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teaching methods and didactic materials on geotechnologies for cultural heritage

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ABOUT THE PROJECT

The MINERVA project, based on transdisciplinary and cross-border tools, aims to develop the efficiency of the learning approach in Cultural Heritage and Geosciences.

Three actions will be analysed. In the first stage, the teaching process will be examined, focusing on HOW the teaching and learning of Cultural Heritage are organized at the academic level. Then we will examine the design concept; WHAT are the needs and WHICH tools are used. The third stage aims at to define WHO is involved in the teaching process. As a result, using cognitive approaches, the tools that will be developed will reflect both the dialectical and the interactive relationship between methods and knowledge, thus bringing students into a learning-action using geosciences.

More specifically, the three main actions of the MINERVA project will follow three main steps:

1. Learning: define the learning needs of the students with a detailed comparison between the job market needs at the European level and the academic profiles related to Cultural Heritage.
2. Thought process: propose a holistic approach linking the Humanities to the Geosciences in order to enhance spatial thinking. A new teaching resource will be designed for graduate and postgraduate students, adjusted to a personalized learning approach. The use of spatial tools, such as GIS and Remote Sensing aims to enhance the disciplines of Cultural Heritage, namely History, Archaeology, Anthropology and Cultural Management.
3. Implementation: activate innovative teaching methods and resources in a structured course, providing a flexible and dynamic learning experience, available on FEDERICA platform; specifically designed to provide Massive Open Online Courses (MOOC).

Finally, the MINERVA project is an efficient response to the current circumstances, where effective distance learning and work tools, as well as electronic platforms, are required.

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EXECUTIVE SUMMARY

The second Intellectual Output of the MINERVA Project (IO2) is the "Teaching methods and didactic resources on Geotechnologies for Cultural Heritage" whose expected outcome is the creation and formalization of an innovative toolkit that will be made available on the MINERVA Website and related platforms and upcoming MOOC.

This report provides an overview on the research and didactic activities conducted by the MINERVA Partners towards developing an innovative toolkit, which can provide both teachers and students with guidance and resources related to the teaching and learning geotechnologies for cultural heritage. The following main themes structured the document:

- teaching methodologies and related wiki-based resources in "Wikinerva" (Section 3)
- skills and tools inventory (Section 4)
- didactic resources including information on online resources (Section 5)
- *ad hoc* developed MINERVA case-studies (Section 6)
- the purposively established MINERVA Repository (Section 7)
- Community of Practice (Section 8).

Hence, in line with the MINERVA Project's objective, the needs for geotechnologies for Cultural Heritage (CH) with respect to both content and teaching methodologies are analysed and discussed towards understanding the opportunities and solving challenges. While this report is primarily targeted to teachers as it enables them to develop their methodologies and content on the basis of the knowledge generated by the MINERVA project, it can also be useful to students (and in particular self-learners). Indeed, it provides different resources and toolkits to allow becoming familiar with the role of geotechnologies applied to cultural heritage sciences.

In fact, a detailed overview of approaches for teaching geotechnologies and training approaches is provided (Section 3) in order to provide guidance on how to best approach the teaching of geotechnologies for cultural heritage. Student-centered methodologies for teaching geotechnologies for cultural heritage are described and discussed on the basis of a review of the relevant literature with particular focus on Flipped Learning (inverse instruction), Project-based and Problem-based Learning, Collaborative Learning, Peer Assisted Learning as well as Service-Learning and Gamification. To complement the theoretical discussion a toolkit has been prepared with a wiki format and titled "Wikinerva"[1]; as an open resource to teachers and students. It collects the main methodologies and on-line tools of interest for the project. Such an endeavour has been supported by an *ad hoc* survey conducted to understand the students' perceptions that they have of the various teaching methodologies and strategies as well as to further the understanding of students' experience with the virtual environment. This has enabled solving/addressing the challenges related to teaching GIS/Geotechnologies to CH students such as those related to the knowledge of new technologies, different spatial thinking/learning and the fact that active or innovative learning methods or strategies are not widespread in university teaching.

Upon these findings, the MINERVA Project's pedagogical approach for the ensuing MOOC has been defined. They confirm the importance to pursue a student-centered approach, based on active and experiential learning, supported by the possibilities enabled by collaborative work and including open

[1] https://sites.google.com/view/wikinerva

educational practices and e-learning environment, and by integrating critical thinking (i.e., Problem/Project-based Learning) and spatial thinking (i.e., Spatial Learning).

Parallel to this research work, the MINERVA Partners have focused on developing a skills and tools Inventory (Section 4) which is introduced by the description of GIS main components, namely (i) people, (ii) data, (iii) methods, (iv) hardware and (v) software. Particular focus has been placed on the latter three components also by identifying Quantum GIS (QGIS) as the main tool for the MINERVA Project given that is a free and open-source software, outlining a skills inventory within the framework of the overarching modules identified by the MINERVA Project (see Kozina et al., 2021[2]). Additionally a detailed tools inventory provides information on open-source desktop software (e.g., QGIS, gvGIS, SAGA GIS) as well as a selection of commercial ones (e.g., ArcGIS Pro and Global Mapper).

An overview of the available didactic resources (Section 5) is provided to allow for further insights of the needs related to re-designing didactic resources and refining new tutorials and case studies that are more fine-tuned to the needs of the Cultural Heritage sector. On this basis, case studies (Section 6) have been identified and developed by the MINERVA Partners by highlighting the main context, the aims, the level of competence, the skills to be learned and the overall workflow and data. Each of the six MINERVA Partners has designed a case-study addressing different themes and skills (e.g., "Coal Basin in Saint-Etienne" by French experts from the Université Jean Monnet-Saint-Étienne and "An evaluation of Cultural Heritage Sites According to the Map of Seismic Hazard" by Slovenian experts from the Research Centre of the Slovenian Academy of Sciences and Arts). The full case-studies including step-by-step information can be accessed via the MINERVA Repository[3] which is described in the report (Section 7).

The report concludes with a description of the purposively launched Community of Practice (CoP) within the Electronic Platform for Adult Learning in Europe (EPALE) Platform on "GIS e-Learning for Cultural Heritage". Its aim is to create a multidisciplinary community of teachers, researchers, professionals and users interested in exchanging knowledge and experiences on the teaching-learning approaches and use of GIS technologies for cultural heritage.

The MINERVA IO2 "Teaching methods and didactic resources on Geotechnologies for Cultural Heritage" provides the basis for the identification of innovative methodologies, content and key resources to be mainstreamed in the development and implementation of the third MINERVA intellectual output (IO3), namely "Massive Open Online Courses (MOOC) course in Geotechnologies for Cultural Heritage". It will allow creating an interdisciplinary and transdisciplinary communities working on geotechnologies for cultural heritage.

[2] Kozina, J., Ciglič, R., Spini, L. (2021). Competence Framework for Teaching Geotechnologies for Cultural Heritage: Intellectual Output 1. MappINg Cultural HERitage: Geosciences VAlue in Higher Education. Erasmus+.
[3] http://minerva.identitaculturale.eu

1. INTRODUCTION

Spatial literacy and knowledge in geotechnologies are becoming fundamental to the study of many different fields related to Cultural Heritage (Bogdani and De Mitri, 2017)[4] (e.g., architecture (Santos *et al.,* 2021)[5], archaeology, anthropology, history and cultural management). Furthermore, they are becoming an important competence for teachers, students as well as for practitioners as it allows for addressing challenges related to the study, management, monitoring, safeguarding and to the promotion of Cultural Heritage. This issue which has been made more and more urgent by the increasing impacts on Cultural Heritage through climate change (e.g., via extreme events) and humanitarian disasters (e.g., civil unrest)[6,7].

In this context, a wide variety of activities in Cultural Heritage now rely on GIS and other Geotechnologies and several didactic resources (incl. self-learning online tools) are becoming more and more available (either in open-access or within paid programmes) on the Internet. However, there is no single data (or meta-data) repository for such resources, and there is not even a review and evaluation, nor a gap analysis nor a community of practice concerning such resources and related teaching/learning methods.

The MINERVA Partners have addressed such issues by conducting research, also through surveying students' perception, and by developing an innovative and comprehensive toolkit that will be made available on the MINERVA Website and will be fed into the upcoming MINERVA MOOC. It is expected that this work will also allow for a common implementation of the geotechnologies teaching methods for cultural heritage to other EU universities, as well as to further capacity-building in cooperation activities with other universities in the Global South. The results (learning/educational resources) of the project will be available free and therefore useful for a wider audience/community [rec1] that is interested in cultural heritage and would like to improve their capabilities in the field of geotechnologies.

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4 https://groma.unibo.it/bogdani_de_mitri_biblio_gis

5 https://www.mdpi.com/2227-7102/11/6/307/htm

6 https://www.iccrom.org/it/publication/first-aid-cultural-heritage-times-crisis-handbook

7 https://ec.europa.eu/echo/funding-evaluations/financing-civil-protection-europe/selected-projects/protecting-cultural-heritage_en

2. METHODS OF TEACHING GEOTECHNOLOGIES AND TRAINING APPROACHES

The objective of the Minerva project, to prepare innovative didactic materials to teach Geotechnologies to Cultural Heritage students, requires us to make a review of teaching methods that can be applied to our purpose. The result of this section will be to select those methods, strategies or techniques that best adapt to a student-centered teaching model in the field of Cultural Heritage.

The focus of this section is on how to teach rather than what to teach (explained in the next sections). We want to answer the question about if there are methods more appropriate for teaching Geotechnologies and what are their main features

2.1. Didactic Guidelines of teaching Geotechnologies for Cultural Heritage

Minerva teaching approach is based on three principles or guidelines:

- active learning,
- open educational practices,
- e-learning environment.

2.1.1. Active learning

In current university education, the role of students tends to be predominantly passive (especially in the traditional oral-based lessons) and therefore does not promote the exercise and development of the essential competencies required in the work environment (Prieto *et al.*, 2021). In addition, there is evidence that shows that students learn more effectively if they are active rather than passive during the learning process (Wood, 2004).

Faced with traditional technologies, Minerva is committed to active learning strategies and methodologies of proven efficiency that seek students to obtain significant and high-level results. Active learning provides students with opportunities to interact with content. Learning by doing (i.e. using information to solve a problem) or experiential learning has been proved to be more effective than learning by reading or listening. The latter refers to a knowledge acquired through practice that also implies a reflection and directs us to the term experimentation (provoking an observation with the intention of studying certain phenomena) (Leininger-Frezal, 2021). The Experiential Learning Theory emphasizes the central role that experimentation plays in the learning process. It is based on the contributions of important 20th century authors and their theories about learning and human development, such as John Dewey, Kurt Lewin or Jean Piaget (Kolb and Kolb, 2005).

Research indicates that active learning improves student academic performance; increases student engagement and critical thinking; and improves student attitudes (Hadman *et al.*, 2013). According to that, it is important to know the emotions implied in the learning process (motivation or lack of it). Encouraging the motivation and involvement of students is essential to guarantee the completion of their program and their academic performance.

2.1.2. Open educational practices OEP (or open pedagogies)

The second guideline refers to the use of both, open educational resources (OER) to support learning (e.g. Campbell and Shin, 2014) and open exchange of teaching practiscs with the aim of improving education and training (BCcampus, 2021).

Open educational resources are defined as “teaching, learning and research resources that, through permissions granted by their creator, allow others to use, distribute, keep or make changes in it” (BCcampus, 2021). Minerva project wants to take advantage of the multiple possibilities offered by the Internet to obtain free-access teaching materials adapted to the most diverse uses.

Collaborative platforms (such as Miro, Draw Chats, or others) are an excellent tool to engage students in learning, collaboration, and critical thinking. It encourages collaboration and creative expression, and it enables allocating assignments and providing feedback. The result can be an expression of collective intelligence, when “a group of average people can –under certain conditions– achieve better results than any individual of the group” (Leimeister, 2010:245). Shared work or cloud labor that has been facilitated by the Web 2.0 promotes the expression of collective intelligence. This can be used for problem solving and joint creation. It can be considered the ultimate goal of any active learning activity aiming at community building and/or knowledge building.

The use of open source software and the use of Open Data available on the Internet so that anyone can download, modify and distribute it allows us to take advantage of a large amount of information that the society began to produce in the 21st century.

2.1.3. E-learning environment

The learning experiences, proposed by Minerva, will take advantage of digital technologies as the way to implement the use of student time more efficiently. In this context, students will independently engage with materials offered in Minerva web (and Minerva MOOC) on their own time and at their own pace. One of the intellectual Outputs of this project is to prepare a Massive Open Online Course aimed at large-scale participation and offering open access via the Web (Daniel, 2012). From 2008, when the first course with this name was offered, until now there has been a growing demand for and interest in this model (Bozkurt, 2017) that at the present has an important role in higher education, lifelong learning, and distance education.

2.2. Student-centered methodologies for teaching Geotechnologies for Cultural Heritage

The review of the relevant literature on student-based methodologies in higher education allows us to select some of the best values to create an educational environment focused on the actions that students perform.

This review includes strategies as:

- Flipped Learning.
- Project-based Learning and Problem-based Learning.
- Collaborative Learning.
- Peer Assisted Learning.
- Service-Learning.
- Gamification.

The compilation of active methodologies and strategies can be enriched with more contributions, but an exhaustive analysis is not intended. In this case, the objective of this reflection is to identify some of the features that should guide the didactic approaches of the project.

As a complement, a toolkit has been prepared with a wiki format (Wikinerva) that collects the main methodologies and on-line tools of interest for the project. It offers a synthesis of some of the main characteristics of the most relevant methodologies for teaching Geotechnologies for Cultural Heritage. You can find more details here: https://sites.google.com/view/wikinerva.

2.2.1. Flipped Learning (inverse instruction)

It is considered not merely a method but an instructional model that shifts from a teacher-centered classroom to a student-centered approach. In this case the content and material of the class are delivered primarily outside of the classroom while in-class time is used to put into practice higher-order thinking skills (according to revised Bloom's taxonomy) such as problem-solving, discussion or debates proposed about advanced concepts, or engage in collaborative learning (Galway *et al.*, 2014; Prieto *et al.*, 2021).

