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D3.4 Consolidation of results and success stories. Edited volume with case studies.

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List of abbreviations

AMU	Adam Mickiewicz University
CTI	Computer Technology Institute and Press "Diophantus"
INESC-TEC	Institute for Systems and Computer Engineering, Technology and Science
ISEL	Instituto Superior de Engenharia de Lisboa
KPI	Key Performance Indicator
PAFSE	Partnerships for Science Education
PRP	Portuguese Road Safety Association
STEM	Science, Technology, Engineering, Mathematics
UOI	University of Ioannina
UCY	University of Cyprus
UMINHO	University of Minho
UNL	NOVA University of Lisbon
WP	Work Package

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1. Summary

Deliverable D3.4 (D3.4) is a compendium of case studies on enactments, supplemented by two theoretical contributions that elucidate the theoretical and conceptual underpinnings of health education and research, emphasizing public health education.

Each Local Partnership organized a case study to monitor and evaluate the enactment of their learning scenarios. This deliverable involves 8 case studies which PAFSE partners developed and evaluated offering insights into, and overviews of the educational scenarios' design, development, implementation, and validation within the PAFSE project stages, through case study approaches and field reports. Each partner was free to choose their own case study focus, but each case study report should include the following:

- a rich description of the school and community context
- the rationale and the procedures of educational scenario development and implementation
- the research plan (research questions, research methods, research tools)
- the research data collected during the enactments
- the ensuing implications for the effectiveness of the educational scenarios
- how those implications will be considered in revising the educational scenario
- suggestions for possible amendments to the educational scenario
- a section with lessons learnt for future enactments.

The case studies of the PAFSE Deliverable 3.4 offer furthermore detailed insights in the theoretical background – the "philosophy" – of the PAFSE project and the pedagogical approach the consortium agreed on and follows. The main theoretical pillars of PAFSE are inquiry and project -based learning, public health socio-scientific issues, and open schooling model. Collaboration of diverse stakeholders and perspectives is an essential part of the open schooling framework, which aims at bringing together various stakeholders to create a local community of educators and a support network for promoting responsible citizenship, sustainable health education and community preparedness for pre-empting and managing risks, as well as to enrich Science, Technology, Engineering and Mathematics (STEM) education, through multi-disciplinary project-based-learning approaches on public health issues.

Case studies' evidence was collected with (i) classroom observations, (ii) interviews with the students, the teacher, the researcher and other participants in the enactment (depending on the scenario); (iii) student

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constructed digital artefacts and their project descriptions, including the data they collected; (iv) students' responses to formative and summative assessment tasks; (v) materials related to the public debate event, including the initial and updated recommendations for community preparedness.

Case Studies within PAFSE stages:

1. University of Ioannina (UOI) case study is entitled: *The contribution of digital learning objects to public health education.*

UOI case study aims to better understand how diseases spread, particularly from an epidemiological perspective, and their connection to the PAFSE framework, which strives to enhance community preparedness and reduce the risk of contagious diseases and epidemics, providing special emphasis on Digital Learning Objects (DLOs)

2. University of Cyprus (UCY) case study is entitled: *Cypriot parents' and secondary school students' views and perspectives on an open schooling model regarding public health education.*

UCY case study aims to investigate Cypriot parents' and lower secondary school students' views and perspectives on an open schooling model regarding public health education, through the implementation of specially designed Educational Scenarios based on an open schooling model for inquiry-based learning in the context of public health socio-scientific issues.

3. NOVA University of Lisbon (UNL) case study is entitled: *Open Schooling and Attitudes towards Science, Technology, Engineering and Mathematics (STEM): A Case Study on the implementation of Educational Scenarios focusing on Public Health.*

UNL case study aims to investigate lower secondary school students' attitudes towards science and STEM curricula influenced by the implementation of specially designed Educational Scenarios that comprise inquiry-based learning in the context of open schooling.

4. University of Minho (Uminho) case study is entitled: *Fostering public health prosumer students through low code learning*

The goal of this case study is to conceptualize a workflow that uses low code learning to promote students' public health awareness and equip them to become informed and engaged contributors to their communities.

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5. Institute for Systems and Computer Engineering, Technology and Science (INESC-TEC) case study is entitled: *A project-based learning approach on 3D printing for public health: a case study on three schools of the northern interior of Portugal.*

INESC-TEC case study aims to develop and implement an Educational Scenario regarding 3D printing that uses project-based learning to address these topics, strengthening the capacity of students in low secondary level and their schools to promote Science, Technology, Engineering, Mathematics (STEM) learning with a focus on public health issues.

6. Instituto Superior de Engenharia de Lisboa (ISEL) case study is entitled: *Potential of a project-based learning in terms of its ability to capture students' interest in the study of STEM areas: A Case Study on the implementation of Educational Scenarios focusing Public Health*

The goal of this case study is to investigate the potential of a project-based learning in terms of its ability to capture low secondary students' interest in Science, Technology, Engineering, Mathematics (STEM) learning with a focus on public health issues.

7. Portuguese Road Safety Association (PRP) case study is entitled: *The impact of a research project-based learning approach on secondary school students' knowledge, risk perception, attitudes, and behaviour in relation to road safety.*

The goal of this study is to assess if the involvement in the data-driven science project as part of the educational scenario "Road traffic crash risk factors" increased the knowledge of road safety and lead to safer behaviours in traffic.

8. Adam Mickiewicz University (AMU) case study is entitled: *Students' developed arguments for nutrition as a public health issue in Biology education in Polish schools – case study.*

AMU case study aims to support argumentation skills about fast food consumption.

The case studies of the PAFSE suggest that the PAFSE proposed theoretical framework, actions and activities can contribute to the responsible citizenship and literacy of students and citizens on a set of public health threats that need to be addressed through coordinated action, with a focus on epidemics. Other challenges such as childhood obesity, tobacco smoking, chronic diseases, climate change, road accidents and vaccine hesitancy are included and discussed (https://pafse.eu/).

Theoretical contributions

The theoretical contributions of this compendium describe the theoretical and conceptual underpinnings of

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health education and research, emphasizing public health education. The first theoretical contribution of this compendium entitled *Enhancing Public Health by Advancing Health Literacy and Health Education* addresses the concepts of public health, health literacy and health education and the relationships among them. The second contribution entitled *Using Controversial Public Health Socio-scientific Issues in Health Education in a Post-Truth Era: Theory, Research and Practice* describes features of controversial socio-scientific issues teaching and learning environments and their impact on health education in a post-truth era.

2. Document history and co-authorship

This document is Deliverable 3.4. (D3.4) collection of case study reports and two theoretical contributions. Each local Partnership analytical case study reports on enactment and evaluation of educational scenarios. These are synthetic texts that provide interpretations on the partnership experience of enacting educational scenarios. This document is the first version of D3.4 to be available in month 34 as PAFSE deliverable.

Version	Date	Released by	Notes
1.0	21.06.2024	Andreani Baytelman (UCY), Costas Constantinou (UCY)	First version

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3. Case Study Reports and Theoretical Contributions

This document includes 8 case study reports and 2 theoretical contributions: The PAFSE partners of the different case studies and theoretical contributions come from the following countries and belong to the listed institutions:

- Greece: University of Ioannina (UOI) case study is entitled: The contribution of digital learning objects to public health education.
- Cyprus: University of Cyprus (UCY) case study is entitled: Cypriot parents' and secondary school students' views and perspectives on an open schooling model regarding public health education.
- Portugal: NOVA University of Lisbon (UNL) case study is entitled: Open Schooling and Attitudes towards Science, Technology, Engineering and Mathematics (STEM): A Case Study on the implementation of Educational Scenarios focusing on Public Health.
- Portugal: University of Minho (Uminho) case study is entitled: Fostering public health prosumer students through low code learning.
- Portugal: Institute for Systems and Computer Engineering, Technology and Science (INESC-TEC) case study is entitled: A project-based learning approach on 3D printing for public health: a case study on three schools of the northern interior of Portugal.
- Portugal: Instituto Superior de Engenharia de Lisboa (ISEL) case study is entitled: Potential of a project-based learning in terms of its ability to capture students' interest in the study of STEM areas: A Case Study on the implementation of Educational Scenarios focusing Public Health.
- Portugal: Portuguese Road Safety Association (PRP) case study is entitled: The impact of a research project-based learning approach on secondary school students' knowledge, risk perception, attitudes, and behaviour in relation to road safety.
- Poland: Adam Mickiewicz University (AMU) case study is entitled: Students' developed arguments for nutrition as a public health issue in Biology education in Polish schools – case study.
- Cyprus: University of Cyprus (UCY) theoretical contribution is entitled: Enhancing Public Health by Advancing Health Literacy and Health Education.
- Cyprus: University of Cyprus (UCY) theoretical contribution is entitled: Using Controversial Public Health Socio-scientific Issues in Health Education in a Post-Truth Era: Theory, Research and Practice.

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3.1. University of Ioannina (UOI) – Case Study Report

The contribution of digital learning objects to public health education

INTRODUCTION

Digital Open Educational Resources (DOERs) play an important role in technology enhanced learning.
UNESCO defines OERs as “learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others” (https://www.unesco.org/en/open-educational-resources).

Digital Learning Objects (DLOs) are DOERs of a specific aggregation level and certain properties. DLOs can be defined as “small, self-contained, reusable and pedagogical complete structure of learning content” (Topali & Mikropoulos, 2018) and can be accessed through their metadata in open repositories.

The properties of DLOs, which make them different than the other OERs are assembled as reusability, granularity, interoperability, accessibility, adaptability, discoverability, durability, manageability, and generativity (Gürer, 2013).

DLOs for science education encompass a broad spectrum of resources such as dynamic models, simulations and visualizations, dynamic representations, virtual experiments, mini games, dynamic concept maps, micro-environments, and assessment tools.

DLOs contribute to positive learning outcomes in general and special science education (Lockyer et al., 2008). DLOs together with other DOERs are often incorporated into educational scenarios to support teaching and learning processes. Depending on their type, DLOs are used in various teaching stages. In inquiry-based learning DLOs are used in all stages namely orientation, conceptualization, investigation, conclusions, and discussion phases. DLOs support mainly the learning activities incorporated into educational scenarios and contribute to learning benefits (Mallidis-Malessas, Iatraki, & Mikropoulos, 2022).

There are many DLOs referring to STEM fields (Sciences, Technology, Engineering, Mathematics), but there is a lack of DOERs and DLOs to support integrated STEM approaches as well as public health education. Literature highlights the positive contribution of DLOs in medical and public health education and indicates the necessity for the development of purposeful DLOs in this field (Ruiz, Mintzer, & Issenberg, 2006; Ren et al., 2015). This led us to design DLOs for public health education to support relevant educational scenarios and be used in other relevant learning activities too.

CONCEPTUAL FRAMEWORK

Inquiry-based learning is an efficient instructional model in science education research and practice. The contribution of inquiry-based learning is enhanced by the use of digital learning environments (Pedaste et al., 2015). Open learning environments, which implement inquiry and project-based learning educational scenarios using DLOs seem promising in science education (de Jong et al., 2012). The project PAFSE contributes “to community preparedness to reduce the risk of communicable disease and epidemics”. This aim, among other activities, involves the design and enactment of educational scenarios that promote STEM education fields and follow the above-

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mentioned principles of inquiry and project-based learning. Public health education, especially in periods of epidemics and pandemics, is important for schools and relevant stakeholders (Li et al., 2020). Teaching about infectious diseases to K-12 students has become urgent but it is rare. Researchers highlight the importance of teaching and learning "both the scientific understandings of epidemiologic disease spread and the socio-scientific issues around scientific knowledge" (Kafai et al., 2022). Topics such as communicable diseases, their evolution, prevention, vaccination, and social determinants of health seem important for relevant educational interventions at schools in an open schooling approach.

RESEARCH QUESTIONS

The absence of evidence in areas like public health education in K-12, technology-enhanced learning environments, and inquiry and project-based teaching methods gives rise to three important research questions. These questions aim to better understand how diseases spread, particularly from an epidemiological perspective, and their connection to the PAFSE framework, which strives to enhance community preparedness and reduce the risk of contagious diseases and epidemics.

1. Which are the guidelines for the design of inquiry and project-based educational scenarios for public health under a certain STEM approach?
2. Which are the guidelines for the design of Digital Learning Objects for public health education?
3. How do teachers use Digital Learning Objects to raise student awareness about ways to mitigate the risk of communicable diseases?

METHODS AND CONTEXT

Context

The literature review has indicated four topics of interest relevant to public health that could be transferred into educational scenarios and led us to the guidelines for their design.

The first scenario refers to the mathematical representation of an epidemic:

- SIR (Susceptible, Infectious, or Recovered) modelling to describe an epidemic and as a case to be used in authentic scientific research.
- Visualization and active inquiry of epidemiological parameters such as cases, deaths, asymptomatic cases, infectivity, healthcare system capacity and the epidemic curve, which are commonly referred to in the public sphere, during an epidemic.
- The decisive importance of non-pharmaceutical interventions during an epidemic, to prevent the spread of communicable diseases.
- Understanding of the decisive importance personal behavior has for the public benefit during an epidemic.

The second scenario concerns the social determinants of health during an epidemic or pandemic:

- The concept of health does not depend only on medical and biological factors.
- Social determinants of health during an epidemic or a pandemic consist of a dimension that is often undermined in science education or STEM courses.
- The comprehension of the connection between science and society, as well as the social embedding of science, is crucial.
- Social and health disparities pose a serious issue in public health promotion.
- Social determinants of health in health-related decision-making are necessary for health promotion in personal and societal level.
- The major problem of the origin of emerging infectious diseases is integrated in the context of the One Health Approach.

Students with disabilities also have to understand cognitive and affective determinants of health during an epidemic or pandemic, enacting a scenario:

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- Students with Intellectual Disabilities (ID) have to acquire relevant scientific knowledge.
- Policies and practices based on evidence-practice that contribute to social disparities reduction regarding health are important for students with ID.
- Awareness and new standards of social behavior have to be developed.
- Measures of prevention and reduced anxiety of co-occurring health problems and social isolation for people with ID are crucial.
- Science and society promotion, social justice, equal participation, accessibility are pivotal issues.

