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GIS4SCHOOLS - Improving STEAM Education in Secondary Schools through the co-creation of new methodologies for teaching GIS products related to climate impact on local communities

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Abstract

As stated in the European Green Deal: "*to tackle climate and environmental-related challenges is this generation-defining task*." Young generations represent a juncture between understanding the potential hazardous impact of climate change on society and local communities. In this frame, STEAM education in school proved its ability to nurture students' curiosity and cognitive resources, provide them with the right tools to understand the world's complexity and face the challenges that the current times are posing, like climate change, among many others. However, STEAM subjects are not always part of educational curricula: according to the OECD Programme for International Student Assessment (PISA) report 2018, more than 20% of pupils in the European Union has insufficient proficiency in reading, mathematics, or science. Such a lack of diversity in the offer may decrease pupils' motivation to pursue STEAM academic paths, often perceived as highly theoretical and complex. The improvement of STEAM education in secondary schools is the core objective of the Erasmus+ funded project "GIS4Schools", which aims at promoting a new innovative approach to foster the teaching of STEAM subjects in secondary schools across four different European countries: Italy, Portugal, Romania, and Spain. The project intends to introduce the education of GIS and satellite technologies for Earth Observation- rarely adopted in secondary schools- and applying them to the thematic area of Climate Change. GIS4Schools will combine Inquiry-Based Science Education (IBSE) with Problem Based Learning (PBL) approaches to an interdisciplinary contextualisation of the science topic. Pupils will actively contribute to the co-creation of new knowledge by assessing with GIS tools the impacts of specific climate challenges affecting their local community thanks to Copernicus products, Sentinels' satellite-derived information, and other ancillary data. The paper will illustrate the genesis of the project, and more specifically, the process leading to the development of training packages for secondary schools' teachers and pupils. Furthermore, the paper will explore which methodology and pedagogic approach must be adopted to transfer new knowledge from teachers to pupils. The paper will also describe how the teaching of GIS and satellite technologies for Earth observation in secondary school can impact pupils' perception of STEAM subjects and how this can impact their future academic careers. Specific attention will also be dedicated to the description of the innovative tools developed and applied for monitoring and evaluation.
Keywords: STEAM, Climate Change, GIS, Earth Observation, secondary schools, teaching

1. The status of STEAM learning and curricula across Europe

Improving STEAM learning is one of the strategic priorities of the EU in the field of education and training. However, as stated in the European Commission Communication on achieving the European Education Area, EU is still far from reducing the share of 15-year-olds' reaching too modest levels of proficiency in reading, maths, and science. [1] In fact, the underachievement in these areas is still up to 22% against the target of <15% by 2020, as also highlighted in the OECD Programme for International Student Assessment (PISA) report 2018. [2]

A clear picture of the status of the art of STEM learning in the European Union has been provided by the Report "Science, Technology, Engineering and Mathematics Education Practices in Europe" elaborated by the Scientix Observatory. [3] It draws on the analysis of almost 4.000 entries to the STEM Education Practices Survey submitted by educators. The scope of the study was to describe the different teaching practices of STEM subjects across Europe.

For the purpose of this paper, three key findings highlighted by the report should be mentioned. With regard to the pedagogical approach, it should be noted how "*traditional direct instruction remains among the most highly reported pedagogical approaches in STEM teaching*" [4], whilst innovative approaches, such as Inquiry-Based Science Education (IBSE) and Problem Based Learning (PBL), considered highly effective in fostering pupils' analytical skills, are still rarely adopted.

With a focus on the curricula composition, mathematics has been identified in the report as the subject with a greatest potential "*to transform STEM teaching and learning*". However, training methodologies are often teacher-focused and more traditional than innovative. This is true especially when compared with ICT subjects where student-centred pedagogical approaches, such as project/problem-based learning and collaborative learning, are most common. In addition, the report points out, a negative correlation between the rise of the pupils' age and the adoption of innovative teaching methodologies such as IBSE and PBL, decreasing respectively by 19% and 12% when moving from pupils of 10-13 to 16-19 age range. According to the teachers participating in the survey some reasons could be associated to the increasing "*Pressure to prepare students for exams and tests*"; "*Insufficient technical support for teachers*"' as well as "*lack of pedagogical models on how to teach STEM in an attractive way*", and "*School space organisation (classroom size and furniture, etc)"*. [5]

The weak use of innovative tools in teaching methodologies represents entry barriers for these learning paths since it negatively affects the pupils' interest in STEM disciplines. In fact, as stated in the policy recommendations "Science Education for Responsible Citizenship" [6], to increase the number of STEAM students and effectively improve their scientific knowledge and understanding, it is fundamental "*to find better ways to nurture the curiosity and cognitive resources of children [...] by linking science with other subjects and disciplines*".