Flipped Learning (FL) has some precedents in different innovative methodologies that emerged and were implemented in the last decades of the 20th century, such as Just-in-Time Teaching (JITT), Peer Instruction (PI), and Team-based Learning (TBL). In these methodologies, teachers also emphasize the importance of the out-of-class pre-study phase as essential to engage in higher cognitive processes and apply knowledge in class. "They sent new materials –printed or electronic documents– to students to be studied before classes", to prepare the training activities to be carried out in class in PI and TBL models. The reflective self-assessment questionnaires in the JITT model contributed to the same objective (Prieto *et al.*).

Definition, according to Flipped Learning Networks, FL is:

"A pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where educators guides students as they apply concepts and engage creatively in the subject matter" (Flipped Learning Network (FLN), 2014).

It is necessary to distinguish between Flipped Classroom and Flipped Learning. It is possible to flip a class by having students, previously to the class session, read texts, watch supplemental videos, or solve additional problems. But to engage in Flipped Learning, teachers must incorporate four pillars into their practice (FLN, 2014). It means: 1.- Flexible Environment in which students choose when and where they learn. 2.- Learning Culture, as a learner-centered approach in which students are actively involved in knowledge construction. 3.- Intentional Content for maximizing classroom time, instructors determine what contents is necessary to teach and what materials students should explore on their own.4.- Professional Educators that continue to be an essential ingredient of the learning process

Discussion

Research has shown some positive effects of this model, that increases motivation and involvement of students, improves academic performance, contributes to better development of competencies and skills and also has a positive impact on students' perceptions of their learning experience (Prieto *et al.*, 2021).

The flipped learning instructional model has been considered as a successful alternative to conventional lecture-based teaching as it offers a framework for integrating online learning technologies with active and collaborative learning (Galway *et al.*, 2014). Some of the features of the implementation of this method may be useful to apply in the Minerva project. For instance, in the Minerva web and MOOC, didactic resources/toolkits/lessons will be available to students to be accessed whenever and wherever it is convenient for them. And also, Minerva teacher team can deliver instructions by recording and narrating screencasts of work they do on their computers, creating videos of themselves teaching, or recommending video lessons/examples/case studies from trusted Internet sites. Students can watch the videos or screencasts as many times as they need to, enabling them to be more productive learners in the academic performance.

In an e-learning system the role of the teacher is reduced while the learning process takes place independently. But even in open classes the role of the teacher is not only reduced to preparing the materials, it can also be important to lead the course, monitor the students or even transmit culture, ethics and cultural background. This may require the figure of the tutor in Minerva MOOC, and it is a matter to take into account in its design and implementation.

2.2.2. Project-Based Learning and Problem-Based Learning

These two teaching/learning approaches that promote meaningful learning, share not only the same acronym, but also similar characteristics. Some authors consider that Problem-Based Learning (Problem-BL) is a subset of Project Based Learning (Project-BL). In fact, the project, that is the focus of these methodology, can adopt several forms (Larmer, 2013) as:

a) Designing and/or creating a tangible product or event.
b) Solving a real-world problem (simulated or authentic).
c) Developing an answer to an open-ended question.

Other authors prefer to recognise the own history and set of procedures of each of these methodologies.

Project-BL is a pedagogical methodology that "places the learner in the focus as the builder of his or her own learning, being able to solve specific problems or challenges autonomously" (Hernández et al, 2021:5). Some advantages of this methodology are: it can be easily applicable to any subject or content; it stimulates autonomous learning, improving decision-making and increasing responsibility, and it is motivating and joyful, setting challenges that arouse curiosity.

The method consists of carrying out a project of a certain size, generally in a group. The teacher must ensure that the student has all the necessary elements for analysis. Its role is to guide the student and direct him towards the development of the skills that must be acquired during the process. Feedback from others in the group (or from the teacher/facilitator/instructor) is essential during the process.

Problem-BL began to be used at the McMaster University School of Medicine in Canada in the mid-1960s. From the health sciences, it was extended to other applications in various disciplinary fields. This method is defined as a multidimensional process in which cognitive, emotional, cultural and social aspects participate, where exercises are replaced by assumptions and real problems that have an interdisciplinary, professional nature, with multiple solutions and / or different resolution strategies. A situation, task or challenge is considered a problem, which is the source of learning. The application of Problem-BL contributes to the development of skills and competencies necessary for intellectual growth. Teaching based on this strategy aims to emphasize activities that pose situations whose resolution requires analysis, discovery, elaboration of hypotheses, confrontation, reflection, argumentation and the communication of ideas to achieve student learning (Pérez and Chamizo, 2011).

Discussion

Both Project-BL and Problem-BL are methodologies that, according to the principles of constructivism, have proven useful for students to learn to perform the cognitive tasks that characterize critical thinking, such as, the judgement between alternatives, search for the most efficient way to perform a task, assessment of evidence, review of original ideas, or planning or summarizing the most important points of an argument.

PBL methodologies share a part of its characteristics with other active learning approaches (such as inquiry-based learning). The key distinction between them is that in PBL the problem, usually set by the instructor, defines what is to be learned (on the contrary, in other strategies, the knowledge to be developed must often be acquired in advance of participation in the problem-solving process).

PBL can be understood both as an active learning method and as a curricular philosophy. It is ideally suited to the field of geography -and geotechnologies- since, by its very nature, geography is already interdisciplinary, and has a tradition of group work, which underlies most practices of PBL. Despite this, it is not as widely used in geography courses as might be expected. It has been shown that it is essential to pay special attention to course preparation, scenario design, guidance to students and assessment methods to maximise the chances of a successful implementation (Pawson *et al.*, 2006).

There are other models (design-BL, challenge-BL...) that fall under the general category of inquiry-based learning. Tasks-based learning is another student-centered approach that is aimed more at developing students' skills than at conveying information. Some of the specific contributions of this wide group of approaches can be taken into account to carry out the objectives of this project.

2.2.3. Collaborative Learning (Team-based Learning)

Collaborative Learning (CL) is an educational approach in which learners at various performance levels work together in small groups for a common goal (to solve a problem, complete a task, or create a product). In this teaching and learning approach students have the opportunity to interact with peers, and to present and defend their ideas. Therefore, they begin to create their own unique conceptual frameworks and not rely solely on an expert's or a text's framework (Laal and Laal, 2012: 491; Srinivas, H., 2011). The students became responsible not only for their own learning but also for another´s learning. The success of one learner helps other students to be successful.

Discussion

The use of this methodology fosters the development of competencies such as flexibility, trust, tolerance, and self-awareness. It allows us to implement the concept of shared responsibility. Students take responsibility not only for their own learning, but also for the learning of others. Its use in work environments can improve productivity as well as the workplace atmosphere. There is evidence that cooperative teams achieve higher levels of thought and retain information longer than learners who work alone (Srinivas, 2011).

It is a very suitable methodology for Geotechnologies, and heritage projects given its transversal nature in multidisciplinary teams.

2.2.4. Peer-Assisted Learning (Peer Tutoring)

The model of "Peer-Assisted Learning" (also called Peer Tutoring, PT) has particularities with respect to the broader concept of "peer teaching" (PI) (developed by E. Mazur in the 90s at Harvard University) or "peer learning" (PL) and it is closely related to the Team-Based Learning, and collaborative learning activities.

The application of this methodology requires working in small groups or pairs of students with the aim of offering mutual didactic support. Participants assume specific roles, either as a tutor or tutored, to develop the contents of the study plan and apply the established interaction procedures, in which they must receive specific training (Topping, 2015). Students of greater age, ability, or experience serve as tutors to systematically teach others of less age, ability, or experience. A specific characteristic of this method is that students take responsibility for both the teaching-learning process and its evaluation. The teacher's task is aimed at providing feedback to each student regarding their performance and can take different forms, such as reinforcing learning or correcting misunderstandings. In reciprocal peer tutoring (RPT) all students function as tutors and as tutored, that is, they give instruction and receive it, thus applying the maxim that there is no better learning to help than being helped.

Discussion

This methodology has proven to obtain positive results not only in academic aspects but also in psychosocial and interaction skills. It also presents some risks, such as the transmission of erroneous knowledge or the lack of communication with the teacher. Planning is essential for the development of this type of practice that is framed in the constructivist theory of the development of knowledge of Jean Piaget, Lev Vygotsky's concept of the zone of proximal development and in various theories related to social psychology, for example, role theory.

2.2.5. Other approaches: Service Learning and Gamification

There are other approaches that can be contextualized within pedagogical trends derived from the contributions of William James and John Dewey and their premise "Learning by Doing" (Sotelino-Losada *et al.,* 2021). This is the case of Service Learning, whose presence in higher education institutions has acquired increasing importance in recent decades. This methodology combines theoretical learning and practical application. It also provide extra value in the framework of social responsibility (Marco-Gardoqui *et al.*, 2020). According to Anderson (1998) Service Learning is a growing pedagogy that integrates community service into an organized curriculum that includes regular opportunities for personal reflection. In Service Learning, youth are encouraged to take the lead, in responding to genuine community needs, through service that is integrated into the academic curriculum.

Finally, it can be mentioned strategies as Gamification, defined as "the use of game design elements in non-game contexts" (Deterding *et al.*, 2011). Its application as a teaching methodology helps to capture the attention of students, generate more attractive content, and improve academic performance. In addition, game dynamics stimulate and motivate both competition and cooperation between players (Kapp, 2016). As has been shown in various studies, gamification is especially useful to enhance cognitive, emotional, and social aspects (Lee and Hammer, 2011). Gamification applied to Cultural Heritage has become increasingly important in recent years for the promotion of cultural spaces and museums. It has become a strategic digital marketing tool, which adds to its traditional function of facilitating learning through play (Bonacini and Giaccione, 2021).

2.2.6. Identifying a methodological approach

After summarizing the main characteristics of the methodologies selected above, it is possible to conclude by identifying some guidelines of the teaching method to be applied in the project. According to the principles that have been explained, Minerva pursues a student-centered approach, based on active and experiential learning, and supported by the possibilities offered by collaborative work. The virtual learning environment will facilitate the emphasis in co-construction of knowledge. These will be the pedagogical bases that will be applied in the later phases and in the design of the MOOC.

2.3. Teaching Geotechnologies and active methodologies: identifying challenges

The experience of different partners in teaching Geotechnologies to Cultural Heritage students offers useful information about some of the difficulties that this process has. In addition, a survey has been carried out with the students to understand the interpretation that they have of the various teaching methodologies and strategies.

2.3.1. Problems in teaching GIS to Cultural Heritage

Now, we can consider the confluence of two facts. In the first place, education in subjects related to Geosciences requires the knowledge of new technologies (GIS, Drone, Remote Sensing…) and the use of information collected in new digital formats. On the other hand, the transition from traditional face-to-face learning to open online teaching (e-learning, m-learning[8], and u-learning[9]) which is increasingly important, creates a new scenario with its own characteristics from the point of view of the teaching-learning process. As a result, students are not familiar with these techniques applied to spatial syntax, even in the case of those who come from disciplines related to new technologies. This dystopia increases for students coming from different backgrounds, such as students in Cultural Heritage, due to their dissimilar perception of key concepts of space or scale, and the distinct glossary context they know. More specifically, on a regular basis, students in CH have a partial view of space, while archaeologists usually focus on an "object". In other words, they do not perceive space as a whole, or they do not have a complete understanding of the spatial structure. Therefore, the goal is to help students achieve spatial perception, and in fact, spatial thinking, which means understanding components as situation, proximity, and relationship.

2.3.2. A conceptual framework: the linking pathway between GIS and Cultural Heritage

A theoretical framework must be designed to establish the linking path between Geosciences and Cultural Heritage Sciences. We can consider GIS as a transdisciplinary tool that can be useful to increase spatial perception and reasoning of students and bring them to spatial-reaction or spatial-reaction.

In other words, we need procedures to familiarize students with the three components of spatiality, namely, *situation, proximity and structure*, which constitute the basis of spatial thinking. The mapping procedure summarizes the differences that constitute the geographical perspective and puts the situation in value with space (Pigaki & Leininger-Frézal, 2014).

Practically, both sciences of CH and Geosciences try to make visible the invisible via an abstract way of thinking. The linking path lies in three components: the reconstitution of the object, the location in space, and narration. GIS as a transdisciplinary tool represents a hyphen between CH and Geosciences. This is because, on the one hand, space is organized around a complex system via abstract concepts and a more abstract system. On the other hand, CH transforms objects in topological terms that are schematic and conceptual constructions of

[8] For Mobile learning

[9] For Ubiquitous learning, an amalgam of e-learning and m-learning

relationships, which, via geometry and mathematics, induce the related to CH notion of *content*, *scale* and *glossary*. As a result, there is a need to organize concepts and propose cognitive processes both adapted to technological progress that leads to changing the paradigm for teaching CH.

In this perspective, **mapping** is a cognitive construction that is part of a socio-constructivist learning approach. Mapping is in line with their epistemological principles of spatial analysis (Fontanabona, 2001) where space is defined as a system of places whose interactions depend on their proximity, their position and their relationships, which map is a scaled representation (Brunet, 1987). In other words, mapping is a metaphor of geographical space required as a tool of spatial investigation (Pigaki, 2000). Students through forms and symbols can apprehend space and observe spatial information. This allows spatial questions: the locations (where), shapes (what), spatial organization (why, how, what relationship?).

2.3.3. Real problems: the perception of students

An online survey was planned for the students aimed at finding out their experience on virtual learning environments, and their opinion on teaching and learning methods, in general, and on those applied to Geotechnologies, in particular. The survey consisted of two parts (“*Assessing Teaching Practices”* and "*Assessing Learning Geotechnologies*”). The objective of the first part was to identify the methodologies that have effectively been implemented in the various training programs and the e-learning experience of students. The second one focused on the learning of Geotechnologies and was aimed at identifying the difficulties perceived by the students of Cultural Heritage.