The fourth scenario refers to vaccines, vaccine hesitancy and misinformation:

- Education regarding vaccination, throughout the entire history of medicine is important.
- Herd immunity and the notion that vaccination is not just concerned with the individual health condition of the vaccinated, but also the public health of the whole community.
- Vaccination is an act of solidarity and protection towards people who cannot get vaccinated due to health issues.
- Confrontation of a modern threat to public health (vaccine hesitancy) is usually due to incomplete information or misinformation.
- Evaluation of the trustworthy of health information, is a skill of vital importance for public health as shown by the vast amount of misinformation (infodemic) during the COVID-19 pandemic.

Development of the educational scenario

In the context of the HORIZON 2020 project "Partnerships for Science Education – PAFSE" (https://pafse.eu/), the research team from the University of Ioannina has designed and developed four educational scenarios following the guidelines presented above, as well as numerous DLOs closely related to the scenarios. Both scenarios and DLOs can be found at the "Photodentro" open repository of the project, https://photodentro.pafse.eu/.

Table 1 shows the final versions of the scenarios developed and internally evaluated. They consist of three scenarios with their two versions, and one scenario for students with Intellectual Disabilities.

Table 1. The educational scenarios developed by UOI.

	Title of educational scenario	**URL**
1h	The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling (high school version)	https://photodentro.pafse.eu/handle/8586/266
1s	The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling (senior high school version)	https://photodentro.pafse.eu/handle/8586/178
2h	Social determinants of health during an epidemic/pandemic outbreak (high school version)	https://photodentro.pafse.eu/handle/8586/267
2s	Social determinants of health during an epidemic/pandemic outbreak (senior high school version)	https://photodentro.pafse.eu/handle/8586/180
3	Cognitive and affective determinants of health during an epidemic/pandemic outbreak for students with Intellectual Disabilities	https://photodentro.pafse.eu/handle/8586/176
4h	Function of vaccines, vaccine hesitancy and misinformation (high school version)	https://photodentro.pafse.eu/handle/8586/268

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4s	Function of vaccines, vaccine hesitancy and misinformation (senior high school version)	https://photodentro.pafse.eu/handle/8586/182

The educational scenarios involve learning activities which are supported by DLOs and other Digital Open Educational Resources (DOERs). The DLOs developed follow the DLOs properties, which differentiate them from general type DOERs, and are based on the following guidelines:

- they are pedagogical documented
- they imply and support certain instructional needs
- they avoid alternative ideas and misunderstandings
- they are based on current and pedagogical mature digital technologies
- they are user friendly and easy to use.

Table 2 shows the DLOs developed and used in each one of the scenarios.

Table 2. DLOs used in the scenarios enactments

	Title of educational scenario	**URL**
1	The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modeling (high school version)	'Global map of communicable diseases' (interactive map) http://photodentro.pafse.eu/handle/8586/44 'Map and timeline of communicable diseases'(interactive map and timeline) http://photodentro.pafse.eu/handle/8586/34 'SIR model of an epidemic' (model and simulation) http://photodentro.pafse.eu/handle/8586/49 'SIR model of an epidemic and non-pharmaceutical interventions' (model and simulation) http://photodentro.pafse.eu/handle/8586/35
2	Social determinants of health during an epidemic/pandemic outbreak (high school version)	'Concept mapping about the social determinants of an epidemic' http://photodentro.pafse.eu/handle/8586/32 'Concept map tool' http://photodentro.pafse.eu/handle/8586/32?&locale=en 'Map concerning the origin of communicable diseases' http://photodentro.pafse.eu/handle/8586/170 'Social determinants of epidemics' (micro-environment) http://photodentro.pafse.eu/handle/8586/239 'Health-related decision-making during an epidemic' (role game) http://photodentro.pafse.eu/handle/8586/240 'Health and social inequities among European countries' (interactive map) https://health-inequalities.eu/el/toolbox/interactive-map/
3	Cognitive and affective determinants of health during an epidemic/pandemic outbreak for students with Intellectual Disabilities	Concept map COVID 19 http://photodentro.pafse.eu/handle/8586/40 Concept map of symptoms COVID-19 http://photodentro.pafse.eu/handle/8586/41 Concept map of the transmission of COVID-19 http://photodentro.pafse.eu/handle/8586/42

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		Dynamic Infographic COVID-19 http://photodentro.pafse.eu/handle/8586/43
4	Function of vaccines, vaccine hesitancy and misinformation (high school version)	'Table of the learning procedure about vaccines' (KWL table) http://photodentro.pafse.eu/handle/8586/50 'Mechanisms of specific immune response' (dynamic visualization) http://photodentro.pafse.eu/handle/8586/242 'Concept map about the immune response' (semi-structured concept map) http://photodentro.pafse.eu/handle/8586/148 'Function of vaccine types' (dynamic visualization) http://photodentro.pafse.eu/handle/8586/172 'Concept map about vaccines' (semi-structured concept map) http://photodentro.pafse.eu/handle/8586/157 'Parameters affecting herd immunity' (simulation) http://photodentro.pafse.eu/handle/8586/171 'Timeline of smallpox' (timeline) http://photodentro.pafse.eu/handle/8586/243 'Vaccine efficacies and adverse effects' (visualization) http://photodentro.pafse.eu/handle/8586/160 'Information and misinformation about vaccination' (micro-environment) http://photodentro.pafse.eu/handle/8586/241

Enactment(s) of the educational scenario

The first scenario focuses on the mathematical modelling of an epidemic - the SIR modelling - and the importance of non-pharmaceutical interventions for the promotion of public health. Students are initially introduced to the distinction between communicable and non-communicable diseases and express their conceptions about the function and importance of certain non-pharmaceutical interventions. Afterwards, they are concerned with various transmission routes and the way they affect the needed interventions. Through interactive maps and timelines students study the spatial and temporal evolution of endemic, epidemic and pandemic diseases in the past twenty years. Then, students are involved in successive inquiry processes, with a lot of scaffolding at answering the assigned questions at the beginning, but with complete independence in the end. During their inquiries students use three SIR simulations from the simplest to the more realistic one, and they study questions concerning the effect of epidemiological parameters (e.g., infectivity, incubation period, mortality, asymptomatics percentage), societal structure (existence of central locations, travelling and transport, healthcare system capacity) and non-pharmaceutical interventions (social distancing, quarantining, mask use, distance education) on the epidemic curve. Students, then, work in small groups and carry out a school project with three options. The first option is the design of a viable plan for the management of an epidemic outbreak by using the SIR models and authentic epidemic data. The second option concerns the input of authentic COVID-19 data to the SIR models and the comparison between the model outcomes and the real COVID-19 values. The third option is the development of a short-scale informative material targeting the general public, regarding the importance of applying non-pharmaceutical interventions during an epidemic. Student groups present their work and findings to one another and discuss about them.

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The second scenario focuses firstly on the social determinants of health during an epidemic, and secondly on some environmental issues concerning communicable diseases, with emphasis on the recent COVID-19 pandemic. Initially, students express their views and attitudes towards the social and environmental determinants of communicable diseases via filling in a short questionnaire and constructing a graphic organizer (concept or mind map). A first discussion on students' initial ideas follows. Afterwards, they study the origin of communicable diseases, with emphasis on recent epidemics and pandemics. They realize their animal origin and correlate it to our modern lifestyle. Then, students critically read some selected information sources (texts, videos and infographics) and study the ways in which social inequities lead to health inequities. Students adopt the role of a citizen with specific personal and societal features (e.g., gender, age, profession, educational level etc.) in a role game, in which they apply what they have learnt during the previous teaching phases. The roles that students adopt will probably be quite distant from themselves. They have to describe the role's personal experience of an epidemic, make health decisions and put values in a scale according to the role's experience of the epidemic. Students put the values in a scale according to their personal criteria, as well. Then, they move on to the school project phase, during which they design a questionnaire and conduct short social research via the Internet on the effect the COVID-19 pandemic had on the local society. They try to bring the citizens' personal experiences of the pandemic to the surface, and especially the way the pandemic affected their way of living. Students design the questionnaire, collect and handle quantitative or qualitative data by using proper techniques and present the project findings in a school festival or even communicate them to the local society.

The third scenario concerns a cognitive approach that used a structured inquiry model with supplemental elements of task analysis, time delay and prompting for small group of students. All the phases of inquiry are applied through a single subject design (baseline, intervention, maintenance, generalization) which is supported through digital educational resources and digital learning objects. Students with ID are introduced in scientific oriented questions regarding infectious diseases. Dynamic simulations contribute to the improvement of students understanding about viruses and vaccination. In addition, students apply social and decision-making skills in a problem-solving experience designed on an educational game. Completing the learning process, students conduct a guided project and produce an infographic presenting and communicate new knowledge and skills.

The fourth scenario focuses on vaccination and particularly on the topics of the mechanism by which vaccines work, the types of vaccines, herd immunity, the eradication of infectious diseases and the misinformation about vaccines. Students are initially shown some facts concerning vaccination and its importance aiming at their more effective engagement in the learning process. Students' initial conceptions are detected with a questionnaire, and they express, then, their expectations from the learning sequence. For the following two hours students are given the necessary conceptual background regarding microorganism biology and immune response mechanisms so that a meaningful conceptualization of vaccination is feasible. For this reason, students make use of a great variety of digital educational resources with emphasis on the visualization of the phenomena examined. Afterwards, students are familiarized with the mechanism with which vaccines function and the different types of vaccines used. They are assigned to match pathogen cases to the more appropriate vaccine types. For the next hours, students are concerned with the importance of vaccination for public health through the phenomenon of herd immunity. Students actively handle simulations by testing parameters that affect the achievement of herd immunity (disease transmissibility, vaccination coverage and vaccine efficacy) and find the critical vaccination coverage point for herd immunity for authentic disease cases. They also study the mechanism with which the application of mass vaccination programs on children can lead to the eradication of a

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disease, and the case of smallpox eradication is mentioned, as well as the reemergence of measles due to reduction in vaccination coverage. Students compare the harshness and the frequency of severe adverse effects of the vaccine with those that are caused by the disease itself and argue whether the vaccine adverse effects are a sufficient reason not to vaccinate. Afterwards, students are trained to recognize and discern medical misinformation texts from scientific texts. Students work in small groups to conduct a mini project. Each group can choose to take over either the making of a short informative guide regarding how one could detect misinformation texts about vaccines, or to prepare the launching of a short informative campaign for the general public, concerning vaccination necessity. The groups present the prepared material to the class and a self-reflective discussion concerning the learning sequence takes place.

Methods

Forty-five (45) high school teachers gave the evidence regarding the third research question (How do teachers use Digital Learning Objects to raise student awareness about ways to mitigate the risk of communicable diseases). Table three shows the number of teachers and their students per scenario.

Table 3. Teachers per scenario

	EDUCATIONAL SCENARIO	TEACHERS	STUDENTS
1	The mathematical representation of an epidemic: the case of SIR (Susceptible, Infectious, or Recovered) modelling	14	270
2	Social determinants of health during an epidemic/pandemic outbreak	11	358
3	Cognitive and affective determinants of health during an epidemic/pandemic outbreak for students with Intellectual Disabilities	1	22
4	Function of vaccines, vaccination hesitancy and misinformation	19	421

The empirical data gathered from a questionnaire which incorporated a series of closed and open-ended questions disseminated through lime survey. The teachers also made certain comments to the PAFSE researchers supervised the scenarios enactments.

RESULTS

Teachers reported that the teaching resources used during the scenario enactment were of high quality (58,5% strongly agree, 36,6% agree). This is corroborated by their opinion that the teaching-learning activities involved in the scenarios have quality (56,4% strongly agree, 41,0% agree), as well by the fact that it makes sense to allocate resources for the development and implementation of the teaching-learning activities (53,8% strongly agree, 41,0% agree).

The teachers' attitudes about the use of the DLOs are presented for each one of the four scenarios. Regarding the first scenario (table 3) the teachers reported that the SIR simulations gave them the opportunity to use a dynamic model to predict the evolution of an epidemic. This contributed to students' positive learning outcomes in cognitive, affective, and psychomotor domains. All the teachers who enacted this scenario, declared that the SIR model helped students understand the evolution of endemic, epidemic and pandemic diseases, make decisions on non-pharmaceutical interventions and raise student awareness about ways to mitigate the risk of communicable

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diseases. Teachers also mentioned that their students understood the way experts discuss the evolution of diseases, the way a mathematical model works. The scenario also gave a chance to teachers to teach concept mapping. The teachers applied interdisciplinary and transdisciplinary approaches and developed STEM skills.

After the enactment of the second scenario “Social determinants of health during an epidemic/pandemic outbreak” teachers highlighted the great value of the DLOs, namely the interactive maps, micro-environments and cognitive mapping tools. They also reported that their interaction with the DLOs make them and their students to deeply understand the value of the social parameters to the evolution of a pandemic. They also mentioned the need to teach concept mapping to their students since concept mapping is a strong tool to the instructional process. Students developed skills to manipulate simulations and empirical data, as well as soft skills such as working in groups, communication knowledge.

Students with intellectual disabilities found the specially designed DLOs easy to use and applied their knowledge interacting with dynamic concept maps and infographics.

As far as it regards the fourth scenario (table 3), the teachers reported that the simulations and visualizations contributed to students’ understanding on herd immunity. They highlighted that simulations are strong educational tools for understanding complex phenomena. The timeline and visualizations increased and sustained students’ interest in vaccines history and vaccination coverage. The DLOs helped students to read, comprehend and create diagrams, thus acquiring a qualitative and not only mathematical knowledge for natural phenomena. Teachers also reported that the DLOs contributed to the development of a scientific way of thinking, critical thinking, and the enhancement of their soft skills.

