The article presents in detail the main outcomes of a recent action – research project PULCHRA – Science in the city (https://pulchra-schools.eu/), funded by Horizon 2020 EU program, promoted by the University of Athens and a consortium of ten academic and research European institutions, including the Education Research Unit from Romania. The project was inspired by the open education principles (Abrioux, 2009) and creates a complex learning by doing framework for secondary students of 14 to 17 years old. The perspective of City as ecosystem creates for the involved partner schools various opportunities for exploiting inquiry-based methods and addresses real-
After three years of implementation, PULCHRA developed a specific methodology, by promoting real life experiments during science classes, in collaboration with community representatives and the support from partners, experts, and other stakeholders. By using a variety of resources, materials, and teaching approaches, specific science teams managed to research, develop, produce and promote solutions to several common issues/opportunities that European cities face due to increased urbanization. Out of the six environmental, social and economic thematic areas of the project, Romanian schools focused on regenerating urban space to connect people in a healthy environment. The article explores the outcomes at grass-root level, as documented by monitoring and evaluation activities conducted in six upper secondary schools from Romania. In particular, we highlight the contribution of the project in building students’ good scientific knowledge, in promoting expert and community participation and encouraging active engagement in shared living environments and futures. The contribution of the project on development of STEM competences, in relation with the national curriculum, is also explored. In the context of COVID pandemics, the article will highlight the importance of the City Challenges Platform, set up to facilitate the learning and collaboration of the members of the city science teams and wider network. The contribution to sharing digital educational material, design relevant experiments and develop distance-learning courses on cities as urban eco-systems will also be documented.

Keywords: open education; inquiry-based learning; STEM competences; EU trans-national projects; Horizon 2020 program.

INTRODUCTION, PROBLEM STATEMENT

Educational policy bodies worldwide regard inquiry-based learning as a vital component in building a scientifically literate community (National Research Council, 2000; European Commission, 2007; The Commonwealth, 2007; Pedaste, et al., 2015; Sjøberg, 2019). Aspiring to engage students in an authentic scientific discovery process, this type of learning is widely recognized as playing an important role in learning of science through approaches which reflect the authenticity of science as practiced by professional scientists while being practical and manageable within the school context (Barrow, 2006; Barron, & Darling-Hammond, 2008). Inquiry and problem solving creates a more engaging learning environment and its positive impact on students’ ability to understand core concepts and procedures is widely recognized (Dochy, 2003). However, contemporary educational researchers promote a myriad of conceptual models and approaches falling under the banner of inquiry-based learning and genuine knowledge creation (Noveanu, et al., 2020), with only few of these models systematically grounded in real-classroom practices (Krajcik, & Merritt, 2012; Simons, & Klein, 2007).

Financed by the European Union’s Horizon 2020 Research and Innovation Program (H2020-SwafS-01 2018–2019, financing agreement no. 824466) PULCHRA – Science in urban environments: building participatory learning centres through research and community involvement, is one of the most important research-action projects at European level, trying to address this challenge. The project (https://pulchra-schools.eu/about/) is based on a specific pedagogical approach, developed from the perspective of the inquiry-based learning and open schooling model in STEM competence development (Noveanu, 2020; Sotiriou, & Cherouvis, 2017)

PULCHRA is focused on 14 to 17 years old students, and it is promoted by 11 partners (universities, public and private research centres) from 10 countries, coordinated by the National and Kapodistrian University of Athens, Department of Physics. The project runs during 2019–2023 and the National Centre for Policies and Evaluation in Education (Romania) is one of the partners, through the Education Research Unit (former Institute of Education Sciences).

The central idea of the project is to to make science, science education and science careers more attractive to young students and the society in general through the promotion of real-life
inquiry-based learning activities, with the support of the research and other representatives of the community around the school. In this view, the project created a trans-national research team developing and testing in secondary schools from partner countries a pedagogical approach that explores the open schooling concept in the theme “Cities as urban ecosystems” and in view of creating new partnerships in local communities to foster science education. This approach is focused on facilitating students’ access to learning contexts where they have the opportunity to investigate various environmental and sustainable real-life development issues of their cities. Other specific objectives of PULCHRA include:

- To bring real life projects as related to cities as urban ecosystems in the classrooms through focused collaborations with professionals and enterprises.
- To take advantage of the infrastructural capacities and experience of the GLOBE-Europe network operating in 41 Europe and Eurasia countries, so as to establish a network of open access urban measuring, observation and experimentation stations by utilizing and augmenting existing points of access (green spaces, school yards, open spaces etc.).
- To motivate students towards new technologies, mainly the use of Earth Observation (Copernicus program and Sentinel missions) and navigation tools, etc.
- To report the concept of the city as an urban ecosystem, as well as Challenges, finding and solutions to the public through the City Reporters action.
- To link the project to the Sustainable Development Goals (SDGs) of United Nations as well as to related EU strategies.

The PULCHRA approach was developed taking into consideration that inquiry moves away from a purely teacher- or student-centred approach to a form of learning that takes its cue from what the field of study requires of those coming to know it. As they pose guiding questions, problems, or tasks that professionals in the field would recognize as important, students and teachers work and learn from experts to develop responses and performances of learning that are meaningful, sophisticated, and powerful.