The questionnaire was disseminated in the 6 countries of the project. The target groups were:

- Master students in Geotechnologies
- Bachelor's degree students in Cultural Heritage with some knowledge of Geotechnologies.

Also, Cultural Heritage students without any experience in Geotechnologies were able to answer the questionnaire in countries where the study program does not include this topic.

A total number of 137 answers were received in a Google Form format. Most of the surveyed students are between 17 and 25 years old (64 %), in second place is the group between 26 and 35 years old (28 %), while the oldest age groups, over 36 years old, are less represented (7 %). Female students predominate (59 %) in the surveyed group. More than 56 % are undergraduate students and 39 % are graduate students. Detailed analysis of the survey[10] allows drawing some conclusions that are briefly summarized here.

The questions in the first part were aimed at knowing the assessment and use of some e-learning instruments, and of various active teaching methodologies.

[10] https://drive.google.com/file/d/1FceNVafmQYc3zs-Grm5joo7_AY37yOw6/view?usp=sharing

E-Learning. According to the responses received, there is a wide use (although it does not cover all cases) of online teaching platforms and especially of the Moodle platform (almost half of the respondents use it regularly). The opinion on its characteristics is generally good. Most of the responses are concentrated on the normal or good level, especially about design and manageability, or teacher-student interaction, although the score is lowered with respect to student-student interaction. The importance that this aspect has for the respondents justifies the higher demand and the lower score awarded. Despite being familiar with online platforms it does not mean that they routinely use many of the tools they offer. The survey shows the scarce knowledge of tools such as the Forum, or the Glossary. Only Chat is used more widely. Regarding the evaluation tools, both the questionnaires and the delivery of tasks have a good score (although in the latter case the percentage of those who do not know or do not respond is important). Students recognize the possibilities that e-learning platforms offer for collaborative work and globally value their platform positively.

Active methodologies. It is found that active or innovative methods or strategies are not widespread in university teaching. The best known are collaborative work strategies, listed first in the answers, as well as problem- or project-based learning, and workshops. Especially noteworthy is the high degree of ignorance of some methodologies such as Gamification, Flipped Classroom or Peer Tutoring. On the contrary, collaborative work which, as has been said, is most used, is also the best evaluated in the opinion of students, followed by the PBL methodology and by Workshops. The use of videoconferencing is quite widespread and almost a third of the responses mention Microsoft Teams, although others such as Google Meets, Cisco, Zoom or Skype are also cited, at a certain distance. Both Teams and Google Meets are preferred. Most of the students surveyed have never used non-formal learning platforms and only a small group have recognized one as Cursera, in the first place.

In the second part of the survey, dedicated specifically to the teaching and learning of Geotechnologies, more than two thirds of those surveyed confirm that they have studied some type of geotechnology. They are mostly beginners or intermediate level and only a small percentage have an advanced level. According to answers about software used, significant volumes of respondents do not use any type of non-commercial software. ArcGIS is the best known. Its manageability is well considered, although there is a high degree of variability in the assessment: a third of the responses indicate that it is quite manageable (4 on a scale of 1 to 5), but also another third of those who have used it, believe that it is little or nothing manageable. The use of non-commercial software is more common and there is a high degree of coincidence with the popularity of QGIS (almost 60 % of respondents use it regularly). Its manageability is valued very positively because almost half of those who have used it think that it is quite or very manageable and another third consider that it is moderately manageable. Regarding the type of knowledge or skills necessary to start learning Geotechnologies, students have selected Geography and Cartography first, followed by Geoinformatics, Statistics and general skills on ICT. Knowledge of computer languages is not widespread since most of the respondents do not know any. Among those mentioned Python stands out, and to a lesser extent, SQL and JavaSript.

Finally, the results on active or innovative methodologies that are useful for learning Geotechnologies coincide with those of the first part of the survey. Collaborative work strategies are mentioned first (almost a quarter of the responses), followed by problem or Project-based learning and Workshops. Peer tutoring, Service learning, and Gamification score low, and lastly is the Flipped classroom.

2.4. Conclusion: Towards a new paradigm for teaching spatial thinking in Cultural Heritage

Geotechnologies has been identified as “one of the three most important emerging and evolving fields, along with biotechnology and nanotechnology” (Gewin, 2004). Its application to cultural heritage requires the training of students in History, Art, Geography, etc. whose study program should include the competences and skills demanded by the labor market (see *Competences framework for teaching geotechnologies for cultural heritage*). Teaching geotechnologies for the research, management and dissemination of cultural heritage presents different challenges. To overcome them, it is essential to find an appropriate method for an open and online active teaching-learning system.

PBL is widely developed and applied in different fields of science (albeit not very much in geography). As other active methodologies, it puts the emphasis on learning rather than instruction and promotes involving students (Pawson *et al.*, 2006). Since problems do not respect disciplinary boundaries, PBL often implies collaboration between disciplines, which is an essential requirement for teaching geotechnologies applied to cultural heritage.

Of the multiple possibilities analysed, PBL stands out for some advantages, although it also presents certain weaknesses and difficulties for its successful application. To overcome them, it is necessary to plan the course in detail, carefully design the scenarios, pay special attention to the orientation of the students and the selection of the assessment tools, as some academic papers recommend. The requirement of a good design of scenario for PBL implies evaluating the relevance of the combined use of other tools and strategies connected with different methodologies such as those explained above. Particularly some related to collaborative work (one of the methods that are best valued by students, as seen in the survey carried out) or digital badges and gamification tools, among others.

In addition to that, to encourage students to think about space and to improve spatial knowledge, contributions of a methodological approach as Spatial Based Learning (SBL), developed in geography and in geosciences learning, can be considered. Spatial thinking is very useful in everyday life (for driving, choosing the best itinerary for going home, etc.). But using spatial thinking to accomplish daily tasks is not the same as what has been defined as spatial literacy (that allows students to describe and analyse the spatial patterns of people, places, and environments on Earth). There is a lack of focus in spatial thinking at Cultural Heritage studies as at Social Sciences and Humanistic fields in general (Hespanha, 2009).

Therefore, assessing prior knowledge is especially important in instruction focused on spatial thinking. This formative assessment can provide information about the degree to which a learner can think spatially within the specific context of interest.

Therefore, by integrating PBL and SBL, it is possible to draft a new learning model more in line with the spatial thinking required to understand phenomena that manifest themselves in space. For the Minerva project, it is an efficient approach that will focus not only on critical thinking but also on spatial thinking.

3. SKILLS AND TOOLS INVENTORY

3.1. GIS components

GIS generally consider five major components:

- People
- Data
- Methods
- Hardware
- Software

Data should be managed by or with Cultural Heritage (CH) domain experts. It will be discussed more in Section 5. This section will only focus on the technical aspect: data formats, data models and so on. The other side of "data" (its quality, its bias and its fairness or absence of fairness) must be acknowledged but domain experts, who know when, why and how this data was made, should do it. It will be outside of the scope of this skills and tools inventory. Needless to say: a good critical mind-set is always a plus when you are dealing with data.

People (users, data producers, data analysts, etc.) are a very important part but we assume that students and professionals in CH already have management skills, "soft skills" and a good understanding of their institutional environment.

This leaves us with **methods**, **hardware** and **software**. As obvious as it sounds GIS is an information system that means a lot of it happens inside a computer. The "cloud" makes it a bit less clear but we are still interacting with a computer behind the Web. We will not spend too much time on the "hardware" component as we feel our goal is not to teach the computer science (CS) behind GIS but we will still give some advice and list some skills related to it. The trade-off here is that we think that a small part of CS that we will use will make the students' life easier and help us avoid some pitfalls while being relatively easy to grasp.

Finally, methods and software are what this inventory will mostly cover.

3.2. The principal tool for MINERVA project: QGIS

For software, we will go with Quantum GIS (QGIS), which is a professional GIS application and developer platform. QGIS is built on top of and proud to be itself Free and Open Source Software[11].

[11] https://www.osgeo.org/projects/qgis/

In particular, we will use the QGIS Desktop, a powerful desktop GIS software to create, edit, visualise, analyse and publish geospatial information (see section 4.4.1.1.1).

We make this choice mainly because:

- "QGIS is the leading Free and Open Source Desktop GIS"[12] : as such, it is available in every operating system (OS), has a broad and active community of developers.
- It follows the *free and open approach*[13].
- It provides a graphical user interface (GUI) perfect for beginners but also offers command line interface (CLI) with a Python console natively and bridge either natively or with the QGIS processing plugins to other software like GRASS[14], R[15] or SAGA GIS[16]

So, the inventory will be based on QGIS, but note that it is fully compatible with other GIS desktop software.

3.3. Skills inventory

3.3.1. Skills level of difficulty

Not all skills are at the same level of complexity. To consider this, we have retained two main levels of difficulty.

So, in this context, skills can be divided in 2 skill levels:

- **1** for Beginner level
- **2** for Advanced level
- **1/2** Means that this skill can be taught at a beginner level but can be enhanced

For example:

- QGIS GUI **1** means that QGIS GUI is adapted for beginner learner
- Lidar / Drone **2** means Lidar / Drone is for advanced learner
- GPS / coordinate data **1/2** means GPS / coordinate data can be started at beginner level, but can also cover more advanced topics

We are linking items of this list with different case studies in Section 6.

"Tutorial or not tutorial" is kind of an existential question. You can already find plenty of them on the internet (some are great, but others shouldn't be followed) and even if QGIS is not a quick development project it is still getting updated and as time goes, the usefulness of a "step by step" guide will lose its interest. However, like a lot of practical knowledge, students still need to practice and be guided. Therefore, we decided to go with a very "tutorialish" approach. We are still emphasizing that working in GIS is a "try-and-error" process and you do

[12] https://www.osgeo.org/projects/qgis/
[13] See Neteler and Mitasova, 2008 p2 for the four principles of "free software" in GIS
[14] https://grass.osgeo.org/
[15] https://www.r-project.org
[16] http://www.saga-gis.org/en/index.html

not have a “perfect solution” but shades of grey solutions that have been taken related to a particular context of any project[17]. We will also try to provide various ways to one goal so it can fit different kinds of students/users.

3.3.2. Skills categorization

The methods will be the core of the skills. We have followed the main overarching modules of IO1: data acquisition, data management, data visualization and data analysis but we added a first part called “A tour of QGIS” and a last one “Looking and asking for help”. The first one is to help students get their feet wet in the software and the last one is how to find and ask for help.

We have chosen to present this inventory as a table.

[17] See *“How to Do Things with Sensors” on Manifold @uminnpress*, 2020 for an interesting exploration of the “How to Do” in a How to do way

Category	Skill				Level
A tour of QGIS This part should focus on showing the various parts of QGIS. It should be an appetizer for the rest of the menu. This should end with the student making their first map and empowering them!	Installing QGIS				
	QGIS GUI	Setting Language GUI exploration (menu, panels…) Add toolbars			
	Loading layers				**1**
	Printing layout				**1/2**
	Discovering GIS file formats	Vector			**1**
		Raster			**1**
		Web service			**1**
	Using Plugins	Useful ones (i.e. Qgis2threejs for 3D rendering, Visibility analysis, QuickOSM…)			**2**
Data Acquisitions Input / Output (I/O) This part will focus on how to import and export some basic GIS data. First the learner needs to import data from various files or gain access to a web service. Then this should cover how he can export them to other common file formats or to print them.	Data with Coordinate Reference System (CRS)	Raster data	Analogue data sources (map base / old map) 1		**1**
			Taking images	Optical sensor	**1**
				Photogrammetric analysis (DEM, etc)	**1**
			Terrestrial or airborne (e.g. UAV) laser scanning (Lidar)		**2**
			Repository		**1/2**
		Vector data	Other softwares (spreadsheet application...)		**2**
			Repository		**1/2**
		Multi-format Platforms and repositories	National providers (*e.g.* IGN)		**1/2**
			European providers (*e.g.* Copernicus)		**1/2**
			Transnational (*e.g.*Geofabrik, naturalearth)		**1/2**

	Data without Coordinate Reference System (CRS)	GPS / coordinate data	**1/2**
		Georeferencing	**1/2**
	Digitizing data		**1**
	Web services (WMS/WFS/WMTS) / API		**1/2**

Category	***Skill***				***Level***
Data Management: Managing/acquiring GIS project files structure Here we will focus on some rules to provide organization to the GIS project. This will increase the learner productivity and ensure good cooperation within other data users. After that we will provide important theories and standards on how spatial information is represented and stored.	Basic rules that help!	Computer Science rules	Writing vs in memory		**1**
			Path: relative vs absolute		**1**
			Encoding: ASCII, UTF-8, ISO8859-7		**1**
			Naming conventions		**2**
			Data types	String	**2**
				Integer	
				Float	
				Date	
		Planning ahead phase / Workflow / (Post-it/paper)			**1**
		Geometry types	Point, lineString, Polygon		**1**
			MultiPoint, MultiLineString, MultiPolygon		**1**
			GeometryCollection		**2**
	Representing data in earth: Coordinate Reference System (CRS) (geographic / projected)	Geographic CRS			**1**
		Projected CRS			**1**
		Reprojecting layers			**1**
		CRS officials for each Minerva's countries			**1**
	GIS Data structure (vector/raster): How data is stored in computer	Resolution, Extent			**1**
		Shapefile, geopackage, kml, geojson			**1/2**
		Arc/Info ASCII Grid, Geotiff (*e.g.* DEM, Aerial photographs)			**1**
		Translate	Shp to geojson (example)		**1**
			Geotiff to jpeg2000 (example)		**2**

		Databases (*e.g.* Sqlite/Postgres+postGIS)			**2+**
		Rasterize, Vectorize			
	Keeping a well organised project: Files / Directories structures	Project repositories/files structures	QGIS project		**1**
			Example of repositories structure		**1/2**
		"In virtual memory" / Temporary files			**1/2**

Category	***Skill***				***Level***
Data Visualization This part will go a bit deeper in how to visualize spatial data. It will provide good practices, a spoon of fundamentals in semiology and various case studies. Those case studies should be adjusted to the student's interest.	Learning cartographic rules: Title, scale, legend, sources, north arrow, authors				**1**
	Semiology graphic	Symbology			**1**
		Qualitative / quantitative symbology			**1/2**
	Localization map				**1**
	Thematic map				**1**
	Classical approaches in cartographic symbology	Coastline presentation			**1**
		Masking study area			**1/2**
		Atlas building			**2**
	2.5 D / 3D				**1/2**
Data Analysis / Spatial Operations With that section students should be able to formulate questions and plan a workflow to answer them with QGIS. This will provide them the tools that allow them to stay productive in QGIS without using other software.	Vector	Getting Basic statistics			**1**
		Doing some Selections	By attributes		**1**
			By locations		**1**
		Geoprocessing	Merge/dissolve		**1**
			Overlay (Intersect, Union, Identity), Clip, Cut/Extract…		**1**
			Proximity (Buffer)		**1**
		Geometry tools	Area, length, centroid		**½**
			Check topological, geometrical rules		**2**
			Converting geometry	Multi to single	**2**

				To other geometry	
		Spatial union			**1**
		Join	Left, right, semi, anti … (in virtual memory)		**2**
		Zonal statistics			**2**
		Field calculator			**1/2**
		Rasterize			**2**
	Raster	Map algebra (Raster calculator)			**1**
		Clip			**1**
		Map algebra	Terrain analysis	Slope aspect, etc	**1/2**
	Toolbox and automation of geoprocesses (with or without spatial operations)	Workflow (flowchart) **1**			**1**
		Model builder			**2**
Looking and asking for help Finally, learning GIS can be a bit overwhelming. The field is always expanding and problems can happen. It happens to everyone, even specialists. This time it can be good to ask for help or find some insight on the documentation or on the web.	Reading the documentation	OGC e-learning center			**2**
		QGIS Docs			**1/2**
		Asking help on forums and boards			**2**

3.4. Tools inventory

3.4.1. Desktop tools

3.4.1.1. Open source Desktop software

Quantum GIS (QGIS)

MINERVA project partners made a collective choice to use open source and free of charges tools. This choice should allow a better adoption by a larger community of teachers and students.

