734. <https://doi.org/10.1007/s12520-017-0564-8>
- Zamora M (2007) Total and cumulative viewshed: an application in the Genil River Valley. In: Figueiredo A, Velho G (eds) *The world is in your eyes: proceedings of the XXXIII computer applications and quantitative methods in archaeology conference, CAA 2005*. Tomar, Portugal, pp 313–318
- Zamora M (2008) Thematic cartography in archaeology. In: *On the road to reconstructing the past: computer applications and quantitative methods in archaeology conference, program and abstracts CAA 2008*. Budapest, Hungary, pp 302–303. Archaeolingua Foundation
- Zamora M (2013) Análisis territorial en arqueología: percepción visual y accesibilidad del entorno. *Comechingonia: Revista de Arqueología* 17(2):83–106. ISSN-e 2250-7728. ISSN 0326-7911
- Zhao W, Forte E, Pipan M, Tian G (2013) Ground penetrating radar (GPR) attribute analysis for archaeological prospection. *J Appl Geophys* 97:107–117. <https://doi.org/10.1016/j.jappgeo.2013.04.010>
- Zhao W, Forte E, Levi ST, Pipan M, Tian G (2015) Improved high-resolution GPR imaging and characterization of prehistoric archaeological features by means of attribute analysis. *J Archaeol Sci* 54:77–85. <https://doi.org/10.1016/j.jas.2014.11.033>
- Zhao W, Forte E, Fontana F, Pipan M, Tian G (2017) GPR imaging and characterization of ancient Roman ruins in the Aquileia Archaeological Park, NE Italy. *Meas J Int Meas Confed* 113:161–171. <https://doi.org/10.1016/j.measurement.2017.09.004>

## *Legislation/Regulations*

- LOMLOE (2020) Ley Orgánica 3/2020, de 29 de diciembre, por la que se modifica la Ley Orgánica 2/2006, de 3 de mayo, de Educación. Boletín Oficial del Estado, núm. 340, 30 de diciembre de 2020, pp 122868–122953. <https://www.boe.es/boe/dias/2020/12/30/pdfs/BOE-A-2020-17264.pdf>
- UNESCO (1972) Convención sobre la Protección del Patrimonio Mundial, Cultural y Natural. París, del 17 al 21 de octubre de 1972. Disponible en: <https://whc.unesco.org/archive/convention-es.pdf>

**Open Access** This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