DISCUSSION AND CONCLUSIONS

The empirical evidence from the enactment of the four scenarios by the 45 teachers, indicated that the certain designs promote public health education in inquiry and project-based approaches through STEM fields.

The same holds for the design of the Digital Learning Objects used in the above scenarios.

The DLOs-enhanced learning activities offered teachers the cognitive tools for their students to manipulate physical magnitudes and social situations and understand complex phenomena. The DLOs contribute to the development of cognitive and soft skills. Especially, the interaction with simulations raised students’ awareness about ways to mitigate the risk of communicable diseases. Simulations also contributed to students’ discrimination between real world and the scientific way of studying reality.

Technology-enhanced learning in STEM fields and students-centered models seems to contribute to public health education and scientific literacy.

RECOMMENDATIONS

The discussions with the teachers led to certain recommendations.

Concerning the educational scenarios, teachers proposed lees hors because of the heavy school program.

Concerning the use of digital technology and DLOs, teachers recommend the extension of their use in other disciplines too. They base their recommendation to the fact that dynamic models, simulations, and visualizations offer interdisciplinary approaches and tools for deep understanding. Teachers also expressed their wish to study other topics of public health and well-being.

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3.2. University of Cyprus (UCY) – Case Study Report

Cypriot parents' and secondary school students' views and perspectives on an open schooling model regarding public health education

INTRODUCTION
The global health covid-19 pandemic has indicated the vulnerabilities and challenges humanity faces in terms of public health, as well as the significant role of education as a key factor in health and well-being (European Commission, 2022; World Health Organization (WHO) Europe, 2019). In particular, research evidence suggests that education in the form of formal, non-formal, and informal education can make a significant contribution to the promotion of public health, as it is the key actor that can inform, educate, and empower individuals and the community at large on issues related to physical and mental health prevention and care (McMahon, 2021; Stock, 2022). In the 21st century, the worldwide community is confronted with many complex public health issues which are multifaceted and subject to multiples perspectives and possible solutions. Educators need to prepare students and future generations to navigate and manage such complex issues as responsible citizens (Baytelman & Constantinou 2018; De Boer, 2011). A holistic approach to health, with an understanding of the action of the various factors that influencing and determining it and their interaction, can significantly assist in the promotion of public health, and addressing challenges and inequalities in public health. It is the belief of various public health experts that reducing health inequalities is mandatory, a promising investment, and achievable because of the strong public support (Abel, & McQueen, 2020; Mogford et al., 2011). *Partnerships for Science Education* (PAFSE) European project is a science education project that addresses the challenges of public health. Specifically, PAFSE explores *science education as a vehicle to provide citizens with knowledge, tools, and skills to make informed decisions on public health challenges. In addition, the project promotes community preparedness, by focusing on risk factors for the health condition of individuals, but also on the pre-emptive and protective behaviors from a personal and population perspective, contributing to more literate communities on healthy lifestyles, injury prevention, as well as detection, prevention, and response to infectious diseases* (http://www.pafse.eu/). Within the context of the PAFSE project, the open schooling model approach is very crucial. Within the open schooling model, various stakeholders employ an inquiry and project-based learning approach to address open-ended, ill-structured public health challenges. These challenges, often characterized by conflicting perspectives and multiple potential solutions, align with the characteristics of socio-scientific issues (as identified by Ratcliffe and Grace, 2003) and have been studied by various researchers (e.g. Baytelman & Constantinou, 2018; Baytelman et al., 2020; Zeidler, 2016; Zeidler et al., 2019). We employed inquiry and project-based learning because it is a student-centered, constructivist pedagogical approach. This approach promotes active student engagement in the learning process, fosters conceptual understanding, and develops higher order thinking skills, including critical and creative thinking (Pedaste et al., 2015; Sandoval, 2005), modeling, argumentation, communication, and cooperation skills (Minner et al., 2010; Baytelman et al., 2020). The teacher serves as a facilitator and guide, challenging students to think beyond their current understanding. This is achieved by providing guided questions, opportunities for reflection, and scaffolding (Anderson, 2002). The present case study aims to investigate Cypriot parents' and secondary school students' views

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and perspectives on an open schooling model regarding public health education, through the implementation of specially designed educational scenarios based on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues. This case study can contribute to the current literature on exploring and understanding how students and parents as civil society actors could participate meaningfully in the development of engaging an open schooling model as part of the school curriculum and promote responsible citizenship and public health.

CONCEPTUAL FRAMEWORK

PAFSE project approach is based on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues, promoting knowledge, skills, key competences related to public health, and Science, Technology, Engineering, and Mathematics (STEM), responsible citizenship, school-community interactions, active participation of students in community discourse.

The term "open schooling" first appeared in the European Commission's report "*Science Education for Responsible Citizenship*" in 2015. This report emphasized the need for science education to equip learners with the knowledge and skills to participate actively in society and make informed decisions about socio-scientific issues. Open Schooling was seen as a promising approach to achieve this goal, as it promotes collaboration, transparency, and public engagement in science education. https://op.europa.eu/en/publication-detail/-/publication/a1d14fa0-8dbe-11e5-b8b7-01aa75ed71a1. The concept of open schooling was further elaborated in the EU's Work Program 2016-2017 for the *Science with and for Society* action plan. This work program identified open schooling as a key priority for promoting responsible research and innovation (RRI). It called for the development of new Open Schooling practices and tools that would enable learners to collaborate with scientists, participate in research projects, and contribute to shaping the future of science and technology. https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-swfs_en.pdf. The EU's Work Program 2018-2020 continued to emphasize the importance of open schooling. This work program highlighted the need for open schooling practices to be inclusive and accessible to all learners, regardless of their background or abilities. It also called for the development of open schooling practices that address global challenges. https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-intro_en.pdf.

In general, within the context of an open schooling model, partnerships between teachers, students, researchers, professionals in enterprise, public and other stakeholders are very essential and promote work in real life challenges and innovations, prepare students to understand the complexity of various socio-scientific issues and develop citizenship responsibility and responsiveness into science education (European Commission, 2015). Furthermore, open schooling projects and initiatives promote the knowledge, practices, visions, attitudes, resources, and values of all stakeholders, empowering them to collectively transform society through a reflective and critical thinking, emphasizing sustainability, equity, social justice, and inclusion. Within this collaborative educational framework, students and parents assume key roles as active participants (European Commission, 2017; 2022; Li et al, 2020).

Inquiry-based learning is an efficient instructional model in science education research and practice. It refers to the active engagement of students in learning processes (Pedaste et al.; Schröder et al., 2007), promoting higher-order thinking skills such as critical and creative thinking (Sandoval, 2005), modelling and argumentation skills, communication, and cooperation skills

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(Minner et al., 2010). Additional, Inquiry-based learning refers to learning processes during which students ask questions about a particular domain, identify the problem, search, and evaluate information, generate testable hypotheses, plan methods, collect evidence, analyze data, draw conclusions, and communicate them (Pedaste et al., 2015; Sandoval, 2005). In such a learning process, the teacher becomes facilitator and guide, challenging students to think beyond their current processes by offering guided questions, scaffolding, and reflection opportunities (Anderson, 2002). Furthermore, researchers reported that classroom inquiry as well as school project can foster students' conceptual understanding of scientific concepts and phenomena, offer experiences with science, promote the development of an epistemological awareness of how science operates (Chinn & Malhotra, 2002) and develops positive attitudes towards science (Shymansky et al., 1983).

In particular, students engaging in inquiry and project-based learning activities, can understand that (i) scientific knowledge is constructed by people and not simply discovered, (ii) scientific knowledge is socially constructed, (iii) scientific methods are diverse depending on scientific disciplines, but rely in scientific standards (iv) scientific knowledge is tentative and can change as new observations, hypotheses, ideas, come to light (Sandoval, 2005). Such understanding about scientific knowledge, as well as reflection and explicit epistemological discourse can improve students' epistemological understanding (Baytelman et al., 2023a; Baytelman et al., 2023b; Sandoval, 2005).

A wide range of health issues can be categorized as socio-scientific issues (Ratcliffe & Grace, 2003), because they are open-ended, ill-structured problems, typically contentious and subject to multiple perspectives and solutions (Baytelman & Constantinou, 2018; Baytelman et al., 2018; Ratcliffe & Grace, 2003; Sadler & Zeidler, 2004; 2005b). The negotiation and resolution of them using inquiry and project-based learning is an important challenge for teachers and students. Engaging with Socio-scientific issues is a complex and difficult process, involving understanding and appreciation of the social and scientific dimensions of them, critical analysis of media reports (from where most of our daily information emanates) and other information sources, constructing arguments, evaluation of claims, making decisions at personal or societal level, consideration of values, and ethical and moral reasoning, and sometimes understanding of probability and risk.

Therefore, the negotiation and resolution of public health socio-scientific issues using inquiry and project-based learning is a pedagogical approach which connects science and society in the classroom (Levinson, 2010; Baytelman et al., 2018) and can promote conceptual and epistemological understanding related to public health, high order thinking skills, investigation skills (Baytelman, 2015; Baytelman et al., 2018; 2020; 2022; Sadler, 2004), a predisposition for engaging actively in citizenship (Levinson, 2010), as well as diversity, equity, and inclusion in science classroom (Abel, & McQueen, 2020).
In particular, PAFSE open schooling model for socio-scientific inquiry and project-based learning in the context of public health education aims to:

- Improve community public health and well-being by raising awareness, prevention and co-creating solutions to both personal and socially relevant public health socio-scientific issues that have a direct impact at a personal and community level.
- Enhance STEM education, a school curriculum, and a pedagogical framework by incorporating a variety of viewpoints and expertise from both educational and non-educational agents and institutions. This approach aims to facilitate meaningful learning and the development of competence among students.
- Empower all stakeholders, including students and their families both within and outside the school, by involving them in continuous inquiry, knowledge generation, creative initiatives,

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and communication. This collaborative effort aims to tackle public health socio-scientific challenges that are relevant not only to the local community but also extend beyond its boundaries.

RESEARCH QUESTIONS

Limited research on students, parents, teachers and other stakeholders' views and perspectives on an open schooling model for socio-scientific inquiry and project-based learning in the context of public health education gives rise to related research questions. In particular, we set out to answer three research questions:

- What are Cypriot parents' and lower secondary school students' views and perspectives on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues?
- Is there statistically significant difference between Cypriot parents' and lower secondary school students' views and perspectives on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues?
- Is there statistically significant difference between urban and rural schools' participants' views and perspectives on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues?

METHODS AND CONTEXT

Context

To address our research questions, we developed a rigorous workflow comprised of four distinct stages:

- Development of the educational scenarios,
- Teacher training courses – workshops,
- Implementation of the educational scenarios,
- Final open schooling event and data collection.

The development of the educational scenarios and the teacher training courses- workshops were carried out by Pafse researchers of University of Cyprus (UCY). The implementation of the educational scenarios used for this case study took place in 8 PAFSE pilot schools located in Cyprus, in rural and urban areas of the island, with students from 12-15 years old. The 8 PAFSE pilot schools for the pilot phase were selected after training of one hundred Biology secondary school teachers and Health Education teachers from various public schools of all regions in Cyprus. Teacher training involved an overview of the PAFSE program, its objectives, and the methodology of educational scenarios' development and implementation. For a teacher training workshops, we used the educational platform of the Cyprus Pedagogical Institute of Cyprus Ministry of Education. Our rationale for the selection of PAFSE schools was: (a) schoolteachers' and principals' interest in collaborating with the University of Cyprus and developing and implementing PAFSE educational scenarios.; (b) implementation of PAFSE educational scenarios in different social and economic contexts of Cyprus; (c) implementation of PAFSE educational scenarios in both urban and rural schools.

Three different educational scenarios were designed and developed by PAFSE team of UCY for the present study. The educational scenarios are the following:

- *Healthy Eating and Childhood Obesity: Challenges and Solutions.* This educational scenario is related to PAFSE topic: Looking after myself and others- Healthy Eating.

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- *Vaccines development and the science that responds to hesitancy.* This educational scenario is related to PAFSE topic: Looking out for my community.
- *Multiple dimensions of tobacco smoking.* This educational scenario is related to PAFSE topic: Looking after myself and others-Tobacco.

Our rationale for the choice of these scenarios was the following: (a) Over the past decade, issues like the safety and effectiveness of vaccines, the growing problem of childhood obesity, and student tobacco smoking have attracted increasing attention and concern in Cyprus, therefore students and other community stakeholders might have been more motivated to engage in a research project and thinking about these topics; (b) the socio-scientific issues related to the educational scenarios are complex and multidimensional and have different scientific, economic, political, cultural and ethical aspects, and are related to public health challenges that the local society of Cyprus has to address. ; (c) the educational scenarios are related to PAFSE topics; (d) the educational scenarios are related to Cyprus Biology and Health Education Curriculum for lower secondary school; (e) the educational scenarios can promote students' public health conceptual understanding, higher-order thinking skills, epistemological understanding and understanding about the complexity and multidisciplinary of public health socio-scientific issues, as well as interest in STEM education, responsible citizenship, and health literacy.

Obesity is one of the most serious global public health challenges of the 21st century, affecting every country in the world. In addition, it is a chronic disease and a major risk factor for the world's leading causes of poor health and early death, including cardiovascular diseases, several common cancers, and diabetes. In Cyprus, childhood obesity is a very serious problem. According to WHO, Childhood Obesity Surveillance Initiative (COSI) (2018), southern European countries have the highest rate of childhood obesity. In Cyprus, approximately 1 in 5 boys (ranging from 18% to 21%) are obese. Rates of obesity among girls are only slightly lower. (https://www.who.int/europe/news/item/24-05-2018-latest-data-shows-southern-european-countries-have-highest-rate-of-childhood-obesity). The main aim of this educational scenario is to raise 8th-grade students' awareness of rational nutrition and the health risks related to unhealthy eating and physical inactivity. Moreover, it aims to foster students' understanding of the role of the socioeconomic, political, ethical, and cultural environment in the rising prevalence of childhood obesity worldwide, increase the interest in STEM education and provide opportunities for critical health literacy and responsible citizenship. Another goal of this scenario is to promote students' epistemological understanding, high order thinking skills and communication and collaboration skills.