As mentioned on the OSGEO website, "QGIS is the leading Free and Open Source Desktop GIS. It allows you to create, edit, visualise, analyse and publish geospatial information on Windows, Mac OS, Linux, BSD and Android (via the QField app). We also provide an OGC Web Server application, a web browser client and developer libraries. The QGIS project is under very active development by an enthusiastic and engaged developer community with good mechanisms for help via stack exchange, mailing lists and (optionally) through a global network of commercial support providers"[18].

QGIS is a powerful desktop GIS to create, edit, visualise, analyse and publish geospatial information. We have selected it because it provides a wide range of functionalities (including related ones mentioned in the skills inventory) whether in vector and raster modes. It also benefits from:

- Numerous plug-ins developed by the user community;
- Additional functionalities provided by links with other software (GRASS GIS, SAGA GIS, Orféo Toolbox or GDAL).

gvSIG

As mentioned on the OSGEO website, "gvSig Desktop is easy to work in a variety of formats, vector and raster files, databases and remote services. There are always available all kinds of tools to analyze and manage your geographic information. gvSIG Desktop is designed to be an easily extensible solution, allowing thus continually improving the software application and developing tailor made solutions."[19]

It could be a good alternative to QGIS in case of incapacity to use QGIS

SAGA GIS

More than a QGIS or a gvSIG (under the name of Sextante), SAGA GIS (for *System for Automated Geoscientific Analyses*) is a powerful Geographic Information System (GIS) software which has been designed for an easy and effective implementation of spatial algorithms. SAGA GIS offers a comprehensive, growing set of geoscientific methods and provides an easily approachable user interface with many visualization options. SAGA runs under Windows and Linux operating systems.[20]

GRASS GIS

Geographic Resources Analysis Support System, commonly referred to as GRASS GIS, is a Free and Open Source Geographic Information System Cross-platform software and technology built for vector and raster geospatial data management, geoprocessing, spatial modelling and visualization. It contains

[18] https://www.osgeo.org/projects/qgis/
[19] https://www.osgeo.org/projects/gvsig/
[20] http://www.saga-gis.org/en/index.html

over 500 modules to process and render geographic data, which allows manipulating a variety of raster, vector and 3D formats, and running simple to advanced spatial analysis and modelling.[21]

3.4.1.2. Some commercial desktop softwares

ArcGIS Pro

ArcGIS Pro[22] is a powerful single desktop GIS application developed by ESRI. It runs on Microsoft Windows. It supports data visualization, advanced analysis and data maintenance in 2D, 3D, and 4D. It supports data sharing across a suite of ArcGIS products such as ArcGIS Online and ArcGIS Enterprise, and enables users to work across the ArcGIS system through Web GIS.

Mapinfo Pro

Mapinfo Pro[23] is a complete, desktop mapping solution for the geographic information system. It is edited by Precisely and runs on Microsoft Windows. It allows analysts to visualize, analyze, edit, interpret, and output data — revealing relationships, patterns, and trends.

Terrset

TerrSet[24] is an integrated geographic information system developed by Clark Labs at Clark University. It runs on Microsoft Windows. It is also an efficient remote sensing software. TerrSet provides numerous GIS analysis and Image Processing tools coupled with a constellation of vertical applications. It also incorporates different specialized modellers for monitoring and modelling the earth system for sustainable development.

Global Mapper

Global Mapper[25] is a GIS software developed by Blue Marble Geographics and it runs on Microsoft Windows. It allows users to manage vector, raster, elevation data and it provides viewing, conversion, and numerous general GIS features. It gives access to a wide variety of data formats.

3.4.2. Some examples of online tools

Many online tools could be useful in the MINERVA project framework. We present below a non-comprehensive list.

Magrit

Magrit[26] is a thematic cartography software, which offers conventional cartographic methods coupled with innovative techniques (proportional symbols, choropleth map, discontinuity map, smoothed map, gridded map, cartogram, etc.). The application accepts many input formats and allows to export the final map in several formats as well as to save it in a "project-file". Produced maps are customizable thanks to a large choice of projections, colour palettes, fonts and more...!

21 https://grass.osgeo.org/learn/overview/
22 https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview
23 https://www.precisely.com/product/precisely-mapinfo/mapinfo-pro
24 https://clarklabs.org/terrset/
25 https://www.bluemarblegeo.com/global-mapper/
26 http://magrit.cnrs.fr/

Members of UMS RIATE develop and maintain Magrit[27]. Code[28] is instrumented for localization and 3 languages are currently available. A full description of each method is available in the user manual. A full description of each method is available in the user manual (in French)[29].

Mapshaper

Mapshaper[30] is an editor for map data. It is a Command line tool using node.js (javascript). Matthew Bloch (famous NYT journalist) and Mark Harrower (University of Wisconsin – Madison, USA) developed it. Mapshaper allows editing Shapefile, GeoJSON, TopoJSON, CSV and several other data formats, written in JavaScript. It supports common GIS tasks like simplifying shapes, editing attribute data, clipping, erasing, dissolving, filtering and more. For smaller files (up to 1GB) the web interface is fine but for bigger files and some specific tasks (simplify on lots of polygons) it will be better to go with a desktop install.

Rollapp

Rollapp[31] is a web service that allows virtualizing different applications, including QGIS[32], and access them directly through a browser. It is free of charge for read-only access with limited computing resources. For full access with extended computing resources for optimal performance, you need to subscribe to a Premium account.

Several Git of researchers, developers…

We propose here just an example of a magnificent interactive web app[33] for easy creating timelapse of annual Landsat imagery (1984-2021) for any location around the globe created by Qiusheng Wu, Assistant Professor at the Geography Department of the University of Tennessee, Knoxville. For a demo video: https://youtu.be/VVRK_-dEjR4

27 https://riate.cnrs.fr/
28 https://github.com/riatelab/magrit
29 http://magrit.cnrs.fr/docs/index.html
30 https://github.com/mbloch/mapshaper
31 https://www.rollapp.com/
32 https://blog.rollapp.com/2015/05/rollapp-makes-qgis-available-online/
33 https://streamlit.gishub.org/

4. DIDACTIC RESOURCES

4.1. Introduction

This section is articulated by providing an overall overview of the existing resources also by providing their relevance to the specific modules in a general course for Geotechnologies for Cultural Heritage (see IO1) and in the upcoming MOOC, as well as a list of existing relevant open data sources (Section 5.3).

Hence, this overview of didactic resources is not only useful to identify stand-alone tools, but also to identify gaps in didactic resources (including tutorials) specific to the utilization of Geotechnologies for Cultural Heritage, in view of the development and implementation of the MINERVA MOOC. In this context, the following sections (Sections 5.3 and 5.8) provide more details on Open Data and Repositories (Section 5.3), Tutorials (Section 5.4), online Forums and Knowledge-Exchange Platforms (Section 5.5), online Courses, Training Workshops and MOOCs (Section 5.6) and on Case Studies (Section 5.7) – these complementary materials are intended to allow for further understanding of the needs towards re-designing the didactic resources and defining new tutorials and case studies which are more fine-tuned to the needs of Cultural Heritage sector, as discussed in the concluding Section (Section 5.8).

4.2. An overview of existing open didactic resources

Here we provide an overview of the existing open didactic resources available on the web, and in particular the web-based tutorials in different languages (e.g., English and French) and at different levels (i.e., Beginner 1 and Beginner 2 levels which may be used for the MINERVA MOOC and/or in other sections of the MINERVA Website). We also provide an overview of open data sources (i.e., at the international and the national levels). The list available in Table 1 has been compiled through inputs by the MINERVA Partners, and hence, it includes resources in different languages. It is important to note that Table 1 below aims at providing a comprehensive list of the links to **OPEN** didactic resources (including software); however, references to relevant “non-open” resources can be found later on in the document.

Table 1a – Tutorials by overarching modules (references to level and language are also given) *(information accessed on 5 October 2021)*

MODULES	OPEN DATA SOURCE
1. DATA ACQUISITION	**BEGINNER 1 & 2** **QGIS Tutorials** - Importing Spreadsheets or CSV files: http://www.qgistutorials.com/en/docs/3/importing_spreadsheets_csv.html - Working with WMS data: http://www.qgistutorials.com/it/docs/3/working_with_wms.html - Georeferencing topo sheets and scanned maps: http://www.qgistutorials.com/en/docs/3/georeferencing_basics.html - Georeferencing aerial imagery: http://www.qgistutorials.com/it/docs/3/advanced_georeferencing.html - Digitizing map data:: http://www.qgistutorials.com/it/docs/3/digitizing_basics.html - Searching and downloading http://www.qgistutorials.com/en/docs/3/downloading_osm_data.html - OpenStreetMap data: http://www.qgistutorials.com/en/docs/3/downloading_osm_data.html **Other (non-QGIS) tutorials** - Geocoding with Google Sheets - Serbian/Albanian: https://www.youtube.com/watch?v=nW6suCiAbYE - Layer changing and basic map alterations Serbia: https://a3.geosrbija.rs/ Data acquisition Serbia: https://geosrbija.rs/en/new-mobile-application-geosrbija-kat/ http://www.crpd.gov.rs/mapserver2015/cityGis/ **(French-only)** -https://sigea.educagri.fr/tutos-sig/tutos-communs (TD1) -https://ouvrir.passages.cnrs.fr/tutoqgis/01_00_prise_en_main.php -https://ouvrir.passages.cnrs.fr/tutoqgis/02_00_geodesie.php

	-https://ouvrir.passages.cnrs.fr/tutoqgis/03_00_recherche_ajout.php
2. DATA MANAGEMENT	**BEGINNER 1** **QGIS Tutorials** - Working with attributes: http://www.qgistutorials.com/en/docs/3/working_with_attributes.html - Working with projections: http://www.qgistutorials.com/it/docs/3/working_with_projections.html **(French-only)** https://sigea.educagri.fr/tutos-sig/tutos-communs (TD2) https://ouvrir.passages.cnrs.fr/tutoqgis/04_00_georeferencement.php https://ouvrir.passages.cnrs.fr/tutoqgis/05_00_numerisation.php **BEGINNER 2** **QGIS Tutorials** - Performing table joins: http://www.qgistutorials.com/en/docs/3/performing_table_joins.html - Performing spatial joins: http://www.qgistutorials.com/en/docs/3/performing_spatial_joins.html - Performing spatial queries: http://www.qgistutorials.com/en/docs/3/performing_spatial_queries.html - OGC e-Learning: https://opengeospatial.github.io/e-learning/index.html - GeoPackage (gpkg): https://opengeospatial.github.io/e-learning/geopackage/text/basic-index.html - web services: https://opengeospatial.github.io/e-learning/visualization-standards/basic-index.html **(French-only)** -https://sigea.educagri.fr/tutos-sig/tutos-communs (TD3, TD4) -https://ouvrir.passages.cnrs.fr/tutoqgis/08_00_jointures.php
3. DATA ANALYSIS	**BEGINNER 1**

	QGIS Tutorials - Calculating line lengths and statistics http://www.qgistutorials.com/en/docs/3/calculating_line_lengths.html - Basic raster styling and analysis http://www.qgistutorials.com/en/docs/3/raster_styling_and_analysis.html - Working with terrain data http://www.qgistutorials.com/it/docs/3/working_with_terrain.html **(French-only)** -https://sigea.educagri.fr/tutos-sig/tutos-communs (TD6) -https://ouvrir.passages.cnrs.fr/tutoqgis/06_00_requetes.php -https://ouvrir.passages.cnrs.fr/tutoqgis/07_00_champs.php -https://ouvrir.passages.cnrs.fr/tutoqgis/09_00_analyse_spatiale.php **BEGINNER 2** **QGIS Tutorials** - Creating heat maps: http://www.qgistutorials.com/en/docs/3/creating_heatmaps.html - Handling invalid geometries: http://www.qgistutorials.com/it/docs/3/handling_invalid_geometries.html - Nearest neighbour analysis: http://www.qgistutorials.com/it/docs/3/nearest_neighbor_analysis.html - Sampling raster date using points or polygons: http://www.qgistutorials.com/en/docs/3/sampling_raster_data.html **(French-only)** -https://ouvrir.passages.cnrs.fr/tutoqgis/11_00_automatisation.php
4. DATA VISUALIZATION	**BEGINNER 1** **QGIS Tutorials** - Making a map: http://www.qgistutorials.com/en/docs/3/making_a_map.html - Basic vector styling: http://www.qgistutorials.com/en/docs/3/basic_vector_styling.html - Raster mosaicking and clipping:

	http://www.qgistutorials.com/en/docs/3/raster_mosaicing_and_clipping.html **(French-only)** -https://sigea.educagri.fr/tutos-sig/tutos-communs (TD5) -https://ouvrir.passages.cnrs.fr/tutoqgis/10_00_carto.php **BEGINNER 2** **(All languages)** **QGIS Tutorials** - Animating time series data: http://www.qgistutorials.com/it/docs/3/animating_time_series.html