Teachers are the key players for enabling this transition, as highlighted by two other interesting findings from the teachers' training perspective. On one hand it is worthy to note that teachers experienced a lack of recent training updates, particularly in ICT-related subjects or in innovative STEM teaching methodologies. On the other hand, it has been reported a high propensity of teachers to collaborate with STEM industries in various domains, to enhance teaching and learning. Indeed, 93% of the respondents to the Survey declared that companies should offer more teaching resources to schools. [7]

In addition to this, STEAM education and climate-induced effects on local communities are two key challenges for Europe and its social, economic, and environmental future. The role and interest of the younger generation is a common thread between these two challenges. The European Commission has increased its investments in space programmes such as Copernicus, which generates high quality data at the basis of any Geographic Information System (GIS). Despite a valuable data supply, many studies highlight a low propensity to exploit this data, because of the absence of a "data culture" as well as a weak analytical skill and an insufficient understanding of the commercial potential that can derive from it. Due to the expansion of the space economy and the GIS based technologies, the demand for a skilled workforce is increasing, but there is currently a shortage of trained skilled people. Many reports (Baker & Bednarz, 2003 [8], T. Collins 2015) observed that "*although much effort has been spent towards (..) promoting GIS in primary and secondary education, adoption of this innovation remains slow*." Within the four EU's Countries involved in the project (Italy, Portugal, Romania, and Spain), the adoption of GIS technology into school education is low and GIS curricula are not compulsory. Although in the most innovative cases, teachers use GIS data (i.e. in geography), but the collection and use of it by students is not yet a training module.

In this frame, the European project GIS4Schools has the ambition to address the issues highlighted by both training the teachers in topics (GIS and EO) not yet covered in the traditional curricula as well as supporting them in the further transfer of knowledge by adopting innovative methodologies fostering pupils' active involvement and learning. Besides, even if direct cooperation with STEM industries is not envisaged in the project as a specific output, the enhancement of the theoretical and practical knowledge on space technologies and data analysis is expected to foster the dialogue between the schools and industry, favouring future cooperation.

2. The climate change effects on local communities

One of the most critical challenges Earth's population is facing in the next decade is climate change. It can be defined as a large scale, long-term shift in the planet's weather patterns and average temperature. [9] The principal source of climate variations are human activities. Since the Industrial Revolution, the increasing release of carbon dioxide and other greenhouse gases (GHG) in the atmosphere (methane, nitrous monoxide) contributed to the creation of a so-called "blanket" that detains the heat from the sun causing the heating up of the temperatures. As reported by the US National Oceanic and Atmospheric Administration (NOAA)'s 2020 Global Climate Report, since 1880 the combined land and ocean temperature globally increased at an average of 0.08°C degrees per decade until 1981, when the average rate increased more than twice up to 0.18 °C degrees. [10]

The impacts of such rise in temperature are numerous and concern the climate system as whole, the ecosystems, the biodiversity, and the people. Some of the most visible effects of climate change include extreme weather events; ocean acidification; and rise of ocean levels, just to mention a few. [11]

Climate change is also one of the main threats to our cities. Globally, more than 70% of cities are suffering from climate change effects. However, cities are not just victims of this global phenomenon: excessive urbanisation and lifestyles in cities are contributing to the exacerbation of climate change effects. Cities are responsible for 75% of the global CO_2 emissions due, for instance, to heavy traffic in urban areas and the increasing number of buildings. Furthermore, the exponential speed of urbanisation has also created vegetation loss that worsens air quality.[12]

2.1 Climate Change and Satellite Technology

Climate Change's mitigation and adaptation strategies have been put in place by local decision makers to avoid a worsening of climate change effects. Satellite technology is contributing to such policies. Indeed, satellites provide key data and information about climate change and environmental variables, in particular Earth Observation (EO) monitors GHG emissions related to deforestation and industrial processes, sea level rise, temperature changes, altering of ice polar caps and glaciers.