After the global health covid-19 pandemic, the hesitancy about vaccines and vaccinations, as well as questioning the way science works, the educational scenario related to vaccines development and the science that responds to hesitancy is truly relevant. The main goal of this educational scenario is to promote 9th-grade students' understanding on the relationships between microbes and infectious diseases, the human defense mechanisms against pathogens, vaccines development and how science responds to vaccine hesitancy, promoting high-order thinking skills, communication and collaboration skills and critical health literacy. Moreover, it aims to foster students' responsible citizenship, increase the interest in STEM education, promote students' epistemological awareness and understanding, high order thinking skills and communication and collaboration skills.

Currently, tobacco products are estimated to be responsible for three million deaths annually worldwide, or about 6% of all deaths. Tobacco is a known or probable cause of about twenty-five diseases; hence its impact on global disease is tremendous, if not yet fully appreciated (WHO,

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2021). The main goal of this unit is to promote 9th-grade students' understanding of the structure and function of the human respiratory system, the health effects of tobacco smoking, the biological, social, cultural, ethical, and economic dimensions of smoking, as well as the challenges of stopping smoking, increase the interest in STEM education, provide critical health literacy and responsible citizenships. Another goal of this scenario is to promote students' epistemological understanding, high order thinking skills and communication and collaboration skills.

Development of the educational scenarios

The educational scenarios development occurred over several steps informed by feedback from consortium partners, using specific criteria for peer-review of educational scenarios. Each educational scenario was designed to provide opportunities to promote understanding of fundamental concepts, phenomena, models and mechanisms of biological sciences and health education, epistemological awareness and understanding, critical STEM literacy, critical health literacy and critical scientific literacy, aspects in STEM instruction with a view to promote active responsible citizenship. Additional objectives of each educational scenario are to highlight the role of science for the establishment of public health, the conduction of authentic socio-scientific research by students (formulating hypotheses and specific research questions, collecting data from a variety of inquiry-based sources, analyzing, making inferences, synthesizing, drawing conclusions, and presenting appropriate research project) to promote the multidisciplinary implementation of health educational scenarios and effective health education. Another semantic objective is to create purposeful collaborations between schools and their broader communities. They have to work together to address local challenges, contribute to community public health.

Each educational scenario is based on an open schooling model for inquiry and project-based learning in the context of a public health socio-scientific issue, using different core teaching practices such as scientific modelling, conceptual mapping, socio-scientific argumentation, decision-making, socio-scientific research, and etc.

Within each educational scenario the following learning processes are put forward:

- Problem identification and contextualization using a local community public health socio-scientific issue.
- Knowledge, skills, and attitudes acquisition using inquiry-based learning activities.
- Conducting school project related to local community challenges of public health, with the participation of various community stakeholders.
- Documentation of students' project outputs.
- Sharing research outputs and experiences among students, parents, teachers, scientists, local community, and other stakeholders during an open schooling event.

Using a socio-scientific issue related to PAFSE topic, teacher and students should discuss the complexity and multidimensionality of each socio-scientific issue, the social risks, and the necessity to analyze such issues and potential solutions from the perspectives of different stakeholders. In addition, it is important to be discussed that many health issues have social dimensions, that cannot be addressed only by science and are considered socio-scientific issues.

The inquiry-based learning activities include adequate provisions for identification of students' preconceptions and alternative ideas (misconceptions) on concepts related to each health topic. Additionally, the activities allow students to work collaboratively in a guided inquiry approach, to investigate specific concepts and problems related to each topic and obtain a deep conceptual understanding about concepts, related mechanisms, and processes of each topic, as well as

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epistemological understanding about several aspects of nature of science, operation mode of science, and history of science. The learning activities are supported by Digital Learning Objects (DLOs) and other Digital Open Educational Resources (DOERs), as well as by pieces of scientific information, which is provided in the form of text, diagrams, models, infographics, historical reports, biographies, conceptual maps, geographical maps, etc.

In this learning process, the teacher becomes facilitator and guide, challenging students to think beyond their current processes by offering guided questions, scaffolding, and reflection opportunities (Anderson, 2002). Students work in groups cooperatively and the teacher moves around the classroom asking reflective and supportive questions and giving feedback. When the students finish activities using specific worksheets, the teacher facilitates a whole-class discussion and provides feedback based on completed worksheets.

To answer the primary research questions of each scenario of PAFSE school project, students are asked to formulate hypotheses and specific questions, to collect data from a variety of inquiry-based sources (e.g. such as texts, articles, pictures and videos, tables and diagrams, simulations, and scientific measurements), conduct interviews, design a questionnaire in collaboration with other community stakeholders (social research tool).

During this process, students work in group cooperatively and could experience how scientists usually work and realize that scientific work does not only include conducting experiments but also includes searching for data and evaluating sources and information, and/or making scientific models. Additionally, they could realize that various socio-scientific issues are multifaceted with multiple perspectives and workable solutions. Teachers' competences on coordinating and facilitating inquiry and project-based learning processes are particularly important and essential. The school project is based on guided research. The project activities should be supervised by the teachers and developed by the students, with scheduled moments for checking the work development. In particular, the role of the teacher was to coordinate students, stating explicitly the aims of each task or reformulating and adapting new key questions in order to help them to find their own learning path. Furthermore, the teacher's role as a facilitator focuses on promoting a gradual development of students' learning autonomy, when questioning, thinking, planning, reflecting, interacting, discussing, and gradually developing conceptual frameworks through the active participation in tasks.

Involvement of stakeholders in a bottom-up process, involvement of civic society actors or the public in general was a significant practice for each PAFSE school project in order to debate public health socio-scientific issues. Additionally, visits to organizations interested in STEM education and public health education could be organized, as well as a conference with STEM professionals. The conference could be organized at the school or stakeholders' location and promotes an interaction between students and STEM professionals, such as medical experts, policy makers, public health authorities, scientists working on urban and environmental health, researchers of PAFSE consortium, parents etc. Using such practices, schools in cooperation with other stakeholders become an agent of community public health and well-being. Parents were particularly encouraged to become real partners in school projects and activities through answering questionnaires, giving interviews, or sharing their experiences and expertise. Professionals from enterprise, civil and wider society could also be involved in bringing real-life projects into the classroom.

Students, after completing their research project, designed, and conducted an open schooling event (final public event). During open schooling events, students communicated their research

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project outcomes and distributed public health brochures among the event participants. They emphasized, among others, the importance of the interconnection between health and society (the notion of social determinants of health), and the participation in civic collective actions for the promotion of public health.

Additionally, open schooling event serves as a platform for engaging with students in schools, parents, teachers, scientists, members of civic society and local community as well as policy makers, facilitating discussion about the results of students' research project, debate, reflection, possible collaborations, and future initiatives.

Both PAFSE educational scenarios and related Learning objects and activities used by the PAFSE school students can be found at the "Photodentro" open repository of the project, https://photodentro.pafse.eu/. Table 1 shows the URL of final versions of the educational scenarios, as well as related learning objects and activities used for this case study.

Table 1. The educational scenarios and related learning objects and activities used for this case study.

	Title of educational scenario	URL
1.	Healthy Eating and Childhood Obesity: Challenges and Solutions.	https://photodentro.pafse.eu/handle/8586/185 https://photodentro.pafse.eu/handle/8586/414
2.	Vaccines development and the science that responds to hesitancy.	https://photodentro.pafse.eu/handle/8586/184 https://photodentro.pafse.eu/handle/8586/416
3.	Multiple dimensions of tobacco smoking	https://photodentro.pafse.eu/handle/8586/186 https://photodentro.pafse.eu/handle/8586/418

The educational scenario on the topic: Looking after myself and others- Healthy Eating and childhood obesity

This educational scenario is an integrated learning module in Public Health Education related to the PAFSE topic *Looking after myself and others- Healthy Eating,* and Cyprus Biology Curriculum for 8th-grade students.

A socio-scientific topic entitled *Healthy Eating and Childhood Obesity: Challenges and Solutions* provided the context for the educational scenario and the primary research questions related to the learning PAFSE topic: *Looking after myself and others- Healthy Eating*.

Socio-scientific issue:
8th-grade students, often, share their opinions, habits and experiences on health and nutrition issues on a google blog, which is often visited by their friends and classmates. Last week four students posted various statements related to health and nutrition issues. Specifically, in their posts they wrote the following:
Georgia: For the last three years I have made tremendous efforts to lose weight, but I have not succeeded. Now I have decided to go vegan, hoping to succeed.
Vasiliki: I do not want to gain extra kilos, so I decided to avoid several types of food and to eat more frequent meals.
Anastasia, reading the posts of her classmates, wrote the following on the blog: the issue of healthy eating and obesity is much more complicated. During a visit to my pediatrician, I heard

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that television advertising of unhealthy food is also a cause for childhood obesity.
George also reacted to his classmates' posts by blogging the following: On a scientific website on healthy eating, I read that the main causes of obesity are related to an individual's personal dietary choices and lifestyle, but also to the socio-economic and political conditions of the area where he/she lives.

The primary research questions of this educational scenario are the following:

- What are the causes, health risks and solutions related to childhood obesity?
- What are individuals' and governments' responsibility for reducing childhood obesity?
- What are the community's perceptions and knowledge concerning childhood obesity?

The evaluative tasks for the educational scenario on the topic *Looking after myself and others-Healthy Eating* were the following:

- Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment)
- Worksheets evaluation (Formative assessment)
- Evaluation of the development of a predictive model of childhood obesity
- Creation of a scientific presentation and a scientific poster on the topic: *Childhood Obesity: Challenges and Solutions.*
- Create a public health brochure promoting healthy eating (Formative and summative assessment).
- Post-test (Final/ summative assessment).

Parents and other stakeholders were encouraged to become real partners in school projects and activities through answering questionnaires, giving interviews, or sharing their experiences and expertise.

The educational scenario on the PAFSE topic: Looking out for my community-Vaccines and vaccinations
This Educational Scenario is an integrated learning module in Public Health Education related to the PAFSE topic: *Looking out for my community-Vaccines and vaccinations,* and Cyprus Biology Curriculum for 9th-grade students.

A socio-scientific topic entitled *Vaccines development and the science that responds to hesitancy* provided the context for the educational scenario and the primary research questions related to the PAFSE learning topic *Looking out for my community-Vaccines and vaccinations.*

Socio-scientific issue:
When a person becomes infected with a virus, the immune system responds to an attack of the virus, so the infected person does not get too sick. Recently, as a new virus spread rapidly around the world, businesses and schools have closed to limit its impact. Pharmaceutical companies are racing to develop a vaccine, and one candidate has passed rigorous tests. However, this vaccine's efficacy rate is only around 50%, meaning it offers some level of protection, but vaccinated individuals are still nearly as likely to get sick as unvaccinated ones. Despite this, the pharmaceutical company argues for its distribution to offer some protection and pave the way for normalcy. Government officials, eager for economic recovery, are inclined to agree. However, public health workers raise concerns that such a low-efficacy vaccine might make people less vigilant about preventative measures like avoiding large gatherings or wearing masks, especially considering many already express concerns about getting vaccinated at all.

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The primary research questions of this educational scenario are the following:

- How do vaccines influence the progress of an epidemic and a pandemic?
- What are the local community's perceptions and knowledge concerning immunity and vaccination?
- Should a low efficacy vaccine be released to the public? (Debate).

Evaluative tasks for the educational scenario on the PAFSE topic: *Looking out for my community-Vaccines* and vaccinations are the following:

- Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment).
- Worksheets evaluation (Formative assessment).
- Post-test (Final/ summative assessment).
- Evaluation of a public debate on the topic: Health and Vaccines: Should a low efficacy vaccine be released to the public?
- Creation of scientific presentation with the results of the research questions on the PAFSE school project: *Vaccines development and the science that responds to hesitancy.*
- Creation of a public health brochure explaining vaccines and vaccinations (Formative and summative assessment).
- Post-test (Final/ summative assessment).

Parents and other stakeholders were encouraged to become real partners in school projects and activities through answering questionnaires, giving interviews, or sharing their experiences and expertise.

The educational scenario on the PAFSE topic: Looking after myself and others - Substance Tobacco

This Educational Scenario is an integrated learning module in Public Health Education related to the PAFSE topic: Looking after myself and others - Substance Tobacco Cyprus Biology Curriculum for 9th -grade students.
A socio-scientific topic related to biological, social, cultural, economic, and ethical dimensions of tobacco smoking provides the context for the inquiry-based primary research questions related to the learning topic: *Looking after myself and others: Substance Tobacco*.

Socio-scientific issue:
Tobacco has been growing wild in the Americas for nearly 8000 years. Around 2,000 years ago tobacco began to be chewed and smoked during cultural or religious ceremonies and events. The first European to discover smoking was Christopher Columbus. In 1531 tobacco was cultivated for the first time in Europe. By 1600 tobacco use had spread across Europe and by the 1700s smoking had become more widespread and the tobacco industry had developed.

Cigarette making machines were developed in the latter half of the 1800s. The first such machines produced about 200 cigarettes per minute (today's machines produce about 9,000 per minute). Cheap mass production and the use of cigarette advertising allowed tobacco companies to expand their markets during this period. The prevalence of cigarette smoking continued to grow in the early 20th century.