4.3. Open Data and Repositories

Table 1b – Open Data Sources *(information on 5 October 2021)*

MODULES	OPEN DATA SOURCE
INTERNATIONAL	Europe: https://www.copernicus.eu/ https://www.copernicus.eu/en/access-data https://scihub.copernicus.eu/ (satellite imagery) https://data.europa.eu/it UN/International Organizations: https://www.wto.org/english/res_e/res_e.htm https://www.unwto.org/tourism-statistics-data https://open.unep.org/ https://whc.unesco.org/ https://srtm.csi.cgiar.org/ (DEM) Space Agencies (es. ESA, NASA): https://earth.esa.int/eogateway https://sedac.ciesin.columbia.edu/data/collections/browse https://asterweb.jpl.nasa.gov/gdem.asp (DEM) Other Organizations:

	https://earthexplorer.usgs.gov/ (satellite imagery) https://www.geofabrik.de/ https://www.naturalearthdata.com/ (topographic data, hillshade basemaps) https://www.openstreetmap.org/ (topographic data) https://www.diva-gis.org/Data (different data and links to other sites) https://srtm.csi.cgiar.org/ (DEM)
NATIONAL	**France:** https://www.ign.fr/institut/identity-card https://demo.openstreetmap.fr/map https://www.data.gouv.fr/fr/datasets/ **Italy:** http://www.pcn.minambiente.it/mattm/servizio-di-scaricamento-wfs/ https://www.istat.it/ https://www.beniculturali.it/dati-della-cultura **Spain:** https://www.ign.es/web/cbg-area-cartografia https://www.idee.es/web/guest/proyectos-idee **Slovenia:** https://www.e-prostor.gov.si/brezplacni-podatki/ (general topographic data, imagery, DEMs) https://gis.arso.gov.si/geoportal/catalog/main/home.page (environnemental data) http://gis.arso.gov.si/evode/profile.aspx?id=atlas_voda_Lidar@Arso (lidar data) https://egeologija.si/geonetwork/srv/slv/catalog.search#/home (geological data) http://www.evode.gov.si/ (hydrological data) https://rkg.gov.si/vstop/ (land use and agriculture data) https://prostor.zgs.gov.si/pregledovalnik/ (forest; data viewer only) http://gis.stat.si/ (statistical data) http://prostor3.gov.si/javni/login.jsp?jezik=sl (real estate, buildings) https://gisportal.gov.si/portal/apps/webappviewer/index.html?id=df5b0c8a300145fda417eda6b0c2b52b (Cultural Heritage)

	http://www.geoportal.gov.si/ (Slovenian INSPIRE portal) https://podatki.gov.si/ (general data hub of Slovenian freely available data) **Greece:** https://www.arxaiologikoktimatologio.gov.gr/ https://map.athenswesternhills.org/ https://map.mappingancientathens.org/ http://mapsportal.ypen.gr/ https://www.statistics.gr/ https://panorama.statistics.gr/ http://geodata.gov.gr/ **Serbia:** https://geosrbija.rs/en/about-us/ https://data.gov.rs/sr/ (publicly available data on various matter / mostly on health and pollution).

As can be seen in the Table 1b above, there are several open data sources at the international (global and regional) and national levels. For instance, at the regional level, there are several open datasets within the European initiatives and frameworks, here we draw attention to Copernicus which is the European Union's Earth Observation Programme which not only gives access to relevant data, but also to learning and funding opportunities. While at the global levels there are several open data sources on several thematic issues; these are datasets managed by the United Nations Systems and (e.g., FAO, UNESCO and UNEP) or other international organizations (e.g., Consortium of International Agricultural Research Centers [CGIAR]). It is to be noted that often these datasets are built through a global coordination of national data collection (hence via these organizations it is also possible to identify the national focal point, and thus request the national data). In addition, national and regional space agencies also provide open datasets, such as for example those by the National Aeronautics and Space Administration (NASA) and by the European Space Agency (ESA), as well as by network-organizations like the Committee on Earth Observation Satellites (CEOS) also provide access to data sources[34].

Other interesting sources of data are those organized and managed by non-profit organizations and other volunteer-community such as Geofabrik which is a source of free, community-maintained data like that produced by the OpenStreetMap project, and Natural Earth which is a public domain map dataset available at 1:10m, 1:50m, and 1:110 million scales.

[34] https://ceos.org/data-tools/

Table 1b, a list of national data set is provided for the country of the MINERVA Partners, here we recall some examples from Greece in order to draw attention to the variety as well as linkages to regional/international initiatives (e.g., Eurostat):

- The Hellenic Statistical System (ELSS)[35] that comprises agencies that have the responsibility or obligation to collect statistical data. ELSS agencies address the development, production and dissemination of the country's official statistics and forward them to Eurostat.
  The Panorama of Greek Census Data[36] that is structured to enable access, increase analysis potential and permit the easy and detailed mapping of data for the last three censuses (1991-2001-2011).
- Geoadata.gov.gr[37] provides open geospatial data and services for Greece, serving as a national open data catalogue, an INSPIRE-conformant Spatial Data Infrastructure, as well as a powerful foundation for enabling value added services from open data.
- Geospatial Portal of the Ministry of Environment and Energy[38] in which the user can display, observe and combine thematic layers on available basemaps. It contains 91 maps, 497 layers, 1 document.

However, as many applications of Geotechnologies to Cultural Heritage sites/goods entails working at the subnational and/or thematic level, it is important to note data sources at subnational level even if sometimes the data can only be viewed online (however data can be usually requested and obtained by contacting the relevant institutions managing the dataset, including local authorities). To exemplify data at the subnational and/or thematic levels, we recall here Slovenian examples of data viewers (municipality data viewers), as well as key Greek initiatives:

Slovenian examples:

- **PISO** (Spatial information system of municipalities)[39] (by Realis).
- **iObčina**[40] (by Kaliopa).
- .

These websites have a direct link to data viewers of spatial data for different Slovenian municipalities. Data cannot be directly downloaded, but the viewers are a great information source for local data (what is available and might be asked for the local or national institutions).

Serbian examples:

- **The Portal of Open Data**[41] provides a list as well as information regarding institutions (e.g. libraries, archives, cinemas) and lists of Cultural Heritage websites in Serbia.
- **The National GIS Portal**[42] offers basic maps and a link to cadastre entries for

[35] https://www.statistics.gr/
[36] https://panorama.statistics.gr/
[37] http://geodata.gov.gr/
[38] http://mapsportal.ypen.gr/
[39] https://www.geoprostor.net/PisoPortal/vstopi.aspx
[40] https://gis.iobcina.si/gisapp/Vstopna.aspx
[41] https://data.gov.rs/sr/organizations/ministarstvo-kulture-i-informisanja/
[42] https://a3.geosrbija.rs/kulturna_dobra

immovable cultural heritage properties.

- **The Information System of Immovable Cultural Property (IS NKD)**.https://nasledje.gov.rs/index.cfm?jezik=Engleski is an information system designed to store digital and digitized data of immovable heritage (immovable cultural properties) of the Republic of Serbia.
- **The UNESCO list of Properties inscribed on the World Heritage List**[43] with five properties listed and a tentative list of cultural properties which Serbia intends to consider for nomination.
- **The Cultural Heritage Browser of Serbia**[44] has been initiated by the Ministry of Culture and Media with the strategic support of Microsoft Serbia. Through a comprehensive search, visitors of the portal can obtain essential information about the digitized cultural heritage and have access to the interactive map of the cultural institutions on the territory of the Republic of Serbia.
- **The Museum Information System of Serbia – MISS**[45] offers a location for the safeguarding of movable heritage based on the contemporary international museological and technological standards.

Greek examples:

- **The Archaeological Cadastre - National Archive of Monuments**[46] pertains the systematic recording and documentation (archaeological, administrative and geospatial) of monuments, archaeological sites and historical sites and their protection zones, and includes descriptive and geospatial data for more than 14,000 Monuments, approximately 3.400 Archaeological Sites and Historic Sites and 844 Protected Areas.
- **ATHENS WESTERN HILLS**[47] is a set of geospatial data that was conceived and implemented by one of the MINERVA Partners, the non-profit organization Dipylon. The old maps of Athens preserve unique archaeological and historical information about the Hills of the Muses, the Pnyx, and the Nymphs. This information is depicted on a single cartographic background, further enhanced with visual resources. For more information visit the website.
- **MAPPING ANCIENT ATHENS!**[48] is a web-mapping platform with all published archaeological remains revealed in rescue excavations in Athens from the nineteenth century onwards. It was conceived and implemented by the non-profit society Dipylon. For more information, visit the site mappingancientathens.org. It contains 16 decades of rescue excavations, 6.7km2 research area, 1473 excavated sites, 240 archaeologists, 1400 bibliographical references, 670 plans.
- **National Inventory of Intangible Cultural Heritag**e[49] is the filing of the elements of the Intangible Cultural Heritage of Greece in the form of an inventory.

[43] https://whc.unesco.org/en/statesparties/rs
[44] https://culture.rs/
[45] http://www.narodnimuzej.rs/expert-s-corner/museum-information-system-of-serbia/?lang=en
[46] https://www.arxaiologikoktimatologio.gov.gr/
[47] https://map.athenswesternhills.org/
[48] https://map.mappingancientathens.org/
[49] http://ayla.culture.gr/

In addition, some universities offer "one-stop-shop" webpages on selected data repositories, as done by Carlton College in Minnesota (USA), which includes also State-level Geospatial clearinghouses[50] (the Website also includes other didactic resources, often specific to the courses taught at Carleton College). While there are also specialized repositories on different aspects of cultural goods and heritage in specific geographic regions (e.g., Archaology Data Service [ADS][51]; Roman Open Data[52]; IllyrAtlas[53]; and Adriaticum Mare[54]).

4.4. Tutorials

Many web-based tutorials can be found on different themes related to overall GIS literacy, data acquisition, data management, data analysis and data visualization, and customized to different levels (e.g., Beginner 1, Beginner 2). They are mostly available in English, but also in other languages. Examples from the ones reported in the Table 1 above, there are the QGIS Tutorials[55] which address several issues on each of the modules and by different levels[56]. They are available in English, but also in different languages (e.g., Italian[57], Spanish and Greek[58]). Other tutorials are designed by other research organizations and/or councils, like the ones in French which are designed by the French National Research Council (CNRS).

Other organizations, including the above-mentioned United Nations and other international organizations, also provide both general/introductory tutorials. For instance, the UN IW:LEARN Spatial Lab (of the IW:LEARN is the Global Environment Facility's [GEF] International Waters Learning Exchange and Resource Network[59]) includes some interesting tutorials (and supporting documents) on e.g., "how to explore map layers" and "how to publish a map"[60]. The above-mentioned European Space Agency also includes a collection of ESA and non-ESA tutorials on many different thematic issues (e.g., Canada Centre for Mapping and Earth Observation's Tutorial on remote sensing[61] also with additional resources for both teachers and students[62]).

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[50] https://www.carleton.edu/spatial-analysis/data-resources/

[51] Archaeology Data Service: https://archaeologydataservice.ac.uk/about/ourWork.xhtml

[52] https://romanopendata.eu/#!/

[53] http://illyratlas.huma-num.fr/fr/

[54] Adriatlas - BdD Sites (http://adriaticummare.org/en/)

[55] https://www.qgistutorials.com/en/

[56] Via the tutorial page: there is also a link to the Spatial Thoughts which is a global academy for modern geospatial technologies. "Spatial Thoughts was founded with a mission to enable everyone to learn, use and master modern geospatial technologies. Our goal is to provide high-quality and affordable learning resources in a wide range of formats. We are strong believers in open-source, open-data and open-learning materials". Source: https://spatialthoughts.com/

[57] https://www.nrcan.gc.ca/maps-tools-and-publications/satellite-imagery-and-air-photos/tutorial-fundamentals-remote-sensing/notes-for-teachers-and-students/9349

[58] https://www.qgistutorials.com/en/docs/introduction.html

[59] https://iwlearn.net/abt_iwlearn

[60] http://geonode.iwlearn.org/toolkit/tutorial/

[61] https://www.nrcan.gc.ca/maps-tools-and-publications/satellite-imagery-and-air-photos/tutorial-fundamentals-remote-sensing/9309

[62] https://www.nrcan.gc.ca/maps-tools-and-publications/satellite-imagery-and-air-photos/tutorial-fundamentals-remote-sensing/notes-for-teachers-and-students/9349

While there are many tutorials on general issues related to the application of GIS/Geotechnologies, there are not many web-based open tutorials concerning the specific application of Geotechnologies to Cultural Heritage. Among the exceptions, there are DAI's online tutorials on Cultural Heritage[63] which offers "online courses and resources for Cultural Heritage professionals. All courses are free of charge and available in English and Arabic".

As can be seen in the different websites where we can access online tutorials, there are also other resources which can support learners also including training manuals and other relevant publications. There are resources provided by open-source GIS software (e.g., QGIS) and others are embedded projects and initiatives by EU and UN, by space agencies and space-related institutions (e.g., ESA), and by national initiatives as well as by universities/research centres.