Copernicus, the European Earth Observation Programme, currently offers the Climate Change Service (C3S) entirely dedicated to observing the evolution overtime of major climate change indicators by providing authoritative information to public for the benefits of European citizens. The Service provides climate data and information on selected domains, as agriculture and forestry, coastal areas, health, tourism, biodiversity, among others. [13]

The use of GIS and satellite-derived data is rapidly increasing among urban planners and decision-makers to understand the effects of climate change on local communities. Satellite data and geospatial analysis offer a guidance to assess Earth's health, by collecting information and tracking trends both at global and local level, enabling effective planning to contain the effects of climate change. [14]

Four case studies located in the partner countries have been selected to illustrate how GIS technology is currently used by city planners and policy makers, to assess specific aspects of the overall climate change impact in urban areas and to identify mitigation measures to limit its consequences. Each example highlights that GIS and EO can improve the understanding of the evolution of the urban context through multiple layers of data in different timeframes, allowing to evaluate the feasibility of initiatives and actions in cities, and to predict their effects on the environment. In the frame of the GIS4Schools project, these examples represent a starting point for the participating schools to understand how to exploit GIS for the development of climate-related products for their local communities. A brief description of the challenges identified by each school is illustrated in the section *4.2. EO and GIS in action: the identified challenges.*

Air Pollution- Bucharest

Air pollution represents a threat to human health and environmental ecosystems. GIS technology has proved to be highly efficient in supporting decision-makers to observe where the highest concentration of pollutants usually happens, as seen in Bucharest.

To monitor air quality in the city, eight stations have been installed by the local authority responsible for environmental affairs as part of a national network that provides hourly data on pollutants' concentration and meteorological data, such as temperature, humidity, and wind. Other data are also available through other sources, as independent sensors, and platforms. Free GIS platforms and environmental portals gathering data collected officially by the municipality through the monitoring stations, can be used to identify zones of the city where pollutants are concentrated to develop *ad hoc* measures and to map priority areas where to intervene with targeted actions (eg. policies, temporary traffic circulation limitations, awareness raising campaign, etc.)*. [15]

* According to the Directive (EU) 2016/2284 of the European Parliament, Member states have the obligation to develop, adopt and apply national air pollution control programmes, to reach air quality level that don't create any significant negative effects or risk for public health and the environment. The European Commission sent Romania and Greece an official reasoned opinion. The two countries have 2 months to take the appropriate actions, otherwise the Commission will refer the matter to the EU Court of Justice. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2016.344.01.0001.01.ENG

Changes in land coverage- Lisbon

Land cover and land use are related to GHG emissions and concentration in the air due to the over urbanisation that affects specific areas in urban contexts. In Lisbon, the relentless growth of the city requires continuous monitoring of the transformation of the land coverage and use, and the assessment of green and inhabited areas.

Since 1990, most of the data used by urban planners to map Lisbon has been retrieved from the CORINE Land Cover (CLC) inventory, initiated back in 1985 to standardise data collection on land in Europe to support environmental policy development. Through CORINE, it has been observed that between 1990 and 2000, Lisbon changed consistently, due to an increasing number of urbanised areas.[16] In this case, GIS technology provided urban planners with useful data to analyse how and where the inhabited areas developed the most. In this way, the GIS products, and the land cover data available helped in modelling urban patterns, in planning infrastructure developments, and in growing boundaries to limit the urban sprawl.

Urban Heat Islands - Barcelona

An Urban Heat Island (UHI) occurs when the temperature differs significantly between a city and its rural area. Barcelona has been affected by rising temperatures over the past years. The average intensity of the city's UHI is about 2 degrees, with peaks of about 7 degrees. Barcelona's heat islands represent a risk for the health of its inhabitants, especially for those living in the city centre, and contribute to an increment of heat-related deaths and illnesses. Greening can help the city in reducing its UHI. [17]

GIS products, especially maps with sky view factors indicating polluted areas have been of great support to policymakers in deciding how and where intervene. These data are available through the City of Barcelona portal. Morphological data are collected through satellite EO technology to determine local climate areas and health exposure indexes.