Smoking increased dramatically during the world wars, mainly due to the policy of providing free cigarettes to allied troops as a 'morale boosting' exercise. Later in the twentieth century, smoking became less popular. According to different researchers, tobacco smoking has been implicated

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as the cause of cancer of the lung, oral cavity, larynx, esophagus, bladder, kidney, and pancreas. The risk of developing cancer is greater for people who smoke more and who start smoking at a younger age. Yet, exposure to passive tobacco smoke is very likely a significant cause of cancer in non-smokers. It has been estimated that thousands of people die each year due to exposure to passive tobacco smoke. On the other hand, documents have come to light that indicate that some tobacco companies have used a variety of methods to increase the amount and potency of nicotine in cigarette tobacco. Unfortunately, many people begin smoking as teenagers and do not give up smoking even when knowing the biological hazards. Various scientists argue that tobacco use is associated with biological, social, cultural, and economic factors.
In recent months, it has been observed that many students in your school smoke a lot, even though they are aware of the biological effects of smoking. Parents and teachers at your school are very concerned about this increase in smoking.

Using the example of the socio-scientific issue related to tobacco smoking, teacher and students discussed the complexity and multidimensionality of socio-scientific issues, the social risks, and the necessity to analyze such issues and potential solutions from the perspectives of different stakeholders.

The primary research questions of this educational scenario are the following:

- What are the biological, social, cultural, economic, and ethical dimensions of tobacco smoking?
- What are the main reasons 9th grade students in our school give for tobacco smoking of students?
- What are the main reasons people of the local community where you live give for tobacco smoking of students in our school?

The evaluative tasks for the educational scenario on the PAFSE topic: *Looking after myself and others - Substance Tobacco* are the following:

- Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment)
- Worksheets evaluation (Formative assessment)
- Evaluation of the construction of a model: “How do lungs work?”
- Evaluation of a scientific presentation and a poster on the topic *Biological, social, cultural, and economic dimensions of tobacco smoking*, and *suggestions for tackling the use of tobacco products.*
- Evaluation of public health brochures concerning the promotion of non-smoking
- Post-test (Final/ summative assessment).

Parents and other stakeholders were encouraged to become real partners in school projects and activities through answering questionnaires, giving interviews, or sharing their experiences and expertise.

Teacher training courses – workshops and implementation of educational scenarios
Before the implementation of each educational scenario in the classroom, teacher training was conducted. Teacher training lasted 15 hours in 5 workshop sessions and were discussed the following topics:

- Pedagogical framework and PAFSE digital educational platforms.
- Development of PAFSE educational scenarios: Pedagogical approaches and strategies for each educational scenario.
- PAFSE digital educational platforms.

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- Planning and enactment of educational scenarios.
- Planning and enactment of School Research Projects and open schooling event.
-

The workshops prepared teachers to enact the PAFSE educational scenarios, school project and open schooling event. In particular, the workshops enhanced knowledge and abilities of teachers and schools to explore effectively public health educational issues, in collaboration with local community stakeholders, within an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues. Furthermore, the workshops enhanced knowledge and strategies of teachers for informed classroom exploration of socio-scientific issues related to public health and promoted their abilities to support students to carry out a relevant school project. Participants found very useful and meaningful the theoretical and practical part of the workshop.

The implementation of the different educational scenarios followed the following phases:

- Introduction of a related socio-scientific issue and students' mission.
- Identifying students' preconceptions, alternative ideas (misconceptions) on the topic. Mapping the preconceptions of the students.
- Inquiry-based learning activities sequence to acquire a basic conceptual and epistemological understanding about topic related concepts, phenomena, and mechanisms.
- School project to investigate and answer primary research questions of each educational scenario.
- Open Schooling event (public event): Students, who had implemented the scenario, presented their research, and distributed information leaflets to their guests, and then they opened the floor to all participants and stakeholders to share their thoughts and remarks about their socio-scientific research, ask questions, and discuss possible implications.
- Evaluation and data collection.

Implementation of the first educational scenario focuses on Healthy Eating and Childhood Obesity: Challenges and Solutions

The implementation of this educational scenario took place during the school year 2022-23 in three secondary schools (2 rural and 1 urban schools) in biology classes, with 8th grade students.

Estimated duration of scenario implementation is:

- 4 lessons of 40-45 minutes for introduction and promotion of conceptual and epistemological understanding related to pafse topic: Looking after myself and others-Healthy Eating.
- 4 lessons of 40-45 minutes for school project.
- Open schooling Event.

Classroom organization for the implementation of a scenario is:

- For lessons 1- 4: Students' groups of 4-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).
- For lessons 5- 8: Students' groups of 4-5 students, cooperative learning method, use of jigsaw technique, whole-class (whole-class discussions).

First, the teacher stimulated the students' interest in the topic *Childhood Obesity: Challenges and Solutions* and introduced a related socio-scientific issue. Then, using specific activities like surveys or discussions, the teacher identified and mapped students' preconceptions or alternative

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ideas (misconceptions) on food and healthy eating.

Afterwards, students worked mainly collaborative using inquiry-based learning activities sequence, with the support of their teacher and other stakeholders, and with a lot of scaffolding (specific Worksheets, Infographic, Digital Learning Objects (DLOs), models, educational videos, other technological tools etc.) in order to obtain a basic epistemological awareness and conceptual understanding about essential organic and inorganic nutrients to human functioning, energy in food, food pyramid, Mediterranean diet, Vegan and Vegetarian diet. Then, they worked to identify the relationship between childhood obesity, healthy eating, and physical exercise. In addition, they looked for various social variables (cultural, ethical, political, economic) related to childhood obesity to perceive both scientific and social dimensions of childhood obesity. Yet, they created a prediction model for the development of childhood obesity in Cyprus.

In order to answer the project primary research questions concerning childhood obesity and community's related perceptions and knowledge, students formulated hypotheses and specific questions, collected data from a variety of inquiry-based sources (e.g., such as texts, articles, pictures, videos, tables, diagrams, simulations, and scientific measurements), evaluated information, developed questionnaires and did interviews, analyzed data, made inferences, synthesized, and drew conclusions. The teacher coordinated and facilitated inquiry and project-oriented learning processes, moved around the classroom asking reflective and supportive questions and giving feedback. After completing the worksheet activities, the teacher offered general feedback to all students.

Students after finishing their investigation, worked cooperatively using a jigsaw technique to create scientific presentations, scientific posters, information leaflets about childhood obesity, which were presented during an open schooling event. For the implementation of the open schooling event, students determined their guests, prepared relevant invitations and event program, as well as they determined all the procedural issues for the open schooling event with the support of the school principal and their teachers.

During the open schooling event, students presented their research project outcomes. They emphasized that health socio-scientific issues are multifaceted, and that health literacy and health promotion is a responsibility of everyone and not only of the ministry of health or healthcare providers. Additionally, students explained the importance of critical health literacy, which mainly consists of the critical evaluation of health information, the comprehension of the interconnection between health and society (the notion of social determinants of health), and the participation in civic collective actions for the promotion of public health. After explaining their research methodology, data collection, analysis, results, and conclusions, they engaged in a discussion with stakeholders (Parents, science teachers, local community, and civic society actors) on the implications for the community. Yet, health experts discussed students' research and the significance of such school projects.

Implementation of the second educational scenario focuses on vaccines development and the science that responds to hesitancy.

The implementation of the second educational scenario took place during the school year 2022-23 in four secondary schools (2 rural and 2 urban schools) in biology classes, with 9th grade students.

Estimated duration of scenario implementation is:

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- 5 lessons of 40-45 minutes for the promotion of conceptual and epistemic understanding related to PAFSE topic: *Looking out for my community: Vaccines development and the science that responds to hesitancy.*
- 4 lessons 40-45 minutes for school project
- Open Schooling Event.

Classroom organization for the implementation of a scenario is:

- For lessons 1- 5: Students' groups of 4-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).
- For lessons 6- 9: Students' groups of 4-5 students, cooperative learning method, use of jigsaw technique, whole-class (whole-class discussions).
-

First, the teacher stimulated the students' interest in the topic: *Vaccines development and the science that responds to hesitancy* using the history of vaccines and vaccinations and introduced a related socio-scientific issue. Using the example of the socio-scientific issue related to vaccines and vaccinations, teacher and students discussed the complexity and multidimensionality of socio-scientific issues, the social risks, because of being open-ended and ill-structured issues, and the necessity to analyze such issues and potential solutions from the perspectives of different stakeholders.

Then, using specific activities like surveys or discussions, the teacher identified and mapped students' preconceptions or alternative ideas (misconceptions) on microbes and diseases.
Afterwards, students worked mainly collaborative using inquiry-based learning activities sequence, with the support of their teacher and other stakeholders and with a lot of scaffolding (specific Worksheets, Infographic, DLOs, models, educational videos and etc.) in order to obtain a basic epistemological awareness and conceptual understanding about the categories, size, structure and functions of microorganisms, the Human Defense Systems against Pathogens, vaccines development, vaccination and herd immunity. In this learning process, the teacher became facilitator offering guided questions, scaffolding, and reflection opportunities.

To answer the first and second project primary research questions concerning vaccines development, vaccinations and the science hesitancy, students formulated hypotheses and specific questions, collected data from a variety of inquiry-based sources (e.g., such as texts, articles, pictures, videos, tables, diagrams, simulations, and scientific measurements), evaluated information, developed questionnaires, and did interviews, analyzed data, made inferences, synthesized, and drew conclusions.

For the third question concerning the socio-scientific dilemma: *Should a low efficacy vaccine be released to the public?* Students constructed arguments, counterarguments, and rebuttals in order to make decisions on the socio-scientific dilemma. Students were asked to support their claims, using as many as possible justifications supported by evidence, and constructed different types of arguments according to their opinion (e.g., scientific, social, ethical, economic, etc.). The debate team members evaluated their arguments using a rubric with criteria. Teacher and students gave feedback for the improvement of arguments. Then, they prepared a debate. A fruitful discussion took place among students and teacher, discussing all the steps of the debate. Some students got the responsibility to organize a public debate for open- schooling event.

Students after completing their research project and the debate preparation, worked cooperative using a jigsaw technique to create scientific presentation and information leaflets about vaccines

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and vaccinations, which were presented during the open schooling events. For the implementation of the open schooling event, they determined their guests, prepared relevant invitations and program, and they determined all the procedural issues for the event with the support of the school principal and their teachers.

During open-schooling events, students presented their research project outcomes. They explained their research methodology, data collection, analysis, results, and conclusions and presented a debate concerning the socio-scientific dilemma: *Should a low efficacy vaccine be released to the public*? Expert in vaccines and vaccinations discussed students' research, as well as their debate. Students moderated an interesting discussion with all participants. In particular, parents, science teachers, local community and civic society actors and students exchanged ideas and perspectives and possible implications for their community.

Implementation of the third educational scenario focuses on multiple dimensions of tobacco smoking.

The implementation of this educational scenario took place during the school year 2022-2023 in four secondary schools (2 rural and 2 urban schools) in biology classes, with 9th grade students.

Estimated duration of scenario implementation is:

- 5 lessons of 40-45 minutes for the promotion of conceptual and epistemic understanding related to PAFSE topic *Looking after myself and others - Substance Tobacco*.
- 4 lessons of 40-45 minutes for school project
- Open schooling event.

Classroom organization for the implementation of a scenario is:

- For lessons 1- 5: Students' groups of 4-5 students (collaborative learning), individual work (individual reflection on one's own learning), whole-class (whole-class discussions).
- For lessons 6- 9: Students' groups of 4-5 students, cooperative learning method, use of jigsaw technique, whole-class (whole-class discussions).

First, the teacher stimulated the students' interest in the topic *multiple dimensions of tobacco smoking* using the history of tobacco and presenting a school project related with students' smoking and the students' mission. Then, using specific activities like surveys or discussions, the teacher identified and mapped students' preconceptions or alternative ideas (misconceptions) on vaccines and vaccinations.

Afterwards, students worked mainly collaborative using inquiry-based learning activities sequence, with the support of their teacher and other stakeholders and with a lot of scaffolding tools (specific Worksheets, Infographic, DLOs, models, educational videos etc.) in order to obtain a basic conceptual understanding about structure and function of human respiratory system, respiration, cellular respiration, energy release, mitochondria, aerobic and anaerobic respiration, lungs diseases and lung diseases caused by smoking.

To answer the three project primary research questions concerning the different dimensions of tobacco smoking, as well as the main reasons 9th grade students and parents give for students' tobacco smoking in their school, students formulated hypotheses and specific questions, collected data from a variety of inquiry-based sources (e.g., such as texts, articles, pictures, videos, tables, diagrams, simulations and scientific measurements), developed and administered questionnaires to students and parents, and did interviews, analyzed data, made inferences, synthesized and drew conclusions.

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Students after completing their research, worked cooperatively using a jigsaw technique to create scientific presentations, scientific posters, information leaflets about tobacco smoking, which were presented during an open-schooling event. For the implementation of the open-schooling event, students determined their guests, prepared relevant invitations and program. Yet, they determined all the procedural issues for the event, with the support of the school principal and their teachers. During open-schooling events, students showcased the outcomes of their research projects and led engaging discussions with community members and other stakeholders present. They exchanged ideas and perspectives and possible implications for their community.

Methods

Participants

The 11 PAFSE pilot open schooling events in Cyprus took place in 8 PAFSE pilot schools (4 urban and 4 rural schools). Urban schools have a higher number of students (M=450, SD=35) than rural schools (M=250, SD=50). The open schooling events were held during February-May 2023. At the 11 Cyprus PAFSE open schooling events, more than 650 participants have been involved from different groups, namely: students in schools, teachers in schools, school principals and vice-principals, parents, scientists, members of civic society and local community. Additionally, members of the Ministry of Education and University of Cyprus were presented.

A PAFSE open schooling event instrument, which was administered at the end of each event, was answered by 648 participants, namely: (i) lower secondary school students in schools (13-15 years old; male and female, n=507), (ii) teachers and school professional in schools (n=33), (iii) parents (n=60), (iv) scientists, members of civic society and local community (n=48) . All presentations and materials that were used for each PAFSE open schooling event were in the Greek language. Table 2 displays the number of Cyprus PAFSE pilot open schooling events and participants who answered the PAFSE open schooling event questionnaire, per PAFSE pilot school and event.