For instance, in addition to tutorials, as also highlighted in Table 1, there are many web-based open resources concerning QGIS, including on its website: for introductory material there are interesting resources titled "A Gentle Introduction to GIS"[64] ; there is also an official Training Manual[65]. There are documents[66] for users (e.g., training material for users – also available in different languages[67] , for developers and for writers.

At the European level, we recall EUROSTAT Handbook of Spatial Analysis[68] aiming at supporting the integration of statistics and geospatial data. The EUROSTAT Website also provide information on "culture statistics" including information related to Cultural Heritage sites and goods[69].

At the national level, for instance, in Slovenia there are also interesting initiatives such as the book series GIS in Slovenia (svn. *GIS v Sloveniji*) that is freely available and publishes different GIS topics every two years. The books present different geoinformation tools in practice and research (including Cultural Heritage)[70,71]

While the MINERVA project fosters the utilization of open-source tools related to Geotechnologies for Cultural Heritage in order to foster inclusion of different countries, organizations, and individuals. It is important to highlight that private-sector/commercial companies also offer different didactic resources, including tutorials and training material.

63 https://tutorials.idai.world/
64 https://docs.qgis.org/3.16/en/docs/gentle_gis_introduction/index.html
65 http://docs.qgis.org/latest/en/docs/training_manual/index.html
66 https://www.qgis.org/en/docs/index.html
67 https://www.qgis.org/en/site/forusers/trainingmaterial/index.html
68 https://ec.europa.eu/eurostat/en/web/products-manuals-and-guidelines/-/insee-estat-spatial-ana
69 https://ec.europa.eu/eurostat/en/web/products-statistical-books/-/ks-01-19-712
70 https://omp.zrc-sazu.si/zalozba/catalog/series/A06
71 https://zalozba.zrc-sazu.si/p/A06

For instance, ESRI provides access, via its Website[72] and YouTube page[73], to many resources on the learning of ESRI's software ArcGIS[74], including free online "step-by-step" lessons[75] and tutorials[76], as well as opportunities for training with certification[77]. While there is no specific focus on didactic tools related to Cultural Heritage, ESRI also run some non-profit activities related to education and capacity-building, also in collaboration with international and UN organizations (e.g., see New UNESCO World Heritage Sites Story Map (2018) which is developed and and described in details on the ESRI/ArcGIS Blog[78]) and universities (see e.g., activities with LabGeo/UNIFI given that LabGEO is recognized "Advanced GIS Joint Laboratory: Joint Research Laboratory in partnership with ESRI Italia"[79]). Another strong GIS community is SCGIS (Society for conservation GIS), which is primarily focused on natural heritage and environment, but can offer useful online webinars, knowledge exchange via email list, and regular events (see https://www.scgis.org/) also for other branches.

4.5. Forums and Knowledge-Exchange Platforms

Online forums on GIS and Geotechnologies can also provide interesting resources for learners; Table 2 below provides some key examples of such forums and knowledge exchange platforms, which allow for dialogue to other experts in the field. There seems to be no specific forum on Geotechnologies for Cultural Heritage; however, it is important to note that Academia.edu is a venue where many ideas have been exchanged in many small clusters on topics related to Cultural Heritage[80] and that ResearchGate includes a Q&A section which may be useful in addressing queries related to Geotechnologies and Cultural Heritage.

Table 2 – Examples of GIS-focused online forums and knowledge exchange platform

[72] https://www.esri.com/en-us/home
[73] https://www.youtube.com/channel/UC_yE3TatdZKAXvt_TzGJ6mw
[74] https://learn-arcgis-learngis.hub.arcgis.com/
[75] See e.g., https://learn.arcgis.com/en/projects/share-the-story-of-an-expedition/ and for all lessons see Lesson Gallery | Learn ArcGIS (https://learn.arcgis.com/en/gallery/ - free trial for the utilization of the software is also available in the lessons: for more information and eligibility see Learn ArcGIS: Education Trial (https://www.esri.com/en-us/lg/training-and-services/learn-arcgis-education-trial)
[76] See "ArcGIS StoryMaps: Getting Started with the New Story Builder": https://www.youtube.com/watch?v=t_oFnIIJA-A
[77] See https://www.esri.com/training/
[78] Making the "New UNESCO World Heritage Sites" Story Map (esri.com) https://www.esri.com/arcgis-blog/products/story-maps/mapping/making-the-new-unesco-world-heritage-sites-story-map/ (Author: Cooper Thomas / date: 13 Feb 2018)
[79] AGJL – LabGeo: http://www.geografia-applicata.it/en/
[80] See https://www.academia.edu/Documents/in/Cultural_Heritage

LANGUAGE	NAME AND WEBSITE
ENGLISH	**Geographic Information Systems Stack Exchange** https://gis.stackexchange.com/
ITALIAN	**Openoikos Forum and Blog** http://forum.openoikos.com/Forum-GIS https://www.openoikos.com/
FRENCH	**GeoRezo** https://georezo.net/

4.6. Online Courses, Training Workshops and MOOCs

There are several training workshops, online courses and MOOCs on the general themes of GIS/Geotechnologies. Among them, there are capacity-building workshops organized by Committee on Space Research (COSPAR)[81] but also other training courses[82], such as the Space School Education Initiative, which is focused on the usage of remote sensing in GIS[83].

There are also fully-fledged MOOCs: here it is important to recall "The Copernicus MOOC" which is an "*online training aimed at enabling anyone to understand how to use Earth Observation data in order to address societal challenges and generate business opportunities. Participants will learn how Copernicus data can be used for evidence-based public policy, as well as to develop new products and services, open up new markets, improve quality of life, and make the most of limited resources in a sustainable way*." Some MOOCs on Cultural Heritage may also include some components on GIS/Geotechnologies[84], but no specific MOOC on the interface between Cultural Heritage and Geotechnologies appears to be available on the Internet.

While there are several general courses on GIS/Geotechnologies, there are also some online courses on Geotechnologies applied to Cultural Heritage, also within the context of capacity-building activities conducted by the UN entities. For instance, given the increasing attention to geo/space technologies applied to natural and Cultural Heritage, in 2009 UNESCO has approved The International Centre on Space Technologies for Natural and Cultural Heritage (HIST)[85] as Category-II Centre under the auspices of UNESCO. The Centre hosted by China,

[81] Committee on Space Research (COSPAR) COSPAR Capacity Building Workshops: https://cosparhq.cnes.fr/events/cospar-capacity-building-workshops/
[82] For some examples, Professional Certifications – Spatial Analysis – Carleton College: https://www.carleton.edu/spatial-analysis/certifications/
[83] http://eng.spaceschoolbg.eu
[84] https://www.mooc-list.com/
[85] http://english.radi.cas.cn/Cooperation/ISTP/HIST/ and http://www.unesco-hist.org/en-us/

upon approval by the State Council of China, was opened in 2011 at the Institute of Remote Sensing and Digital Earth (RADI) of the Chinese Academy of Sciences (CAS). The objective of the HIST Centre is to provide technical services to UNESCO and its Member States on the application of geo/space technologies for UNESCO designated sites (e.g., World Heritage Sites, UNESCO Biosphere Reserves and GeoParks), as it is also seen in the "Atlas of Remote Sensing for World Heritage: China" published by the HIST Centre. In this context, the HIST Centre conducts courses and capacity-building activities, such as the recent hybrid Seminar on Sustainable Development of UNESCO Designated Sites (Beijing & online, 16 March 2021) which was widely attended[86]. A section on the HIST Centre's website is dedicated to "Exchange"[87] and includes links to material (e.g., presentations, videos, background reading material) of training programmes held in the past, such as the 3rd International Training Workshop on Space Technologies for Management and Conservation of World Heritage Sites in 2016. On the same webpage there are links to the HIST Centres' Conferences "Huangshan Dialogues".

In this context, it is important to highlight collaboration between UNESCO and space agencies, including ESA, as exemplified by past joint initiatives as well as the recent UNESCO and ESA "Space for Cultural Heritage Workshop" (24 February 2021) which addressed how the space sector combined with cutting edge technologies can support the protection of the world's Cultural Heritage. The videos of the workshops that can also be considered as additional didactic resources are available in open access on the ESA website[88].

Among UN organizations providing training opportunities, it is important to highlight the United Nations Institute for Training and Research (UNITAR)[89] that provides training for individuals, organizations and institutions on many different topics, including GIS, also within the context of sustainable development. The focus on GIS is also related to the UNITAR's Operational Satellite Application Programme (UNOSAT) that supports the international community through a series of services also related to capacity-building. Many resources ("Map Library") are available via the dedicated UNITAR webpages[90]. Here we also recall the UNITAR/UNOSAT courses such as the Geospatial Information Technology (GIT) in Fragile Contexts (available in English, French and Arabic); this e-learning course is free self-paced (over 2-day) and has been created as part of the "Earth Observation for Sustainable Development: Fragility, Conflict and Security" project (funded by the European Space Agency)[91].

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[86] Information on seminar at HIST Holds Seminar on Sustainable Development of UNESCO Designated Sites (unesco-hist.org): http://www.unesco-hist.org/index.php?r=en/article/info&id=1593

[87] See Exchange (please note that most recent workshops are not posted – yet – on the web) – see training programmes from 2017:
http://www.unesco-hist.org/index.php?r=en/article/index&cid=186&year=2017#content

[88] Space for Cultural Heritage Workshop - Downstream Gateway (esa.int):
https://down2earth.esa.int/2021/03/space-for-cultural-heritage-workshop/

[89] https://www.unitar.org/

[90] See https://www.unitar.org/sustainable-development-goals/united-nations-satellite-centre-UNOSAT

[91] https://www.unitar.org/event/full-catalog/geospatial-information-technology-git-fragile-contexts.

Furthermore, UNITAR/UNOSAT collaborates with ESRI on the utilization of ArcGIS for sustainable development, as exemplified by “The GIS for a sustainable world” Conference (formerly known as the GIS for the United Nations and International Community Conference), is now co-hosted by UNITAR’s Operational Satellite Application Programme (UNOSAT), and ESRI. The conference addresses how ESRI’s ArcGIS platform empowers the international community to achieve the global goals. The 2021 Proceedings includes open access proceedings (including videos and presentations which can be useful as didactic resources[92]). ArcGIS has also been used within activities of UNITAR/UNOSAT and the United Nations Development Programme (UNDP) and UNITAR-UNOSAT with the aim at developing a web-mapping interface for the monitoring and evaluation of 15 UNDP projects focused on infrastructure rehabilitation in Sub-Saharan Africa: the ‘*Geolocalized Maps and Satellite Imagery Analysis’* interface provided story maps for 156 sites, in seven African countries (i.e., Guinea, Liberia, Libya, Mali, Niger, Nigeria, and Sudan[93]).

UNITAR has also collaborated on initiatives using other softwares, such as in the case of the development of UNITAR Tutorial Workbooks which include exercises based on the TerrSet software (even if the workbooks do not include the commercial software)[94,95]. They enable users to explore and understand the use of GIS and image processing techniques, thanks the availability of a review paper and a set of exercise on different topics: “Applications in Forestry”; “Applications in Coastal Zone Research and Management”; “GIS and Mountain Environments”; and “Applications in Hazard Assessment and Management”.

Furthermore, there are training programmes and workshops also organized by national organizations including the ones organized by the MINERVA Partners (e.g., Dyplon’s workshops[96] and UNIFI/LabGEO’s training activities[97]) and by other organizations. Here for instance, we recall the online courses developed by the Greek elearningekpa[98] as well as those by the German Archaeological Institute (DAI) such as the one on “Recording Cultural Heritage for Post-Conflict Recovery using GIS” and “Cultural Heritage Documentation with Smartphone cameras” held early in 2021 (the focus groups of the online courses are early-career experts from the MENA region specialized in archeology, architecture, history and other related disciplines)[99,100].

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[92] The Conference’s proceedings (videos and presentations) are available at https://proceedings.esri.com/library/userconf/gissw21/index.html

[93] https://unitar.org/about/news-stories/news/using-earth-observation-and-gis-monitoring-and-evaluation-development-projects

[94] https://clarklabs.org/terrset/

[95] https://clarklabs.org/download/unitar-workbooks/

[96] https://dipylon.org/gr/drastiriotites-workshops/

[97] http://www.geografia-applicata.it/en/didattica/

[98] https://elearningekpa.gr/courses/gewgrafika-susthmata-plhroforiwn-gis-gia-arxaiologous

[99] https://www.archernet.org/en/2021/07/07/new-online-course-recording-cultural-heritage-for-post-conflict-recovery-using-gis/

[100] https://www.archernet.org/en/2021/03/13/online-courses-2021-cultural-heritage-documentation-with-smart-phone-cameras/

Furthermore, within the context of DAI activities and collaborations, the ONLAAH-Online Learning on African Archaeology and Heritage project[101,102] is working towards offering the first MOOC on African Archaeology and Heritage, accessible worldwide. MOOCs with a focus on African archaeology and heritage will be the first of a series of e-learning courses produced by the DAI. It will be a Coursera MOOC. Also, the websites provide links also to a series of GIS-related resources and courses on 3D modelling and photogrammetry as well as on specific aspects of Cultural Heritage (e.g., H2020 NETCHER Project, Ca' Foscari University of Venice (Italy) and the Center for Cultural Heritage Technology – Italian Institute of Technology (Italy) 4-day Online Training about "Remote Sensing to fight illicit excavation"[103])

4.7. Cases-studies

The web also offers several case studies; for instance, on the QGIS website there are also a series of case studies (e.g., "THE HISTORICAL MAPS AND THE QGIS PROJECT the City Wall characterizes the city of Cesena"[104]; and "The Burgundy Historical Landscapes Working Group"[105]). Each of the MINERVA countries can also offer a series of case studies, such as in the case of Greece:

- https://athenswesternhills.org/
- https://dipylon.org/gr/2018/06/12/chartographontas-tis-archaiotites-athina/
- https://mappingancientathens.org/en/methodology/
- https://scholarworks.iu.edu/journals/index.php/sdh/article/view/24440

In addition, case studies may be embedded within theses and published papers (e.g., UPENN Thesis: GIS as a Tool to Assess Heritage Risk: A Case Study in Frijoles Canyon, Bandelier National Monument (upenn.edu)[106], Scientific Article: A digital information system for cultural landscapes: the case of Slender West Lake scenic area in Yangzhou, China, springeropen.com[107]), and most likely within grey literature reports (e.g., from UNESCO and ICCROM).