Flooding- Venice

According to multiple studies and scientists, by 2050 many cities around the globe might be submerged. Venice is one of these cities. The "*Acqua Alta*" phenomenon is considered as one of the most evident effects of climate change. Usually, it is caused by a combination of high spring tides and meteorological storms driven by sirocco winds blowing across the Adriatic Sea. [18]

Bathymetry, digital elevation models and other meteorological data (e.g. precipitation values, stream data, etc.) prove their efficacity to foresee and model different flooding patterns, usually in combination with high-tide sea levels. In this case, GIS data and analysis can be used as a baseline to foresee which urban areas need to be protected to preserve public spaces, heritage sites and avoid economic damage.

3. State-of-the-art of the teaching of GIS and Earth Observation technology in secondary schools

For the younger generation, climate change represents a threat to their future. Over the past few years, the young people's awareness, curiosity, and eagerness to better understand the climate crisis increased dramatically. As demonstrated by demonstrations and youth-led initiatives on climate resilience, it is important to equip young generations with the right tools to act becoming the engine of a cultural switch towards a more environmental-friendly world.

School represents the best place to provide young generations with an increased knowledge on climate change and its effects, responding to their willingness to stay on the frontline to fight this crisis. For this reason, it is relevant today to introduce in schools' curricula climate change education as a subject. Such a bottom-up request from students across the globe, has been occasionally welcomed by Institutions though the establishment of initiatives such as the EU Education for Climate Coalition a platform seeking to create an education community- composed by students, teachers, trainers, parents, and other education stakeholders- to support the definition of a climate-neutral society. [19]

Besides this initiative, at European level, the response to the students' need to improve their knowledge about climate change remains fragmented but partially compensated with national initiatives both for teachers and pupils. [20] In this frame, the teaching of GIS and EO can be extremely relevant to develop a critical thinking while adopting a hands-on approach using cartography and data, looking at climate change from multiple interconnected perspectives.

Most teachers need specific training in non-traditional subjects, especially in topics like EO and GIS, as well as data analysis to acquire working knowledge and to fully understand its educational benefit. Universities carry out on a regular basis course on EO and GIS, addressing graduate students, but no relevant experiences have been developed in teaching methodologies for GIS in secondary schools. Many of the professional and learning opportunities for teachers and students are all organised at national level, as demonstrated by national associations engaged in promoting the teaching of GIS. An example is the UK Geographical Association that created dedicated teaching materials on GIS, climate change and sustainability, environment, climate resilience, downloadable from the website. [21] Also in France, the Reseau Canopé- a public entity operating under the French Ministry of Education- provides the teachers materials and recommendations on how to introduce GIS teaching in geography curricula. The aim is to provide the pupils with innovative ways to study the world and to look at the seamlessly evolving environment. [22]

Learning at secondary schools GIS and EO can help students in defining the next steps in their career. In the US, a federal decision of the Department of Labor introduced in 2010 GIS teaching in high schools because of its relevance for career development. [23] In Europe, each country is responsible for its own education system. The EU policy in this regard supports actions at national level and helps in addressing common challenges. However, each school can decide if introducing in their curricula principles of GIS and related activities. For instance, in Italy, the National Guidelines for the curriculum (*Indicazioni nazionali per il curricolo*) issued with the Ministerial Decree 254/2012, promote the use of GIS in the teaching of geography at every level, to develop multiple abilities and geographic competences, as for instance building and interpret a map. To this purpose digital classes to teach geography by using ESRI resources, as ArcGIS, have been developed for those teachers that are interested in introducing GIS in their teaching schemes. [24]

In the frame of a climate change education, introducing EO to explain climate change in schools, will help students in understanding the difficult aspects of climate change science as the remoteness of impacts, the temporal gaps between human activities and corresponding effects on the environment, but also allows students to manage authentic scientific data to analyse environmental changes happening at multiple temporal and spatial scales. [25]