Scaffolding activities, frequent opportunities for formative assessment, as well as powerful guiding questions are vitally important for ensuring inquiry-based projects to lead to deep understanding (Darling-Hammond, 2008). An effective scaffold involves excluding elements of a task which are beyond the learner’s capability in a way that allows the learner to concentrate upon and complete only those elements that are within their range of competence (Simons & Klein, 2007).

Along with scaffolding, a large body of research concludes that the learning gains engendered by formative assessment were amongst the largest ever reported among any educational interventions (Bransford, Brown, & Cocking, 2000; Darling-Hammond, 2008; Hattie, 2009; Heritage, 2010). Heritage’s (2010) review of the literature asserted that feedback designed to improve learning is most effective “when it is focused on the task and provides the student with suggestions, hints, or cues, rather than offered in the form of praise or comments about performance” (p. 5).

Another important assumption of the project was that, depending on student’s age and project complexity, critical thinking, culturally situated learning, cooperation skills, co-responsibility, public visibility, etc. are encouraged and assessed as outcomes of the project-based learning, beside academic achievements. With project based interdisciplinary activities, students not only learn important STEM content and practices, but also practice applying them in conjunction with other skills and knowledge in a realistic context (Noveanu, et al., 2020).

**LITERATURE REVIEW**

The work of PULCHRA was based on an extensive analysis of relevant literature review, as indicated below:


All research outcomes of PULCHRA are available on the official platform of the project (https://platform.pulchra-schools.eu/supporting-tools/e-lessons/), including Handbook of Education Materials and Handbook of a Young Reporter.

METHODOLOGY

In addition to its innovative pedagogical approach, outlined in the first section of the article, PULCHRA project methodology is based on a specific understanding of the “city” concept. Urban schools are not ivory towers and are not disconnected from their environment. A key of their success is how well they understand the cities as “living organisms” (exchanging heat, mass, energy, information, ideas and culture) and as complex urban ecosystems of natural, built and socioeconomic environment. The perspective of the cities as urban ecosystems is directly linked to a number of recent European Union strategies for nature-based solutions, circular economy in cities, low carbon economies, climate friendly cities and smart and learning cities.

The main approach of PULCHRA project is also based on a specific set of tools aiming at facilitating the creation of meaningful curricular contexts for STEM competences: development of learning paths within each community (LEAPS); creating a City Challenges Platform allowing experts to guide non-experts in interpretation of data collected/findings; development of open source educational e-material, e-guidelines and smartphone apps; creation of City Science Teams with the participation of teachers and students, parents, professionals from the business community, scientists, citizens, local authorities representatives, etc.

Examples of participatory and activating challenges were rolled out as City Challenges Platform using Web based Interaction and visualization modules to support partnerships in local communities (schools, agents of formal and non-formal education, enterprises, industry, local administrations, NGOs, civic groups, etc.). Pilot schools also promoted, in coordination with local research centers, Universities and scientific associations, open activities, also in support of the City Challenges, to students, parents and citizens in general, under the theme “Meet the scientists – Introduce science in the city – approach the city as an urban ecosystem”.

All the educational materials of PULCHRA are organized along the specific methodological guidelines, as detailed in the Handbook of Education Materials (Schneider, et.al., pp. 9–10):

- Provide clear and direct links to the competence building goals of science education standards; fostering the understanding of scientific concepts and developing the ability for inquiry and evidence based evaluation; strengthening the learning of subject matter in the context of personal and societal perspectives; implementing inquiry based learning approaches to address the diversity of the students’ skills, proficiency and abilities; strengthening the communication of science explanation in the classroom and beyond, e. investigating over an extended period.
– Offer a clear structure that splits topics into small independent learning modules with a clear-cut content and a set of teaching materials; assigning the modules to learning units; identifying the contextual links to the City Challenges provided by PULCHRA and enabling easy extension through adopting additional teaching material developed by the PULCHRA network of schools or other institutions.

– Present clear instructions for activities, experiments, and digital learning tools, which are based upon scientific approaches and thus, clarify the method of science from a research question, via the research method, to data analysis, and from data analysis to evaluation and communication and discussion of the results.

MAIN RESULTS

Defined synthetically, the main challenges identified by PULCHRA project, linked to UN Sustainable Development Goals, refer to:

1. Powering Cities without Harming the Climate
2. Buildings for the Future City
3. Regenerating Urban Space to Connect People in a Healthy Environment
4. From waste disposal to Resource Efficiency – Circular Economy at the City Scale
5. Mobility Patterns that support Community Development
6. Innovation for Social and Environmental Benefit

Each project partner has selected one of these challenges to focus on together with partner schools and organizations. Romanian schools chose to address the challenge of the urban environment related to the regeneration of space and the promotion of a clean/healthy environment (George Cosbuc National Bilingual College, Bucharest; Gheorghe Ţincari National College, Bucharest; Virgil Madgearu Economic College, Galati; Dinicu Golescu National College, Campulung; Axente Sever Theoretical High School, Mediaş).