The MINERVA Partners have designed *ad hoc* case studies to further highlight the utilization of Geotechnologies to different aspects of cultural goods and heritage and to serve as a key didactic resource for the upcoming MINERVA MOOC. The list of the case-studies (one for each of the MINERVA countries) is available in Chapter 6.

101 http://www.onlaah.com/
102 https://www.dainst.blog/elearning-africa/?page_id=96
103 https://tutorials.idai.world/
104 https://www.qgis.org/en/site/about/case_studies/italy_cesena.html
105 https://www.qgis.org/en/site/about/case_studies/france_burgundy_region.html
106 https://repository.upenn.edu/cgi/viewcontent.cgi?article=1270&context=hp_theses
107 https://built-heritage.springeropen.com/track/pdf/10.1186/s43238-020-00004-8.pdf

4.8. Concluding section: re-designing didactic material and designing new tutorials (and case studies)

The MINERVA Project has identified many didactic resources – including open resources and at different levels – on GIS/Geotechnologies, mostly in English but also in different languages such as French, Spanish, Italian… However, this study has noted that while there is an increasing attention to the application of Geotechnologies to different aspects to cultural goods and heritage, and while there are very specific didactic resources on the Geotechnologies for Cultural Heritage, there is a need for establishing a coherent didactic pathway addressing Geotechnologies for Cultural Heritage for students, teachers and practitioners, at different levels.

The MINERVA Project aims at re-designing some of the existing resources such as tutorials, case-studies and forums towards establishing a pathway within multiple-modules and multiple-level MOOCs. This could also be achieved by building on the increasing use of online learning and availability of online resources and tools. For instance, there could be videos/resources from training workshops which can be used as the basis towards re-designing tutorials and case studies. Existing forums and knowledge-exchange platforms can be induced towards creating specific Q&A sections, conversations and/or blogs on the interface between Geotechnologies and Cultural Heritage in an interdisciplinary and transdisciplinary dialogue to discuss problems/challenges and identify best practices.

Furthermore, the MINERVA Project will also pay specific attention not just to the provision of the online resources - whether existing and/or redesigned – but also to the prioritization so as to highlight the most important ones in the Tool Kit by providing metadata on the resources and advice on their utilization.

Last but not the least, the identification of the existing resources and related re-designing and fine-tuning for the development of the MINERVA MOOC will also allow for building new transdisciplinary communities of practice at the interface between Geotechnologies and Cultural Heritage.

5. MINERVA CASE STUDIES

5.1. Introduction

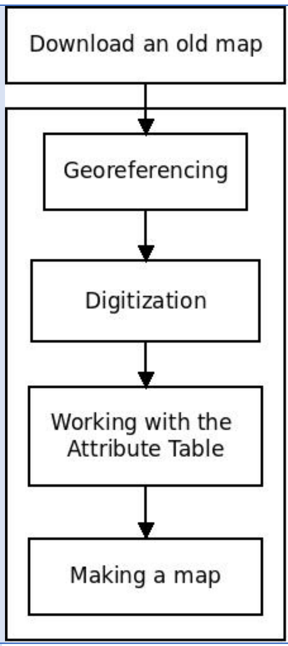
Each MINERVA partner proposed one case study about a local issue related to Cultural Heritages. Each case is structured as follows:

- An introduction that presents context
- Aims of the case
- Skills involved and level of competences
- A comprehensive workflow
- Data needed

Seven online tutorials detail all steps of workflows with includes screenshots

5.2. French Case Study: Coal Basin in Saint-Etienne

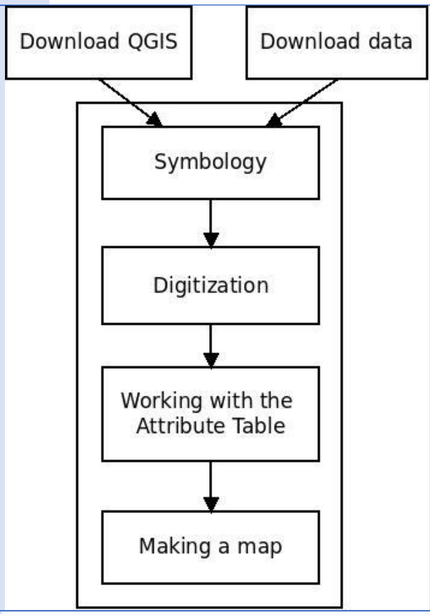
INTRODUCTION	The Loire coal-mining basin is an area of France that has been shaped by seven centuries of coal extraction from the 13th century to the 20th century and represents a significant period in the history of European industrialisation.
AIMS	The Bibliothèque nationale de France (National Library of France) owns an 1846 old map showing the location of different coal mining concessions in the region of Saint-Etienne. Several pieces of information are stored in the legend, including area. But some of them seem incorrect. We want to confirm that. We will create a shape file and then calculate some basic statistics.
LEVEL OF COMPETENCE	Basic to advance.
SKILLS TO BE LEARNED	• Archive data acquisition • Georeference a map • CRS management • Digitize data • Create new shapefile and Snapping Options • Create and modifying features • Select features • Attribute Table • Add/delete fields • Field calculator • Add geometry attributes • Basic statistics for fields • Create map • Using a Web Map Service

WORKFLOW	
DATA	An historical map[108]: Carte du bassin houiller de Saint-Etienne et de Rive-de-Gier (1846) Reference map: OSM Web Map Service, IGN Web Map Services

5.3. Spanish Case Study: Cultural trail

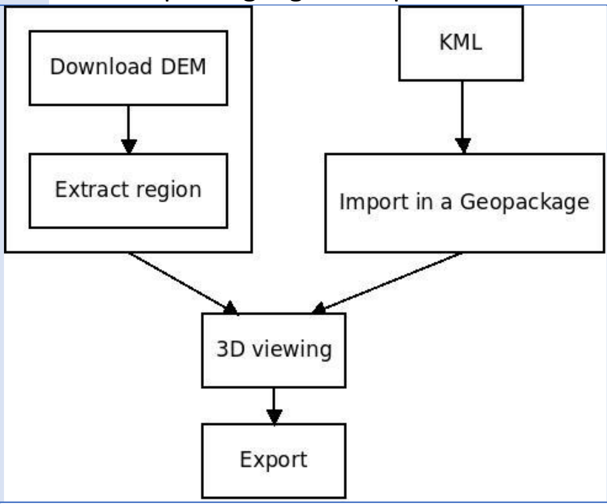
INTRODUCTION	
AIMS	The main objective of the activity is the creation of a route in areas of cultural interest, both human and natural, using GIS as the main tool. This general objective can be broken down into several smaller objectives. • To understand the importance of GIS in relation to heritage. • To understand and apply the concept of Geolocation and Geocoding. - To plan and manage geospatial information in a Geographic Information System. • To value cultural and natural heritage through the design of a route.
LEVEL OF COMPETENCE	Basic to advance
SKILLS TO BE LEARNED	• Download Data from Spanish Government • Basic use of GIS software • Import, export and management of georeferenced data. • Digitalization • Installation and use of [plugins]

[108] https://gallica.bnf.fr/ark:/12148/btv1b53085116w.r=saint-etienne?rk=257512;0&lang=EN

	• Management and knowledge of spatial reference systems • Production of cartographic outputs • Use of the field calculator
WORKFLOW	
DATA	Data from Spanish Government

5.4. Serbian Case Study: Mapping Natural and Human Made Borders

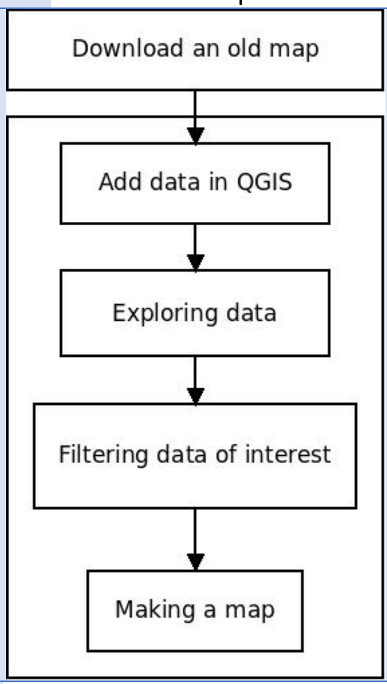
INTRODUCTION	The small, mountain historical and geographical region of Visok consists of a few dozens of small pastoral villages along the Visočica River, which flows on the Stara Planina Mountain, and north to the Nišava River. The local picks and ranges separate the highland region of Visok from the neighboring small-size geographical units, making it distinct and seclusive. The area is now divided between the Republic of Serbia (biggest part) and the Republic of Bulgaria based on the borderlines set in 1878 and 1920 with no regard for the local ethnographic or ethnic situation at the time of partition. The region of Visok may be observed and researched as a historical and geographical/environmental phenomenon.
AIMS	Creation of a digital map which will contain three layers: • All villages belonging to the Visok region • Villages of the Znepolje region that are bordering the Visok • Villages of the Vidin sandjak that are bordering the Visok Methodological and Didactic aspects: • Creation of a research question as well as digital products that may help to resolve them, and test the suggested model. In this case, the position of

	settlements should indicate the geographical limits of the Visok region and help us discuss the natural and human-made factors which crucially contributed to this situation
LEVEL OF COMPETENCE	Basic to advance
SKILLS TO BE LEARNED	• Extracting geodata from written historical sources • Import a KML file • Convert a KLM into a GPKG • Manage GPKG • Merge vector layers • Extracting metadata (longitude, latitude, elevation) • Crop a raster • Modelling data • Creation of digital maps with different layers • Creation of a 3D terrain model • Interpreting digital maps
WORKFLOW	
DATA	Нахија Висок - МАПА.kml (Provided by the Serbian team) EU-DEM v1.1[109]

5.5. Slovene Case Study: An evaluation of Cultural Heritage sites according to the map of Seismic Hazard

INTRODUCTION	Earthquakes affect our everyday lives and when they occur, they often cause casualties and damage on infrastructure, including Cultural Heritage sites. There have been many earthquakes in the past. One of the most known earthquakes took place in 1895 in Slovenia, when an earthquake damaged the capital city of Ljubljana. The Ljubljana basin is one of the most endangered areas according to seismic activity. Another endangered area is NW Slovenia. In the Breginj area (W Slovenia), there were many earthquakes in the past, including

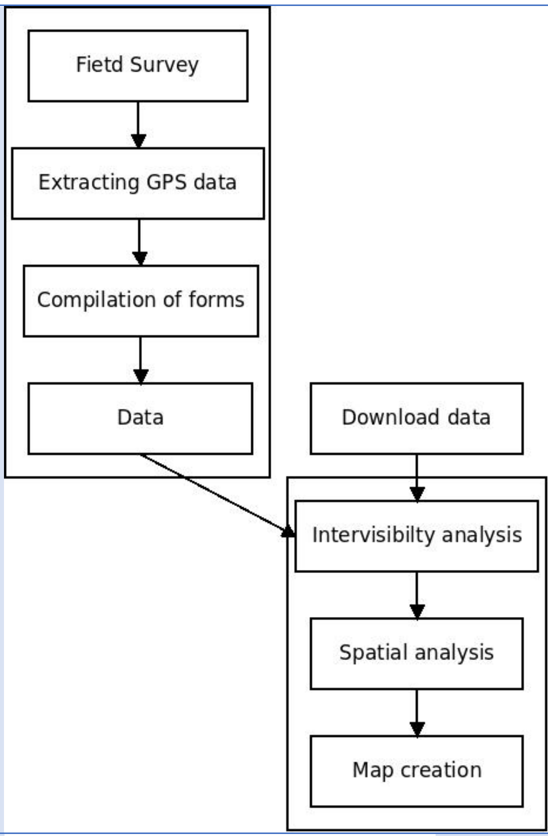
[109] https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1

	the one in 1976 (known as Friuli earthquake). Also in other areas (e.g. L'Aquila, Italy; Petrinja, Croatia) earthquakes caused a lot of damage.
AIMS	The aim of the case study is to collect data on Cultural Heritage sites in Slovenia, select and extract sites classified as buildings, and intersect them with a map of Seismic Hazard (Design ground acceleration) in order to assess the most endangered locations of buildings listed in the Register of Slovene Cultural Heritage.
LEVEL OF COMPETENCE	Basic to advanced.
SKILLS TO BE LEARNED	● Manage QGIS project (open layers, rename, change symbology…) ● Filter data by attributes ● Spatial join ● Select data by expression ● Select data by location ● Create map
WORKFLOW	
DATA	The data is freely available at the website of ARSO (Slovenian Environment Agency) and MK (Ministry of Culture). The data used in this tutorial and results presented are only intended for simulation of GIS tool usage. There is absolutely no guarantee that data are valid and have high accuracy.