Data Collection

To assess Cypriot parents' and secondary school students' views and perspectives on an open schooling model regarding public health education, we used a PAFSE open schooling event questionnaire. Data collection took place at the end of each of the 11 open schooling events of the 8 Cyprus PAFSE pilot schools.

The PAFSE open schooling event instrument contained 5 items regarding participants' views and perspectives on an open schooling model for inquiry learning in the context of public health socio-scientific issues. Table 3 displays the items of the open schooling event questionnaire. Items 1, 2, 4 were rated on five-point Likert scale ranging with the following scoring options: strongly disagree=1, disagree=2, neither agree nor disagree=3, agree=4 and strongly agree=5. Item 3 was rated on a five-point Likert scale ranging with the following scoring options: Highly unlikely=1, Unlikely=2, Neither likely nor unlikely=3, Likely=4, Strongly likely=5. Item 5 was rated on a 5-point Likert scale ranging with the following scoring options: Very low=1, Low=2, Moderate=3, High=4, Very high=5.

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Table 2: Number of Cyprus PAFSE open schooling events and participants who answered the PAFSE open schooling event instrument per pilot school and events.

PAFSE pilot Schools	Number of Events	Number of answers				
		Student	Teachers and School professionals	Parent	Members of civic society and local community	Total
Urban school 1	2	179	7	17	16	219
Rural school 1	2	148	11	19	10	188
Rural school 2	2	29	1	3	0	33
Urban school 2	1	12	1	0	0	13
Urban school 3	1	48	0	3	3	54
Urban school 4	1	46	3	3	6	58
Rural school 3	1	37	4	0	0	41
Rural school 4	1	8	6	15	13	42
Total	11	507	33	60	48	648

Table 3: Items of the open schooling event questionnaire.

A/A	Items of the open schooling event questionnaire
I	The project presented at the event is a contribution to the school and community health and well-being.
II	The collaboration between school and local community can help students, teachers, parents, and local community in contributing to public health.
III	How likely are you to attend another event in the future and recommend it to a friend?
IV	PAFSE project improved my preparation to deal with public health issues and risks.
V	What is your intention to recommend PAFSE to others in the future?

RESULTS

First, the means, standard deviations, minimum and maximum scores, and values of skewness and kurtosis of all variables of this study were calculated. The measures of skewness and kurtosis indicated that all score distributions were approximately normal and, thus, appropriate for use in parametric statistical analyses. Table 4 displays the means, standard deviations, minimum and maximum scores, and values of skewness and kurtosis of all variables of this study.

Rural schools' participants' scores on their views and perspectives on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues are higher than the urbans schools' participants' scores. Furthermore, parents' scores on their views and perspectives on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues are higher than students' scores.

To answer the first research question, namely, to examine Cypriot parents' and lower secondary school students' views and perspectives on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues, the measures of Table 4 were used.

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Table 4. Descriptive statistics for all variables related to this case study.

Variable	M	SD	Min	Max	Skewness (SE)	Kurtosis (SE)
Urban schools' participants of open schooling events (N=343)	3.82	1.05	1.00	5.00	-0.97(0.13)	0.70 (0.26)
Item I	3.89	1.08	1.00	5.00	-1.16(0.13)	1.14(0.26)
Item II	3.28	1.21	1.00	5.00	-0.32(0.13)	-0.70(0.26)
Item III	3.60	1.11	1.00	5.00	-0.69(0.13)	0.08(0.26)
Item IV	3.31	1.25	1.00	5.00	-0.47(0.13)	-0.68(0.26)
Item V						
Rural schools' participants of open schooling events (N=305)	4.26	0.9	1.00	5.00	-1.67(0.14)	2.18(0.28)
Item I	4.14	0.95	1.00	5.00	-1.51(0.14)	2.17(0.28)
Item II	3.76	1.09	1.00	5.00	-0.83(0.14)	0.25(0.28)
Item III	3.89	0.95	1.00	5.00	-1.00(0.14)	1.34(0.28)
Item I	3.78	1.20	1.00	5.00	-0.89(0.14)	0.03(0.28)
Item V						
Students in school of open schooling events (N=507)						
Item I	3.95	1.07	1.00	5.00	-1.13(0.11)	0.95 (0.22)
Item II	3.87	1.06	1.00	5.00	-1.20(0.11)	1.25(0.22)
Item III	3.27	1.13	1.00	5.00	-0.45(0.11)	-0.40(0.22)
Item IV	3.67	1.09	1.00	5.00	-0.85(0.11)	0.26(0.22)
Item V	3.31	1.23	1.00	5.00	-0.45(0.11)	-0.63(0.22)
Parents in school of open schooling events (N=60)						
Item I	4.53	0.75	2.00	5.00	-1.71 (0.31)	2.20 (0.61)
Item II	4.75	0.47	3.00	5.00	-1.66(0.31)	1.67(0.61)
Item II	4.53	0.79	2.00	5.00	-1.71(0.31)	2.25(0.61)
Item IV	4.13	0.72	2.00	5.00	-0.48(0.31)	0.20(0.61)
Item V	4.52	0.89	1.00	5.00	-2.17(0.31)	0.73(0.61)

As seen in Table 4, parents reported that they agree -strongly agree that the project presented at the event is a contribution to the school and community health and well-being (M=4.53, SD=0.75), that the collaboration between school and local community can help students, teachers, parents, and local community in contributing to public health (M=4.75, SD=0.47) and that PAFSE project improved their preparation to deal with public health issues and risks (M=4.13, SD=0.72). Answering the questions *How likely are you to attend another event in the future and recommend it to a friend?* parents reported that they are likely- strongly likely to attend another event in the future and recommend it to a friend, (M=4.53, SD=0.79). In the question *What is your intention to recommend PAFSE to others in the future?* parents responded high-very high (M=4.52, SD=0.89).

On the other hand, students reported that they agree that the project presented at the event is a contribution to the school and community health and well-being (M=3.95, SD=1.07), that the

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collaboration between school and local community can help students, teachers, parents, and local community in contributing to public health (M=3.87, SD=1.06) and that PAFSE project improved their preparation to deal with public health issues and risks (M=3.67, SD=1.09). Answering the questions *How likely are you to attend another event in the future and recommend it to a friend?* students reported that they are neither likely nor unlikely to attend another event in the future and recommend it to a friend (M=3.27, SD=1.13). In the question *What is your intention to recommend PAFSE to others in the future?* students responded moderately (M=3.31, SD=1.23).
To answer the second and third research questions, namely if there is a statistically significant difference between Cypriot parents' and secondary school students' views and perspectives as well as between urban and rural schools' participants' views and perspectives on an open schooling model for inquiry learning in the context of public health socio-scientific issues independent-samples t-tests at 95% confidence were carried out.

Table 5 displays independent-samples t-tests at 95% confidence, comparing Cypriot parents' and lower secondary school students' views and perspectives on an open schooling model for inquiry learning in the context of public health socio-scientific issues.

The independent-samples t-test analyses indicate that the parents' views and perspectives on an open schooling model for inquiry-based learning in the context of public health socio-scientific issues are significantly higher at the P<0.001 level for items I, II, III, V level, and p=0.001 level for item IV than the secondary school students' views and perspectives.

Table 5: Independent-samples t-tests at 95% confidence comparing Cypriot parents' and secondary school students' views and perspectives on an open schooling model for inquiry learning in the context of public health socio-scientific issues.

Variable	M	SD	t(df)	Sig. (2-tailed)
Cypriot parents' views and perspectives: Item I	4.53	0.75	-4.09 (565)	0.000
Cypriot students' views and perspectives: Item I	3.87	1.06		
Cypriot parents' views and perspectives: Item II	4.80	0.55	-6.33 (565)	0.000
Cypriot students' views and perspectives: Item II	3.87	1.06		
Cypriot parents' views and perspectives: Item III	4.53	0.79	-8.37 (565)	0.000
Cypriot students' views and perspectives: Item III	3.27	1.13		
Cypriot parents' views and perspectives: Item IV	4.13	0.72	-3.20 (565)	0.001
Cypriot students' views and perspectives: Item IV	3.67	1.01		
Cypriot parents' views and perspectives: Item V	4.51	0.89	-7.35(565)	0.000
Cypriot students' views and perspectives: Item V	3.31	1.24		

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These results suggest that parents' views and perspectives are statistically significantly higher than the lower secondary school students' views and perspectives on the following items: (1) contribution of open schooling public in the context of public health education to schools and community health and well-being, (2) contribution of collaboration between school and local community for the promotion of health and well-being among students, teachers, parents and local community, (3) contribution of PAFSE project to students, teachers, parents and local communities' preparation to deal with public health socio-scientific issues and risks, (4) interest to attend another such public health event, (5) readiness to recommend PAFSE to others.

Table 6 displays independent-samples t-tests at 95% confidence, comparing urban and rural schools' participants' views and perspectives on an open schooling model for inquiry-based learning in the context of public health socio-scientific issues.

The independent-samples t test analyses indicate that the rural schools' participants' views and perspectives on an open schooling model for inquiry learning in the context of public health socio-scientific issues are significantly higher than the urban schools' participants' views and perspectives at the P<0.001 level for items I, III, IV, V, and at P<0.05 level for item II.

Table 6: Independent-samples t-tests at 95% confidence comparing rural and urban schools' Cypriot parents' and secondary school students' views and perspectives on an open schooling model for inquiry learning in the context of public health socio-scientific issues by rural and urban schools.

Variable	M	SD	t(df)	Sig. (2-tailed)
Rural schools' participants' views and perspectives: Item1	4.26	1.00	-5.47 (646)	0.000
Urban schools' participants 'views and perspectives: Item I	3.75	1.08		
Rural schools' participants 'views and perspectives: Item II	4.14	0.95	-3.18 (646)	0.02
Urban schools' participants' views and perspectives: Item II	3.86	1.07		
Rural schools' participants' views and perspectives: Item III	3.76	1.10	-5.23 (646)	0.000
Urban schools' participants' views and perspectives: Item III	3.58	1.09		
Rural schools' participants' views and perspectives: Item IV	3.91	0.95	-4.09 (646)	0.000
Urban schools' participants' views and perspectives: Item IV	3.58	1.09		
Rural schools' participants' views and perspectives: Item V	3.78	1.20	-4.74(646)	0.000
Urban schools' participants 'views and perspectives: Item V	3.31	1.25		

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These results suggest that rural schools' participants' views and perspectives are statistically significant higher than those of urban schools' participants on the following items: (1) contribution of open schooling in the context of public health education to schools and community health and well-being, (2) contribution of collaboration between school and local community for the promotion of health and well-being among students, teachers, parents and local community, (3) contribution of PAFSE project to students, teachers, parents and local communities' preparation to deal with public health socio-scientific issues and risks, (4) interest to attend another public health event, (5) readiness to recommend PAFSE to others.

DISCUSSION AND CONCLUSIONS

The aim of the present case study was to investigate Cypriot parents' and lower secondary school students' (at urban and rural schools) views and perspectives on an open schooling model regarding public health education, through the implementation of specially designed educational scenarios based on an open schooling model for inquiry-based learning in the context of public health socio-scientific issues. The Cypriots' students presented and debated three different public health socio-scientific issues, namely: (1) *Childhood Obesity: Challenges and Solutions*, (2) *Vaccines development and the science that responds to hesitancy*, (3) Multiple *dimensions of tobacco smoking.*

According to the results of our case study, parents agreed – strongly agreed that open schooling in the context of public health education is a contribution to the school and community health and well-being, that the collaboration between school and local community can help students, teachers, parents, and local community in contributing to public health, and that the PAFSE project improved their preparation to deal with public health issues and risks. In addition, parents reported that they were likely- strongly likely to attend another event in the future and recommend it to a friend, as well as recommend PAFSE to others in the future. The equivalent scores of students were lower and moderate.

The parents' results emphasize the importance of creating school-community partnerships to enhance public health and science learning experiences, understand, recognize, and consider the multiplicity of perspectives of public health socio-scientific issues, in order to analyze and manage them. Yet, the results highlight the importance of involving parents and the local community in open schooling activities that feature public debate on public health, socio-scientific issues, and democratic processes.

Lower education students agree less than parents that open schooling in the context of public health education is a contribution to the school and community health and well-being, that the collaboration between school and local community can help students, teachers, parents, and local community in contributing to public health, and that the PAFSE project improved their preparation to deal with public health issues and risks. In addition, students reported that they were less likely than parents to attend another event in the future and recommend it to a friend, as well as recommend PAFSE to others in the future.

Students' ratings highlight the importance of enhancing teachers' and students' familiarity with effective approaches, such as the open schooling model. This integration into the school curriculum would boost motivation and deepen engagement with science-related societal issues. Recognizing the critical role of teachers in facilitating inquiry-based learning, support from school leaders and ministry advisors becomes essential.

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Our results further demonstrate that participants from rural areas strongly agree that the open schooling model, within the context of public health education, contributes to both school and community health and well-being. The collaboration between schools and the local community benefits students, teachers, parents, and the community at large in their efforts to promote public health. Additionally, the PAFSE project has enhanced their preparedness to address public health issues and risks.

Furthermore, participants indicated their likelihood to attend future events and recommend them to friends. They also expressed a willingness to recommend the PAFSE initiative to others in the future. These findings underscore the importance of creating more opportunities in rural schools. Such opportunities should facilitate dialogue among students, parents, scientific experts, and the civil community. This collaborative approach can contextualize public health and science through real-life situations involving the local community. Additionally, it supports the implementation of socio-scientific inquiry and project-based learning, benefiting both teachers and school principals.

Our results further show that participants from rural areas agreed strongly that the open schooling model in the context of public health education is a contribution to the school and community health and well-being, that the collaboration between school and local community can help students, teachers, parents, and local community in contributing to public health, and that the PAFSE project improved their preparation to deal with public health issues and risks. In addition, they reported that they were likely to attend another event in the future and recommend it to a friend, as well as recommend PAFSE to others in the future. These results highlight the necessity to create more opportunities in rural schools to bring together students, parents, scientific and civil community to debate public health issues, contextualize public health and science through work in real-life situations involving the local community, and implement socio-scientific inquiry and project-based learning, supporting more teachers and school principals.