The learning contexts promoted by the project involved hands-on experiments, environmental observations, as well as the use of digital equipment and applications (e.g. using smart phones) to make guided observations or access data from external sources, such as aerial photography or data collected by satellite. Science reporters are members of the research team and have a specific role to develop and implement a communication strategy regarding the project and its results. PULCHRA thus becomes a tool that connects classroom learning with out-of-classroom learning through which environmental education and education for sustainable development is encouraged and which, at the same time, facilitates active participation/citizenship.

Students had the opportunity to explore complex issues such as water management, green spaces, energy efficiency, air/water pollution, climate change, road and building management, public health. The project facilitated the transfer from a content-centred learning to a learning centred on real problems in the community. The social relevance and immediate connection to the known living environment make the challenges of the city particularly motivating to learn and experience scientific discovery, for the development of key competences.

In all the schools, scientific research teams were created, mixed teams made up of students, teachers, other interested parties: parents, experts/scientists, practitioners, local authorities, civil society organizations, representatives of the business environment, universities, researchers and others with expertise in the above areas.

As a more in-depth look on how the project worked at grass-roots level is offered by a case-study from the Dinicu Golescu National College, and this team initiative in support of integrating sustainability of the city by researching the topic of air pollution and engaging in addressing this challenge. Their project, entitled 'Regeneration Urban Space to connect People in a Healthy Environment', started from the premise that the municipality of Câmpulung, like any urban
settlement, has different levels and types of pollution that affect the health of its inhabitants. Therefore, the city needed a permanent tool to inform the people of Câmpulung about local environmental issues.

The aim of the project was to assess the quality of life of the inhabitants of Câmpulung in relation to environmental factors (water quality, air quality, noise level, and other sources of pollution), by identifying their opinions and perceptions, but also by using objective methods (measurements of some parameters). Lastly, the highlight of the project was the creation of an interactive map of air pollution in the municipality of Câmpulung.

As part of the desk review, the team of students researched information online (newspapers, television, documentaries, and recent publications) about the history of pollutants and an observation of the chronology of incidents that affected the quality of the environment. In order to gain more information about measuring pollution by utilizing sensors and the situation of toxic waste dump on the outskirts of the city, the team participated at lectures and met with various professionals. The dissemination and communication strategy included written articles, press releases, radio and TV shows, and announcements on social networks (Facebook and Instagram).

Through all these activities, the endeavor became more than a school project, it actually led to becoming a community project. The students learned how to conduct research on real-life issues in collaboration with representatives of the community, with the support of partner organizations, experts, and other stakeholders.

A public opinion survey revealed that the locals (approx. 90%) believe that air pollution is their city's worst type of pollution. Therefore, the team created an online map that tracks real-time data transmitted by air pollution measurement sensors. The Pollution Map is an application built on Node.js as an event-driven asynchronous JavaScript runtime (http://hartapoluarii.herokuapp.com/harta1). The map was designed to permanently and in real time inform the citizens about the air pollution levels in the city. The website will become an important tool of ecological education, it will strengthen the social cohesion of the inhabitants and it will inform and encourage the implementation of various small projects focusing on the environment. Moreover, the project has great potential for sustainable replication.

The key message of the school-based project is that a better-quality atmosphere benefits people's health. The well-being of a community is defined by social unity and the sharing of common values. The team tried to highlight one of these values: respect for the environment. Thus, many of the sensors are located in schools, so the team will carry out ecological education actions together with the students of those schools. They will teach them how to monitor and research data received from sensors and they will identify together solutions to improve air quality in their city.

CONCLUSIONS

Current internal assessment of PULCHRA outcomes is promising and worth being more in-depth documented and piloted in new environments (new education systems, new education levels). Beyond increasing the motivation for STEM learning activities identified among students, the project offers evidences of positive impact on specific areas, such as:

(a) Bringing new scientific knowledge for the city as an urban ecosystem and facilitating participation of citizens of all ages in scientific discovery.

(b) Building trust in the method of science through the own experience of participation.

(c) Establishing concepts to link the natural environment, the built environment and the socio-economic environment in order to form a learning, exploring and activation network, which allows to experience and understand the urban ecosystem as a living organism.

(d) Developing knowledgeable, innovative and participatory communities able to cope with and actively contribute to addressing current and anticipated problems and challenges at the city scale.
The project created the conditions of transferring in general schools the much-needed scientific know-how, offering to students and teachers new, hands-on learning contexts. It also demonstrated the feasibility of building a bridge between competences developed in the school context and active use of them/transfer in real-life situations. PULCHRA is not an extra-curricular project, working in addition to current learning activities, but rather a curriculum embedded approach, extended to families and communities and making the learning experience participatory and wider, using the urban environment as the realm of exploration.

The key elements of project added value documented by internal evaluation are related to: its innovative character (promoting STEM education by exploiting the concept of urban ecosystems, and embracing a new look to cities and their functions); the clear and logical interrelation of objectives/activities/outputs; participative approach, promoting external expertise; measurability and replicability of solutions developed in the framework of the project throughout European education systems.

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