5.6. Italian Case Study: Coastal towers and fortifications in Tuscany

INTRODUCTION	The coastal towers and forts of the littoral are part of the historical and architectural heritage of Tuscany. In the course of time, some of them have been completely destroyed and

	the traces can be found only through documents, archives and historical maps. For others, only the ruins remain or, sometimes, as in the case of the Matilde Tower of Viareggio, restoration and renovation works have saved them.
AIMS	The following case study presents a methodology for creating a digital database using previous studies, archival documents and completed by field surveys. Each tower had to be visible from two towers. The main aim is to proceed to an intervisibility analysis that will allow us to hypothesize potential location areas of the towers destroyed in the present time.
LEVEL OF COMPETENCE	Basic to advanced.
SKILLS TO BE LEARNED	• Methodology to realize field surveys for cultural heritage (using GPS, relevant information). • Create a Geodatabase with field surveys data. • Transform GPS data into a shapefile. • Merge raster data • Use DEM hillshading • Manage vector and raster layers symbology • Add labels to a layer • Install a QGIS plugins • Add a basemap using QuickMapServices (QMS) plugin • Proceed to an intervisibility analysis • Polygonize raster data • Select by an expression • Measure distance on a map • Use some geoprocessing tools (buffer, clip) • Repair geometry

WORKFLOW	
DATA	Tinitaly 10-m-resolution DEM[110] Preprocessed data from boundaries of italian administrative units[111] : ● Coastline for the DEM extent ● Terrestrial and sea surfaces for the DEM extent Torri_costiere_32632.gpkg (provide by the italian team)

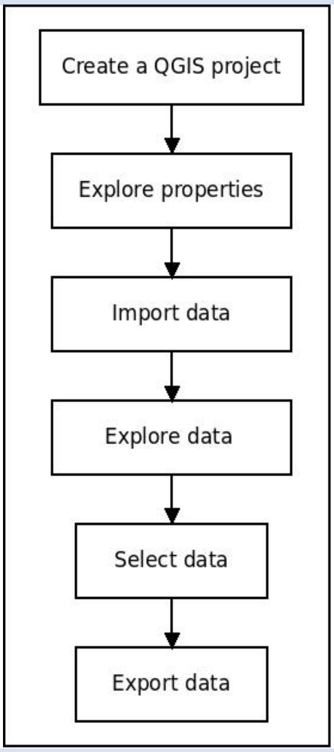
5.7. Greek Case Study: Athens western hills - Explore, Manage and Export Geospatial Data

INTRODUCTION	The rocky heights of the Hills have always been a place of inspiration for the passers-by. As the French archaeologist Émile Burnouf, one of the early admirers of the Hills, narrates in the mid-19th century: *There, upon the highest areas of the hills the view reaches all the way to the sea and Piraeus, and extends further, to the surrounding mountaintops; the air roves about unhindered*. The case study ATHENS WESTERN HILLS is an archaeological and historical perambulation of the

[110] Tarquini S., Isola I., Favalli M., Battistini A. (2007) TINITALY, a digital elevation model of Italy with a 10 meters cell size (Version 1.0) [Data set]. Istituto Nazionale di Geofisica e Vulcanologia (INGV). https://doi.org/10.13127/TINITALY/1.0.

[111] https://www.istat.it/it/archivio/222527

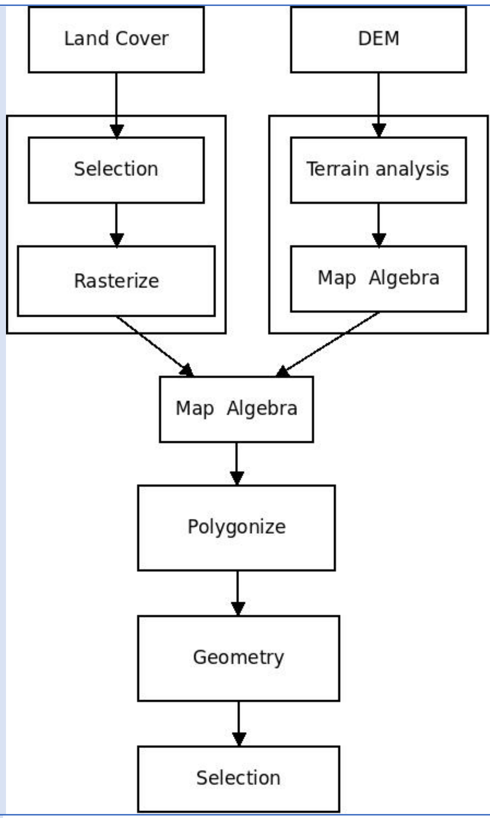
	Hills through valuable testimonies depicted on early maps of Athens. The Western Hills have been incorporated from the outset into the urban environment of Athens and have since been the focus of a variety of interventions, such as stone extraction, landscaping and afforestation, individual or collective appropriation, and visual arts. Apart from the known antiquities, such as the Pnyx and the Philopappos monument, there is a vast archaeological reserve and noteworthy, as well as inexhaustible, documentation material with regard to the long life of this place. The recording of cartographic and photographic evidence of the past is but one step towards highlighting and transmitting this material that sheds light on some of the most important aspects of history that may be known or occasionally unknown. The map by Ernst Curtius and Johann August Kaupert (1878), which was the springboard for the present case study, is valuable because of its diligent recording and annotation of the archaeological remains. The use of GIS has enabled us to set up a meticulous "body" of data pertaining to various periods of time
AIMS	The aim of the case study is to explore data on Cultural Heritage sites in the western hills of Athens, Greece in the context of QGIS, and export selected features based on cultural-related characteristics and/or spatial relations.
LEVEL OF COMPETENCE	Basic
SKILLS TO BE LEARNED	• Exploring QGIS project: Create QGIS project, explore QGIS project's properties, save QGIS project • Discovering GIS file formats: Vector & Raster • Managing datasets: import datasets in QGIS project as layers, explore layers' properties (Layer Name, Display Name, CRS, encoding), attribute table • Querying: selection of CH objects based on their attributes and/or their location • Export selected objects as new shapefile

WORKFLOW	

DATA	Dipylon provides the data for the Greek case study. The data used in this tutorial and results presented are only intended for simulation of GIS tool usage. There is absolutely no guarantee that data are valid and have high accuracy. Specifically, the following data are provided:
	• Vector
	    ○ Ancient_Remains.shp: Line dataset depicting the ancient remains in the west hills of Athens. The attributes of this dataset include a field (txt_Class) indicating the type of the remain in English and a field (txt_Cl_GR) indicating the type of the remain in Greek
	    ○ Ancient_Remains_Cisterns_points.shp: Point dataset depicting the ancient Cisterns in the west hills of Athens. The attributes of this dataset include a field (txt_Class) indicating the type in English and a field (txt_Cl_GR) indicating the type in Greek.
	    ○ walls.shp: A polygon dataset depicting the wall
	• Raster
	    ○ Kaupert_georef.tif: A georeferenced historic map of Athens, by Ernst Curtius and Johann August Kaupert (1878)
	    ○ VLSO_low.tif: A georeferenced aerial photo of Athens

5.8. 7th bonus Case Study: Raiders of the Lost Temple

INTRODUCTION	This is an imaginary storyline: no ancient texts mention a Roman temple in the Monts du Forez, France. Keep in mind that this is just a learning activity. By studying newly discovered ancient texts, Professor Diane Janonsi thinks she has identified mentions of an enigmatic small Roman temple. Apparently, this temple should be in the Monts du Forez a few kilometers from Forum Segusiavorum, a Gallo-Roman city (known as Feurs now). She understands that the temple was located on a low slope area (<4°), relatively large (more than 15ha), facing east, at an altitude of more than 1200m. Moreover, its current location could certainly be overlayed by forest, which could explain why no one has noted any evidence on the ground surface. Professeur Janonsi is a brilliant archeologist but... she is really old school. In addition, she has absolutely no skills in GIS. She recalls that she attended a conference on spatial analysis by a cool geographer… but she has no contact anymore. Let's help her!
AIMS	By mobilizing relevant data and efficient tools, we have to find potential locations for the temple.
LEVEL OF COMPETENCE	Basic to advance
SKILLS TO BE LEARNED	• Project management • CRS management • Reproject vector layer • Reproject raster layer • Select features using a expression • Terrain analysis (slope, aspect) • Attribute Table • Join by attributes • Add geometry attributes • Raster calculator • Polygonize • Rasterize • Export selected features • Raster layer symbology • Vector layer symbology • Repair geometry

WORKFLOW	
DATA	For this case study, we provide you already extracted data for the field of study. Data are : ● Corine Land Cover 2018[112] ● A text file (CLC_legend.cvs) ● EU-DEM v1.1[113]

[112] https://land.copernicus.eu/pan-european/corine-land-cover
[113] https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1

5.9. Summary of case studies' skills

	Case study SKILLS	FRA	GRC	ITA	SRB	SVN	ESP	7th
Theory	Management CRS	×	×	×	×	×	×	×
	Field surveys for cultural heritage			×				
QGIS – Principles	GUI	×		×			×	×
	QGIS Project	×	×	×				×
	Plugin installation			×	×			
	Measure distance on a map		×	×				
QGIS - Load layers Import/Export	Load Shapefile	×	×			×	×	×
	Load GPKG			×				
	Load KML file				×			
	Load GPS data			×				
	Load TIFF	×	×	×	×		×	×
	Save as...	×			×			×
	Add Web Map Service	×						
	Add a basemap (QMS)			×				
	Add XYZ tiles layers	×				×	×	×
	Check metada				×	×		
QGIS - Vector data	Create a new vector layer	×			×		×	
	Attribute table	×	×					×
	Identify features	×	×					
	Select features						×	×
	Select features by expression	×	×			×		×
	Select features by location					×		
	Export selected objects as new shapefile		×			×		×
	Filter data by attributes					×		
	Add/delete fields	×						
	Field calculator	×						
	Add geometry attributes	×						×
	Basic statistics for fields	×						
	Joins							×
	Spatial joins					×		
	Symbology	×			×	×	×	×
	Set vector layer transparency	×		×				
	Add labels to a layer	×						
	Merge vector layers				×			
	Geoprocessing tools (buffer, clip...)			×				
	Repair geometry			×				
	Digitization	×					×	×
	Snapping options	×						
	Polygon editing	×						
QGIS - Raster data	Georeference an image	×						
	Calculatrice raster							×
	Aspect/Slope							×
	Merge raster data			×	×			
	Crop a raster				×			
	Rasterize vector data							×
	Polygonize raster data			×				×
	Symbology			×	×			×
	Set raster layer transparency			×				
	DEM hillshading			×				
	3D terrain model				×			
	Intervisibility analysis			×				
QGIS – Layout	Making a map	×	×	×		×	×	×

6. REPOSITORY

Taking into account the main goals of the project, the MINERVA Team has developed and provided some specific software tools able to create and publish an open repository of materials created and built during this IO2.

The tool manages all learning resources in one accessible and easy-to-use web application, in order to be managed by each teacher producing didactical tools and materials.

In order to pursue those objectives, our technical team provided a web app that will coexist alongside MOOCs in the Federica platform and the Minerva official website.

The tool have the following features:

- CMS (Content Management System) Open-source solution,
- Free material downloads by users connected to website,
- Downloading statistics tools to keep some BI data to improve itself,
- Authenticated access to teachers to upload all materials,
- Custom fields for each materials uploaded (*e.g.*, authors, publisher, original URL, licensing, bibliography, etc.),
- Uploading many file formats (like images, vides, PDF, URLs, etc.),
- Fully customizable graphics and UI/UX by Minerva teams indications,
- Contents fully managed by each non-technical user,
- Providing links to Minerva website and future links to Federica platform Minerva courses space.

The MINERVA Repository is available at the following link: minerva.identitaculturale.eu

7. COMMUNITY OF PRACTICE

A Community of Practice (CoP) within the Electronic Platform for Adult Learning in Europe (EPALE) has been created as a part of the IO2 Objective of Minerva Project, and the group “GIS e-Learning for Cultural Heritage” has been launched. Its purpose is bringing together a multidisciplinary community of teachers, researchers and GIS users interested in exchanging knowledge and experiences on teaching-learning approaches and the use of GIS technologies for cultural heritage. It can be accessed at the link: https://epale.ec.europa.eu/en/private/gis-e-learning-cultural-heritage.

The European platform offers a means to disseminate news and events, sharing documents and participating in discussions that are related to the group's purpose. This allows for amplifying the impact and feedback of the Minerva Project in general and of IO2 in particular. For instance, the information on the Seminar *Geotechnologies for cultural heritage. New challenges for the Humanities in the digital age*, held in Albacete, Spain, on November 3, 2021, is displayed in EPALE and it is available at:

https://epale.ec.europa.eu/en/private/gis-e-learning-cultural-heritage/seminar-geotechnologies-cultural-heritage-new-challenges.

At time of writing, around 20 members, academics and researchers in andragogy, have joined the group. It is expected to continue expanding the CoP’s target audience in the next phase of the project. All the information can be accessed by registering in EPALE at https://epale.ec.europa.eu/en

8. CONCLUSION

In conclusion, the research findings and ensuing products of the MINERVA IO2 “Teaching methods and didactic resources on Geotechnologies for Cultural Heritage” have created and formalized an evidence-based and innovative tool-kit which will be available on the MINERVA Website and related websites. In particular, it is important to highlight that the tool-kit comprises access to resources to teaching methodologies, didactic resources and to a knowledge-exchange platform. In brief, the tool-kit includes the following three interlinked components:

1. **Wikinerva**: https://sites.google.com/view/wikinerva

Wikinerva is a collaborative tool dedicated to supporting teachers. Its purpose is to contribute to the dissemination of active teaching-learning methodologies, and the use of geotechnologies in the teaching of cultural heritage. In its two sections, it includes references to the different student-centered teaching-learning approaches, as well as tools/strategies for online teaching.

2. **The MINERVA Repository**: http://minerva.identitaculturale.eu/

It will include a wide-variety of information including case-studies, link to online resources, bibliographic references, and the reports and papers ensuing from the MINERVA Project.

3. **The Community of Practice** (CoP) on the EPALE Platform: https://epale.ec.europa.eu/en

The CoP has been implemented by launching a group in EPALE: *GIS e-Learning for Cultural Heritage* (https://epale.ec.europa.eu/en/private/gis-e-learning-cultural-heritage where a multidisciplinary community can exchange experiences and knowledge about this issue.

4. In addition, MINERVA project propose a **glossary** as result of a compilation of several other ones.

This report and the above-mentioned tool-kit provides the basis for the identification of innovative methodologies, content and key resources. They will be mainstreamed and fed in the development and implementation of the third MINERVA intellectual output (IO3), namely “Massive Open Online Courses (MOOC) course in Geotechnologies for Cultural Heritage” which will be offered through the Federica Platform, as well as to strengthen interdisciplinary and transdisciplinary communities working on geotechnologies for cultural heritage.

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