Also in this case, the initiation of EO technology in schools' curricula and initiatives is very susceptible to national education guidelines. This might be explained by a very limited supply of information appropriate for non-experts and the lack of an adequate equipment to visualise and collect data, not always easy to find in schools. Nevertheless, user-friendly resources have been put at the disposal of teachers and students thanks to the efforts of the European Space Agency (ESA), that develops environmental EO-based activities for classrooms and training courses for teachers. Another element that could be considered as an obstacle in the integration of EO in high schools, is represented by language barriers: ESA tries to address the issue by translating their resources in all their MS languages. Also, ESERO- ESA Education Resource Offices all around Europe- tries to overcome the language-related problems by adapting EO (and other space knowledge materials) according to national curricula. ESERO offices also propose learning tools (eg. courses, video-lessons, seminars, brochures, etc.) to teachers for training purposes. [26]

4. The GIS4Schools project

In the frame of the climate change education and STEAM learning promotion at European level, the Erasmus+ funded project, GIS4Schools, is poised to play a significant role. The project, kicked off in September 2020, addresses on a transnational basis, digital skills (along with underlying technological elements), climate change awareness and understanding (along with basic scientific elements) for secondary schools' pupils and teachers supported by experts' guidance. Ultimately, the GIS4Schools long-term goal is to increase the interest of secondary schools' pupils in STEAM disciplines. It will enhance their level of knowledge and capabilities by involving them in the co-creation of new methodologies and replicable digital tools using and exploiting EO and other data to develop GIS products to address the impact of climate change on their local environment.

Based on the findings of the needs analysis distributed among the project's partners, and according to the literature review, pupils of secondary schools are digital native but not acquainted with processing GIS data. There is a need to integrate EO and GIS technologies in the education curriculum as early as possible to make pupils aware and interested in data analysis mostly related to climate change. To engage pupils, it is necessary to introduce project-based teaching programs and develop innovative methodologies to foster their familiarity with EO and GIS to encourage them to choose STEAM in the continuation of their studies. As a matter of fact, the project intends to create a new approach for the involvement of pupils in STEAM learning, by introducing the teaching of GIS and the supporting technology- not yet or rarely adopted in secondary schools- and by applying it to the thematic area of Climate Change.

GIS4Schools leverages on the curiosity of the pupils and aims at stimulating their proactive attitude on Climate Change to further engage them in STEAM and in the basics of data science and GIS learning. Pupils will be able to acquire new specific knowledge, reinforce their interest towards STEAM subjects and develop cognitive skills (i.e. problem solving, creativity, etc.). They will be motivated to create a concrete and valuable product for their local community (e.g. maps and reports) and to replicate the case study for a developing country. Making pupils active players of this co-creation process will contribute to keep high their level of engagement, and to foster their curiosity into environmental and climate phenomena strictly connected to their local communities. Besides, the transnational dimension of the partnership will allow a transfer of practices between different schools to better understand different contexts in environmental, social, and cultural terms.

4.1 The project's objective and methodology

Direct beneficiaries of the GIS4Schools project are 180 secondary school pupils (15 – 18 age) and 24 teachers from four Secondary Schools involved in the partnership coming from Italy, Portugal, Spain, and Romania. Indirect beneficiaries are 1000 pupils and 200 teachers from the schools involved.

Throughout the project's duration (2020-2023), the following objectives will be achieved:

- Development of a secondary school reusable training package aimed at raising awareness and understanding of pupils on EO, GIS and Climate Change;
- Pupils' engagement in development of open-source GIS products focused on climate change;
- Pupils exploitation of the co-created GIS software to analyse a case study concerning the impact of climate change on their local environment;
- Improvement of the quality of training in STEAM, by providing teachers with a self-paced training package combining virtual learning, pre-services training and a short-term training event;
- Promotion of pupils' employability by enhancing their analytical abilities in a high growth potential sector (space economy, GIS and Climate Change), as well as their propensity to choose STEAM in the University paths;
- Pupils' engagement in storytelling actions;
- New enhanced cooperation between Schools, Local Authorities, Academia, NGOs, and other stakeholders.