In summary, the present case study expands upon the current literature by investigating Cypriot parents' and lower secondary school students' views and perspectives on an open schooling model for public health education. The study reveals that parents hold more positive views and perspectives than students, and that participants from rural schools outreach those from urban schools. These findings have significant implications for health education.

However, successful implementation of the open schooling model in the context of public health education requires a multifaceted approach. Key educational implications include: (i) Fostering Teachers' Skills: Teachers need support to effectively implement open schooling approaches. This involves enhancing their skills and competences. (ii) Integration into the school curriculum: Open schooling approaches should be integrated into the curriculum. This ensures that students benefit from them as part of their regular learning experiences. (iii) Digital Tools and Resources: Providing access to a wider range of digital tools and resources enhances learning and collaboration. These resources can enrich students' understanding of public health issues. (iv) Community Involvement: Promoting the involvement of parents, public health experts, STEM educators, civil society actors, and the local community is crucial. Their collective efforts contribute to a holistic approach to science and health education. (v) Investigation of socio-scientific issues with multiple dimensions such as scientific, economic, political, cultural, and ethical, which are related to public health challenges that the local society has to address.

The main limitation of our case study is that we used only questionnaire data in the current study, and we could not probe participants' responses to items as with in-depth interviews. Future

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studies should take a closer look at participants' responses in-depth. Further research is needed to gain a more nuanced understanding of open schooling's effectiveness and explore its wider educational benefits.

RECOMENDATIONS

- Incorporate public health education into the national curriculum.
- Promote an open schooling model in the context of health education.
- Provide teacher training on the effective implementation of educational scenarios based on an open schooling model for inquiry and project-based learning in the context of public health socio-scientific issues.
- Conduct principal training regarding the significance of public health education and the use of an open schooling approach.
- Enhance teachers' competences in coordinating and facilitating socio-scientific inquiry-based learning processes.
- Encourage multidisciplinary implementation of health educational scenarios.
- Promote the use of digital learning objects in inquiry-based teaching and learning environments enriched by technology.
- Advocate for science education to incorporate socially responsible inquiry embedded in contemporary multidimensional socio-scientific issues.
- Involve stakeholders in public health and STEM education in a bottom-up process.
- Promote diversity, equity, inclusion, responsibility, and democratic citizenship in science classrooms through an open schooling model.

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3.3. NOVA University of Lisbon (UNL) – Case Study Report

Open Schooling and Attitudes towards Science, Technology, Engineering and Mathematics (STEM): A Case Study on the implementation of Educational Scenarios focusing Public Health

INTRODUCTION
In an era characterized by globalization and rapid technological advances, people of all ages find themselves at the crossroads of change, which compels them to develop and cultivate a diverse skill set that extends beyond their chosen fields of action (Skare, 2021). A solid grounding in one's field is essential, but it's no longer enough due to the rapid and constant evolution of the state of the art. This requires people to be constantly learning and adapting, while simultaneously being able to dissect complex issues, analyse information and make informed decisions (Barak, 2017; Boon, 2022). Additionally, and since knowledge in various fields is necessary, people must be able to behave and work in diverse teams. These teams are made up of individuals from diverse backgrounds, each bringing a unique perspective. Beyond technical skills, social and global awareness is also essential (Barak, 2017; Boon, 2022). The fusion of knowledge, skills, flexibility, and an appreciation of interconnectedness defines what is recognized as "21st-century skills" (Barak, 2017; Boon, 2022). These skills - critical thinking, problem-solving, communication and adaptability - are the foundation of success. Educational institutions play a key role in nurturing these skills. By integrating them into the curriculum, schools empower students to thrive in dynamic environments, fostering both personal growth and career development (Barak, 2017; Boon, 2022). The importance of the 21st century skills is common ground in science education, although current school practices often reflect conventional and classical models of teaching, emphasizing standardized curricula, learning through repetition and teacher-dominated instruction (Arthurs & Kreager, 2017). These skills are often overlooked in science education due to conventional classroom practices such as teacher-dominated instruction and standardized curricula. This discrepancy is evident when considering the physical arrangement of desks in rows facing the teacher. On the opposite, active teaching-learning methodologies empower students to thrive in the dynamic and interconnected landscape of the 21st century (Arthurs & Kreager, 2017). The traditional classroom arrangement often prioritizes information recall over practical problem-solving and connectedness (Darling-Hammond & Bransford, 2005). To prepare students for the demands of the 21st century, where adaptability, analytical thinking, conflict resolution, and teamwork are paramount, active learning is essential. Our educational institutions should transition from traditional lecturing to empowering students to navigate complex situations and align with our ever-evolving, interconnected world (Darling-Hammond & Bransford, 2005). Furthermore, schools and educational systems need to equip students with the critical skills necessary to thrive in our technology-driven world (Li & Gu, 2023). STEM education plays a pivotal role in shaping scientifically literate individuals capable of navigating complex global challenges influenced by science and technology (Li & Gu, 2023). Therefore, STEM education is crucial not only for academic purposes but also for meeting the requirements, in the medium and long term, of having a qualified workforce. This involves effective citizenship and social

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readiness in an early stage of individuals development, and cultivating a generation of scientifically literate individuals who can navigate a world that is increasingly influenced by science, technology, big data, and AI (Han, Kelley & Knowles, 2021).
In the era of widespread adoption of AI and machine learning, we need informed, confident, and observing students who can critically evaluate information. As we observe significant progress and technological advancements, STEN education is proving to be a powerful facilitator. It provides essential knowledge and fosters critical thinking and problem-solving abilities. Science education prepares individuals to navigate the complexities of our dynamic global landscape by empowering them to overcome intricate obstacles (Han, Kelley & Knowles, 2021).

Open Schooling appears in this context, as it equips individuals with relevant skills. As an innovative concept, it aligns seamlessly with the goals of STEM education (International Centre for STEM Education, 2023). Open Schooling envisions learning beyond the confines of traditional classrooms by integrating the resources of the community, making every space a learning space (International Centre for STEM Education, 2023). This approach promotes students' engagement, relevance, and deeper understanding. STEM education in Open Schooling is a powerful catalyst for progress and technological advancement. It provides essential knowledge and nurtures critical thinking and problem-solving skills, preparing individuals to navigate the complexities of our dynamic global landscape (International Centre for STEM Education, 2023).

In parallel, project-based learning (PBL) has gained prominence as a teaching approach that focuses on open, authentic, inquiry-based projects. PBL encourages students to tackle complex problems, conduct research in relevant environments, collaborate and produce tangible results (Kurt, 2020).

Partnerships for Science Education (PAFSE) is a collaborative initiative aimed at improving STEM education through open Schooling and PBL. The PAFSE project, based on the principles of Open Schooling, views learning as a dynamic process that extends beyond the walls of traditional classrooms. The project includes learning activities that occur within or outside classroom environment that promote the development of 21st-century skills, mainly through inquiries, group discussions and debates. The program begins with classroom activities and progresses to include activities outside the classroom. It culminates in the development of a scientific project led by the students, which allows them to actively participate in the process of reinforcing the health of their community. These projects are then presented to the wider community, engaging all members in the learning process.

The present case study aims to describe how the implementation of the PAFSE project affects the attitudes of lower secondary school students (aged 12 to 15) towards science, public health, STEM curricula, and professions. The case study focuses on Educational Scenarios that combine project-based and inquiry-based learning in the context of open schooling. This case study presents various perspectives on the implementation of PAFSE, exploring its transformative potential to impact academic outcomes, as well as students' perceptions, interests and aspirations in following STEM curricula and careers.

CONCEPTUAL FRAMEWORK

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STEM education is a social construct that aims to enhance learning across science, mathematics, engineering, and technology fields (Akerson et al., 2018). However, there is no consensus on the specific disciplines under the broad umbrella of STEM (Akerson et al., 2018). While some scholars argue that STEM lacks a distinct identity and is a social construct born out of economic and global pressures, others advocate for an integrative perspective called I-STEM. This approach emphasizes how STEM areas converge to address problems requiring science, technology, engineering, and mathematics (McComas & Burgin, 2020; Grimalt-Álvaro et al, 2021). It includes problem-based, project-based, and inquiry-based learning, which foster engaged, informed, and participatory citizens (Grimalt-Álvaro et al, 2021). Due to these beliefs, STEM policy documents promote an integrated strategy for teaching science, technology, engineering, and mathematics.

Despite the focus on STEM engagement in the past two decades, there remains limited understanding of integrated STEM projects and methods, and there are still disagreements about models and effective approaches for integrated STEM instruction- a literature review has identified a gap in understanding how STEM domains are integrated in classroom projects, with concerns about contextualization, relevance, and diversity (McLure et al., 2022). Even though there are still disagreements about models and effective approaches for integrated STEM instruction, several scholars suggest the conduction of further research, to develop instructional strategies that focus on teaching and learning across all three domains: cognitive, affective, and psychomotor, in order to enhance student learning and create a more dynamic and open educational experience (McLure et al., 2022).

Following up on this, the topic of open schooling may be addressed. Introduced in 2015 by the European Union education policy document 'Science Education for Responsible Citizenship', open schooling aims to transform schools into innovation hubs within local communities (Sotiriou et al, 2021; Hazelkorn, 2015). This approach involves collaboration with families and the community, promoting education as part of community development. Open schooling typically involves inquiry-based and project-based learning (PBL) opportunities, which may address real needs outside of school, and these are shared publicly to enrich local expertise (Sotiriou et al, 2021). Open schooling fosters diversity, experimentation, and social capital, leading to diversified recognition of competencies in the labour market. It enhances the relationship between schools and local communities, promoting learner independence and interdependence. Hence, open schooling fosters holistic skill development in IBL, PBL, and STEM education through nurturing inquiry, collaboration, and practical problem-solving. Inquiry-based teaching and learning is a commonly used pedagogical approach, particularly in secondary science education (Kersting et al., 2023). It is often based on the constructivist approach, which allows for the creation of learning environments that promote active engagement and student-centred learning. Knowledge is actively constructed and cumulatively developed by establishing a contrast with reality (Antonio et al., 2023). The approach promotes active engagement and student-centred learning, enabling students to acquire and retain knowledge over time (Antonio et al., 2023). Common inquiry models involve students asking questions, collecting information, conducting investigations, and interpreting findings. These activities require planning, experimental steps, and proposing results, fostering scientific competence, reasoning, communicative focus, and scientific practices in students (Antonio et al., 2023). Research from international assessments such as the Program for International Student Assessment (PISA) and TIMSS shows that there is a non-linear relationship between inquiry-based teaching and student science achievement (Cairns & Areepattamannil, 2019; OECD, 2016; Teig et al., 2018). A study by Cairns and Areepattamannil (2019) investigated the correlation between inquiry-based science teaching and students' science achievement and

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dispositions. The study found a negative correlation with science achievement. However, a correlation was found between inquiry-based science teaching and various science dispositions, such as students' interest in and enjoyment of science learning, their future-oriented motivation towards science, and their science self-concept and self-efficacy (Cairns & Areepattamannil, 2019). Therefore, the effectiveness of IBL may vary depending on the framework of implementation. Poorly designed activities may hinder the development of science literacy (Kang, 2020; Kersting et al., 2023). However, the relationship between IBL and science literacy could be significantly impacted by instructional quality and variations in IBL approaches. This could occur through the adoption of a spectrum of IBL implementation approaches, ranging from open-ended investigations to more structured guided inquiries (Kang, 2020). A study of inquiry-based teaching in Norwegian science classrooms has revealed inconsistencies in implementation and highlighted opportunities to enhance student participation and agency. The research, based on observations of 20 primary and lower-secondary classrooms, identified discrepancies in the quality of inquiry phases and variations in implementation according to grade levels (Kersting et al.,2023). However, teachers have not widely implemented IBL opportunities that involve exploring student-generated questions, allowing students to create their own hypotheses, and guiding students in designing investigations (Kersting et al.,2023).

This statement contradicts the findings of Kersting et al. (2023), which suggest that allowing students to create their own questions and hypotheses can enhance their engagement in the learning process and deepen their understanding of the scientific method.

Regarding PBL, it is a teaching and learning model that links practice to the teaching process and provides a holistic view of a subject. It challenges learners to interlink various disciplines to provide a comprehensive perspective on a topic (Reis et al., 2020). This approach requires learners to delve deeply into a real-world topic, which positively impacts their attention and efforts. Unlike traditional classes where teachers are often the primary source of information, this learning model positions the teacher as a facilitator, guiding learners to discover answers through alternative sources (Unaizahroya et al., 2022). Therefore, teachers guide learners to find answers from other sources. Students engage in research, formulate hypotheses, explore resources, and apply theoretical information to practical scenarios until they find a satisfactory solution (Reis et al., 2020). Collaborative learning in groups is a central aspect of the process. It allows students to observe different solution strategies, engage in argumentative discussions, and take responsibility for their own learning (Reis et al., 2020). Research about PBL, using randomized control trials, have shown promising evidence of its effectiveness, with students outperforming control groups on various measures (Dean et al., 2023). Identifying the characteristics and criteria of high-quality PBL instruction remains a key challenge. Markula & Aksela (2021) suggest further research into the intricacies of PBL implementation, such as integrating key content, guiding student questions, and formulating driving questions. Dean et al. (2023) propose a definition of PBL that is anchored in specific instructional practices for high-quality PBL. This definition suggests that effective project-based learning is usually characterized by a process that includes:

- Encouraging meaningful inquiries that are relevant to the real world, with authentic and core learning questions.
- Providing sufficient depth and rigor to sustain student investigation.
- Promoting student agency by giving them space to have a voice, choice, and ownership within a collaborative learning environment.
- (and) Allowing opportunities for students to reflect, revise, and assess throughout the process.