The methodology of the project combines IBSE and PBL approaches to an interdisciplinary contextualization of the science's topic: pupils will learn how to capture EO information and other data to turn them into GIS products and how to use them to analyse specific local climate challenges that will be identified by them thanks to a participative process. Many reports stressed the importance of inquiry-based teaching in STEAM learning. In this approach, GIS is a precious enabling tool for the engagement of pupils in analysis related to the environment and community. As observed by researchers and scholars in GIS technology and education "*GIS education leads to critical thinking in a wide range of disciplines and is fundamental to the creation of decision-maker*". [27] Besides, "*Using GIS as a tool for PBL may be beneficial for students with multiple backgrounds and professional goals because the GIS interface allows students to experience solving real world issues*". [28] The project addresses both "*teaching GIS"* and "*teaching by GIS*".

4.2 EO and GIS in action: the identified challenges

To let the pupils familiarising with GIS, the four participating schools identified four applications:

Air Pollution: The Romanian school National Colegiului "Ion Neculce" focuses on a sensible topic for Romania, as it is air pollution and its relation with climate change, and its threats to human health and environmental ecosystems.

Flooding: The Portoguese school Escola Secundaria "José Afonso" identified the topic of land coverage and the increasing risk of flooding in the country. Focusing on weather conditions in Lisbon and Madeira, pupils will study the causes and effects related to such an extreme weather event. In addition to this, the students will also study how changes in land coverage can increase the risk of flooding.

Sea temperature rising: Based on the Island of Formentera, the secondary schools IES "Marc Ferrer", will develop a GIS product focused on the impact of climate change on its main resource, the sea. In particular, the students will concentrate on the increasing of sea temperature and its effects on the water biodiversity.

Forestry plague: The Italian School ITT "Guglielmo Marconi"' pupils will be studying the spreading of the processionary moths, considered by the Intergovernmental Panel on Climate Change (IPPC) as one of the insect indicators of climate change because of its expansion with warm temperature. In particular, the focus will be on the consequences on local forestry and human health.

5. The design of GIS4Schools training package and GIS products

The GIS4Schools project's activities have been built as an "*unicum*" following a coherent approach according to which each project's deliverable is strictly connected and propaedeutic to the following one. The first deliverable is focused on the design of a suitable training package, namely an interactive handbook, to be transferred to both teachers and pupils.

5.1 Design and implementation of the web training book

The design and implementation of the handbook has been realised by a team of 11 experts among professors and researchers from the Politecnico di Milano (POLIMI), the scientific and technical partner of the project. The project proposal was developed around the idea of training the teachers on GIS and EO fundamentals and to provide them the needed skills to transfer this knowledge autonomously to the pupils. To accompany the teachers in this learning process, the group of experts designed together with the handbook a training path for teachers divided into five days online training course structured into theoretical and applied modules.

The training book has been developed in HTML language using Sphynx[†], a tool to produce interactive documentation written in Python, and hosted on GitHub. The handbook combines theory and practice, in the form of step-by-step exercises following a learn-by-doing approach. It is divided into two sections: the first one dedicated to GIS fundamentals, retracing its history- from the Palaeolithic period when the evidence of maps was identified, to the computerisation of GIS in 1963 by the British geographer Roger Tomlinson- and introduces the GIS data modelling and the QGIS software. QGIS will be a key tool for teachers and pupils in the development of the GIS product during the second phase of the project. It will allow them to create maps and perform spatial data analysis based on the data collected via multiple sources such as aerial, drone, satellite imagery, and geo-localized temporal series. The second part of the handbook is dedicated to Earth Observation and Imagery Analysis. In this part, besides providing the teachers with main elements on spatial resolution, the focus moved on Copernicus and the Geospatial data management related to climate change and hazards. The theory has been complemented by hands-on exercises to show the application of the learned concepts and to lay the basis for the projects that the pupils will develop in the project framework. The exercises have been selected to show interesting cases related to the partners Countries and considering their interests for the development of the projects. The handbook implementation took place, as planned, in the first six months of activity of the project, it has been used as a reference for the training of the teachers and it will be used as well to train the students. The information included in the handbook are retrieved through open-source software and data, to foster accessibility and interoperability. In addition, the handbook itself has been offered as openly available through GitHub and Read the Docs[‡].

The training package has two objectives: on one side, it aims at providing the teachers with a new teaching methodology for GIS and EO; while on the other side, and strictly connected to the first objective, it facilitates the transferring of knowledge to the pupils. The main challenge identified in the designing of the training package, was represented by the need to find a good balance between the technical information to be included in the handbook and the language to describe it. The use of an over technical language could have a negative impact on the transfer of knowledge phase generating a potential counterproductive effect on the pupils, discouraging them from an active learning. To overcome this potential risk the experts included a set of interactive features (hyperlinks to institutional websites, images, practical examples, etc), in the clear and plain language readable by teachers with maths, geography or IT background. In addition, the handbook has been built based on the learning environment and learners' existing knowledge and skills which has been ascertained during the project meetings with the schools' teachers. In the view of making accessible and user-friendly the training package, a supporting scheme for teachers have been structured. It consists of the mentioned training course and a helpdesk, available on a reserved section of the project's website, whose objective is providing constant and remote assistance to those teachers that requires it.

The design of the training package has been done also considering the sustainability of the project after its ending: in this sense, the handbook should be considered as a self-standing tool that teachers from interested schools can adopt and integrate in their curricula.

5.2 Training course for the teachers participating in the project

The training course was initially planned to take place in person, easing the learning process and favouring the exchange and interactions with the other teachers and the experts. COVID-19 clearly impacted the organisation of the course, that had to be moved online adding an extra layer of difficulty for the teachers.

The objective of the training course was to introduce the training book and provide the teachers with a more impactful experience, also thanks to the

† https://www.sphinx-doc.org/en/master/

‡ https://readthedocs.org/

guided exercises explained by the experts from POLIMI.

The course lasted five days and covered the topics included in the handbook, and the hands-on exercises explained step-by-step. The training online did not reduce the interactivity of the course, that gave the teachers the opportunity of confronting and exchanging on the subjects and exercises identified by the experts. The POLIMI team could benefit of two semesters of online and blended teaching experienced during the pandemic, for which they received professional training. The programme of the week was dense, but the experts managed to translate complex scientific language into a simple narrative tailored for all backgrounds. The course gave the 24 participating teachers, elements to organise their activities with the pupils, and to structure how to introduce such new knowledge to them.

As a follow-up after the training course, the team from POLIMI involved the teachers in an internal assessment to evaluate the difficulty of the course through a short questionnaire. The results of this survey showed that the teachers had some difficulties in acquainting the new language and the contents of the course. According to the answers collected, the hardest topics to assimilate were EO and Geospatial Analysis for crisis management for which the teachers would prefer an increased number of allocated hours. In general, the main difficulty of the teachers has been the impossibility of attending the course in presence since some issues in connectivity slowed down the learning process.

To complement the online course, the teachers will be invited to a peer training event in presence- according to the evolution of the sanitary crisis- in late fall 2021. The objective is to enhance the training of the teachers and to share new inputs before the practical new phase of the project starts.

6. The Digital Diaries: an *ex ante* learning assessment

The Digital Diaries tool has been designed and developed as a cornerstone of the strategy of monitoring and intervention in the project. It is a fast, not expensive, and scalable tool based on open-source digital technology that provides valuable information for:

- Real-time monitoring: for timely intervention and a more in-depth long-term assessment.
- Thematic monitoring: to obtain a general overview of the progress of the project and the detail of a single problem.

It can be adapted and improved over time as an open-source tool, adding elements to enhance and introduce new functionalities and multiplying its reuse even on new projects.

6.1 How the Digital Diaries tool work?

The idea behind the Digital Diaries is that all the participants in the project must keep a "*standard diary*" where they can anonymously collect and share their impressions and progress with the evaluation group throughout the project's progresses through the compilation of diary pages.

Being digital, the diary allows the evaluation team to collect feedback and send inputs to and from the interested parties in real-time through a specific encrypted communication between the dedicated information system and the smartphone device (notifications) of the participants where they can display and interact with the digital diary.

The subject can send impressions about the project as voluntary feedback- so called “open diary page”- or as answers to precise questions-structured diary pages- sent by the research group in a planned, automated, and standardized way through direct messages to the compilation.

The system simplifies the relationship between the subject examined and the survey group, allowing management in parallel on several groups that may have carried out activities at a different stage of progress, maintaining a high degree of comparability between the responses.

The digital diaries tool is composed of two main elements:

1) **A smartphone application to be installed by the project participants.** The protocol used by the open-source software is also adaptable to third-party applications. In the case of the GIS4Schools project, it was agreed on using the Telegram application as a client, which guaranteed the highest level of security and extreme ease of installation and compatibility with a wide range of devices.

2) **A scalable application (serverless).** It manages the entire communication path (sending diary pages / receiving responses), the analysis of compiled diaries, and two types of reporting:

- a dashboard for the staff to show the evolution of the main project indicators.
- a dashboard for participants to self-assess their path within the project and check the progress of the group they belong to.

The tool can manage several thousand interactions per minute, ensuring the monitoring of large groups of participants without increasing management costs. In the GIS4SCHOOL project, the digital diaries have been used by the teachers before, during and immediately after the on-line training course.

During the five days of training, each of the 24 teachers completed seven diary pages with a response rate of 91%, grouped as follows:

- *Ex-ante* course knowledge and expectations' diary.
- Five ongoing diaries to track the implementation level of the training activities.
- *Ex-post* course diary to test knowledge and achievement.

In the *ex-ante* phase, the data collected outlined a comprehensive picture of the previous knowledge of the teachers who stood at a medium-low level concerning all issues related to GIS. On a scale of self-perception ranging from 1 to 10, where 5 was considered a "positive" value, the average value stood between 3 and 4. On the other hand, there were strong expectations of reaching a level of knowledge on the GIS topic sufficient to guarantee the success of the project.

During the ongoing phase, teachers' difficulties and fatigue levels were constantly monitored following the contents of the training. Even in the context of distance learning and highly compressed training times, it was possible to adapt training in a way that was compatible with the levels of attention of the audience.

Finally, in the *ex-post* phase, it was possible to detect the high levels of satisfaction of the teachers who declared in their diaries to be very satisfied with the training activities (with an average value of 8.4). Teachers also reported a significant increase in their knowledge about GIS from a theoretical perspective (with an average value of 8) and practical competencies (with an average value of 7.8). Indeed, teachers declared to be trained to transfer acquired knowledge to their students (with an average value of 7.8).

6. Conclusions

The GIS4Schools project partners currently achieved the objective of developing the training book and of performing the transfer of knowledge to the pupils in each of the four schools before the summer break.

With the beginning of the new school year, the project will enter a new phase. Currently, the four schools participating in the project are involved in translating the training package in Italian, Portuguese, Romanian and Spanish, to starting the promotion and dissemination of the training package at national level. Such a dissemination phase will result in a series of four so-called, local multiplier events. These outreach events have the objectives of presenting the project's outputs to a wider audience, that in this case will be composed by local public administration responsible for education, national ministries of education, climate change experts, other local secondary schools' representatives, and space actors.

Besides this, from October 2021 to March 2022, GIS4Schools' partners will be working on two new outputs. The pupils and teachers will be exposed to the practical application of the newly acquired knowledge about GIS and the underlying science, technology, and data, by familiarising with data manipulation, and the design and development of a software to obtain GIS products. This output is the core of the whole project because it will contribute to the creation of open training material based on case study that will be shared with interested external schools, after the project's lifecycle. At the same time, partners will be involved in the development of an e-learning platform that will serve as an open repository where the different outputs of the project will be gathered. The platform will allow the schools to stay engaged in a community learning process, that will also ensure the scalability and replicability of the process to other ones. In fact, the creation of such tool will play a central role in the second half of the project to start a new phase for STEAM learning, more technology-based and interdisciplinary, more centred on global challenges with a relevant impact on the future generations.

Acronyms/Abbreviations

CLC CORINE Land Cover
C3S Copernicus Climate Change Service
EO Earth Observation
EU European Union
GIS Geographic Information System
GHG Greenhouse Gases
IBSE Inquiry-Based Science Education
NOAA US National Oceanic and Atmospheric Administration
OECD Organisation for Economic Co-operation and Development
PISA OECD Programme for International Student Assessment
PBL Problem Based Learning
STEAM Science, Technology, Engineering, Art, Mathematics
STEM Science, Technology, Engineering, Art, Mathematics
UHI Urban Heat Island

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