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Partnerships for Science Education (PAFSE) project was designed based on this knowledge and principles of action. The project is led by the National School of Public Health at NOVA University of Lisbon and involves the participation of nine organisations based in four European countries: Portugal, Cyprus, Greece, and Poland. The aim of the project is to enhance STEM education by incorporating public health topics. PAFSE's mission is to equip students with the skills to become public health ambassadors and disseminators of scientific knowledge.

Integrated learning scenarios were implemented in 40 schools across Europe during the 2022/2023 school year. In Portugal, the project was implemented in 25 schools, with 3rd cycle students. This phase was the pilot phase, during which we tested materials and collected data on the project impact.

Learning scenarios were developed to provide public health education and address present and future challenges using active, student-centred methodologies. The scenarios are linked to the national curriculum and are to be implemented by schools and schools' science clubs.

Integrating life sciences into science education can enhance students' comprehension of scientific principles and increase teachers' confidence in addressing these topics (Boedeker et al., 2023). Partnerships between schools and health organizations are crucial for developing precise and informative lessons (Boedeker et al., 2023). Learning scenarios are structured resources that anticipate future situations, identify potential problems, and generate innovative solutions. They have proven valuable in various domains, including marketing, software development, medicine, game development, and economics (Pedro et al., 2019). Teaching-learning supported on learning scenarios promote the development 21st-century skills, particularly problem-solving, communication, critical thinking, and creativity (Pedro et al., 2019).

The 21st Century Framework is a tool that aims to equip students with non-cognitive skills, also known as 21st-century skills, to succeed in the STEM-based job market (Stehle & Peters-Burton, 2019). It categorises these skills into four categories: life and career skills, learning and innovation skills, information and media literacy, and key subjects (Stehle & Peters-Burton, 2019). These components are interconnected and can be integrated into any academic lesson. The fourth component, key subjects, proposes interdisciplinary themes that are relevant in the 21st century and engage students in authentic learning experiences (Stehle & Peters-Burton, 2019).

Current educational standards emphasize the importance of incorporating STEM subjects into project-based instruction to enhance students' 21st-century skills and boost their confidence (Han et al, 2021). Teachers must explicitly integrate science and engineering practices into their classrooms to provide real-world problem-solving opportunities and improve students' 21st-century skills. Social, motivational, and instructional factors significantly influence students' achievements in STEM learning and their future careers (Han et al, 2021). Therefore, the 21st Century Framework is a valuable tool for preparing students for the STEM-based job market.

Learning scenarios are hypothetical situations used for teaching and learning (Matos, 2014). They describe the context and structure of the learning environment, embracing uncertainty and encouraging creativity (Pedro, 2019). By transitioning from conventional problem-solving approaches, scenarios encourage the exploration of alternative pathways, leading to innovative and effective solutions. According to Pedro (2019), scenarios foster a sense of possibility.

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Misfeldt & Zacho (2015) suggest that scenarios can be used in educational settings to enhance contextualization, foster relevance, and promote immersion in learning experiences.

PAFSE develops digital educational scenarios and learning objects for public health education while promoting project-based learning to involve a wide range of actors in addressing public health challenges through an open school model. The 'Open School' model is an inclusive and participatory educational approach that promotes lifelong learning for all members of the school community, as was mentioned above. This model promotes interaction and collaboration among students, teachers, educational assistants, and parents to disseminate knowledge and develop formative processes. Project-based learning is a crucial element of this model, as it brings real-world problems, needs, and challenges to the school, fostering collaboration among various stakeholders, including teachers, students, researchers, entrepreneurs, and professionals in the STEM field. The PAFSE project's learning scenarios/packages consist of a series of lessons, followed by a science education activity, where students engage with STEM professionals. Lastly, students carry out research projects. In short, the PAFSE project is a science education initiative that aims to address public health challenges. It is an innovative initiative that explores science education to equip citizens with the knowledge, tools, and skills necessary to make informed decisions regarding public health and utilizes education to promote sustained engagement with important socio-scientific issues. More specifically, through the collaborative implementation of educational scenarios focusing critical public health topics, PAFSE seeks to equip individuals with the knowledge and skills necessary to make informed decisions about their health and the health of their community, thus contributing to health promotion, disease prevention, global (public) health literacy, and emphasizing community preparedness and readiness for hazards.

Fundamentally, the PAFSE project adopts an open schooling model, allied to PBL, in the context of health education. This model/ approach is known for its effectiveness in equipping learners with essential 21st-century skills and promoting inclusivity, as it involves students, teachers, medical professionals, scientists, researchers, entrepreneurs, software developers, and science communicators (Partnerships for Science Education Project, 2022). It breaks down barriers and ensures that STEM education is accessible to a wider audience, regardless of their geographical location, physical abilities, or socioeconomic status (Partnerships for Science Education Project, 2022).

Integrating health into science education can enhance students' comprehension of the scientific principles that support public health guidelines. Even a short period of additional lessons can have a positive impact on students' knowledge and attitudes. Partnerships between schools and health organisations are crucial in improving the pace of developing and integrating accurate and informative lessons (Sotiriou et al., 2021).

An open school environment that welcomes external ideas can benefit both students and the community. Sharing students' projects that address real needs outside of school publicly can significantly contribute to the community's enrichment (Sotiriou et al., 2021).

This case study explores the impact of open schooling and the implementation of educational scenarios on shaping individuals' attitudes towards STEM, with a focus on public health education. The case study sets out to achieve specific objectives, notably to assess how students' perceptions of STEM curricula and fields shift, especially when confronted with public health issues, through their engagement in open schooling activities. Such activities encompass interactive sessions with STEM experts and the creation of a scientific project,

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providing a practical context for learning and appreciation of STEM disciplines. Additionally, the study will investigate the learning outcomes of such initiatives, specifically whether exposure to educational scenarios that focus on public health leads to an improved understanding, engagement, and interest in STEM subjects. Finally, the case study will identify best practices and effective strategies for implementing educational scenarios that positively impact attitudes towards STEM and public health. These strategies may be implemented in schools in the future.

RESEARCH QUESTIONS

How are lower secondary school students' attitudes towards science and STEM curricula influenced by the implementation of specially designed Educational Scenarios that comprise inquiry-based learning in the context of open schooling?

The case study assesses the following hypotheses:

H1. Students' attitudes towards science are positively influenced by the implementation of PAFSE Educational Scenarios.

H2. Students' attitudes towards Math are positively influenced by the implementation of PAFSE Educational Scenarios.

H3. Students' attitudes towards Engineering and Technology are positively influenced by the implementation of PAFSE Educational Scenarios.

H4. The implementation of PAFSE Educational Scenarios positively influences students' knowledge, beliefs, and attitudes regarding public health.

CONTEXT AND METHODS

Context

The implementation of the educational scenarios took place in five schools located in the district of Lisbon, in both rural and urban areas of the territory. The schools were identified by the National Portuguese Directorate-General for Education and were selected to participate in the pilot phase of the PAFSE project, to ensure that the implementation of the educational scenarios and their effects could be measured in different (social and economic) contexts.

School A is part of the Program of Priority Educational Intervention Territories - the TEIP program -, a government initiative currently implemented in 146 school clusters/ individual schools in Portugal. The program targets economically and socially disadvantaged areas characterized by poverty and social exclusion, where issues such as violence, disciplinary problems, dropout rates and academic failure are more prevalent. In this school, the notion of a pursuing a career in STEM may seem remote, largely due to preconceived stereotypes, parents background, social and cultural capital. Inadequately equipped classrooms lack critical resources necessary for effective teaching and learning. The building is showing signs of aging, with decaying walls and infrastructure. Shortages of natural light yield dim and occasionally unwelcoming classrooms, which can negatively impact physical comfort of students and teachers and hinder the overall educational experience. Improving school infrastructure to cultivate a safe and supportive learning environment that fosters the growth and development of students.

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Regarding **School B,** most students reside in the municipality where the school is located. However, in the 1980s, the area experienced an increased influx of people from certain Asian countries and Portuguese-speaking African countries. Additionally, for a period of approximately 10 years following this migratory influx, the municipality in question underwent further relocation due to a special relocation program that provided housing for numerous Roma families. In terms of socioeconomic characterization, the social fabric consists of what is generally considered "traditional families" with a medium to medium-low socio-economic status. There are some social neighbourhoods with families from different ethnic backgrounds, characterized by low economic resources, low levels of education and high levels of long-term unemployment and/or precarious employment. In addition to these characteristics, it is important to mention the existence of some structurally weak family situations, with low parental expectations and insufficient or inadequate supervision. These factors typically affect young people by lowering their self-esteem, reducing their interest in attending school and affecting their academic performance. It is noteworthy that great emphasis has been placed on the upkeep excellent indoor and outdoor spaces. Laboratories and classrooms are very comfortable and well equipped with modern technologies (e.g., interactive whiteboards). The pavilions are modern, there is a community garden and spaces for students to play, exercise and socialize.

School C is located in a central urban area and is part of a larger School Group. The socioeconomic context of the area presents some vulnerabilities, reflecting the reality of the parishes in which the school is situated. A significant portion of families belong to the middle and lower-middle class and have a medium to low level of educational and professional qualifications. However, there is also a notable number of parents and guardians with higher education qualifications. Several students benefit from School Social Action due to the impact of unemployment or low wages on families, including traditional, single-parent, and other types. School C is a highly multicultural and multilingual institution that welcomes students from 55 different nationalities. The school has ample communal spaces, including a well-stocked library and interesting exhibitions, which contribute to the vibrant atmosphere of the school. However, there is a pressing need to update the infrastructure of classrooms and communal spaces, as the current equipment is outdated. Additionally, there is a noticeable absence of heating during the winter months and air conditioning to combat the summer heat. The quality of facilities varies which poses a significant challenge in creating a suitable learning environment for students. In some cases, this may even be considered a safety hazard, highlighting the crucial need for infrastructural improvements.

School D comprises educational institutions located in a predominantly residential region, near the coast. This region has acquired urban features gradually due to the growth of local economic activities, particularly in the tertiary and higher tertiary sectors, with the establishment of diverse business and science and technology parks within its sphere of influence. Most students are Portuguese nationals, although a significant number of foreign students also attend. However, the majority of the foreign students come from Portuguese-speaking countries, particularly Brazil and Angola. The student body is diverse in terms of socioeconomic and cultural backgrounds. According to available data, there is an even distribution across the middle and/or upper-middle class, as well as the middle and/or lower-middle class. The number of students from lower-income backgrounds is comparatively lower. The latter benefit from the School Social Action Services. The educational facilities are typically situated in sizeable locales, equipped with appropriate and necessary amenities and apparatus for the educational services they offer their communities. The local authority has actively intervened in diverse facilities, supporting their maintenance and rehabilitation/ renovation.

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Finally, **school E** is situated in a rapidly expanding area with a relatively young population, which is unusual for Portugal. The institution maintains admirable standards, even amidst ongoing construction initiatives designed to improve its facilities. Despite these upgrades, students benefit from good conditions that prioritize their welfare and educational experience. These developments illustrate the institution's dedication to furnishing exceptional academic amenities and guaranteeing optimal student resources. The classrooms feature up-to-date equipment and resources- all school classrooms are supplied with computers, internet access, and projectors, ensuring that scholars have access to a conducive learning environment and effective access to digital resources. It is noteworthy that great emphasis has been placed on the upkeep of the outdoor spaces. The pavilions have been seamlessly incorporated into landscaped areas consisting of carefully maintained lawns, trees, and flowers. Given the asymmetrical surroundings of the school, there is a need to devise customized solutions for students of diverse profiles, to enhance inclusivity within the school and community. The school's services should consistently confront this challenge and devise innovative, adaptable solutions to meet the unique needs of their pupils, collaborating with families, student, and parent associations, as well as other local stakeholders. Consequently, the school has spearheaded initiatives that champion multiculturalism, inclusivity, and the digital shift. The school boasts a motivated teaching staff, consisting of teachers who possess a good understanding of the school's identity principles and uphold them accordingly. Additionally, newly recruited teachers are seamlessly integrated into the existing teaching staff, ensuring that students receive adequate support.

It is important to acknowledge that schools can differ significantly due to variations in their resources, teaching methods, and student populations, which may unavoidably affect educational assessments. However, precisely because of these differences, evaluations must be conducted rigorously and consistently. This is why we conducted our evaluation under these conditions. Appraisals and assessments in education should be designed to factor in variations to ensure accurate and impartial outcomes. Standardized testing procedures, controlled variables, and statistically valid sampling techniques were used to acquire a more precise representation of educational outcomes while minimizing the impact of school-related variations. The aim of the evaluations was to allow for meaningful comparisons and assessments of educational effectiveness across diverse settings, rather than disregarding differences between schools. This goal was successfully achieved.

Development of the educational scenario

Learning scenarios were designed to engage the participants in inquiry-based activities addressing a set of public health topics, such as zoonotic diseases, epidemics, health determinants, major chronic diseases, sustainable development. The topics were selected through a rigorous process that included alignment with national curricula, evidence on major public health issues, advising from experts and the advisory group of PAFSE, which includes educators and national education authorities. Each scenario was designed to achieve specific learning objectives. The teaching plan includes lesson outlines, evaluation strategies, and additional learning tasks. A practical guidebook is also provided to support classroom-based projects on the selected subject area. STEM experts, such as scientists, health professionals, engineers, and project managers, are welcome to participate in the educational path. Students are responsible for planning and implementing research projects, with the support of teachers, parents, stakeholders, and presenting the results in open schooling events.

The educational scenarios developed by National School of Public Health of NOVA University of Lisbon were on the following topics:

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- Sustainable development goals (SDGs)
- Non-communicable diseases (NCDs)
- Artificial intelligence (AI) in public health
- The role of environment and animal health in zoonotic diseases and pandemics

Integrating the study of SDGs in schools is crucial for fostering an informed and proactive future generation. It equips students with an understanding of global challenges such as poverty, inequality, climate change, zoonosis, environmental degradation. By learning about the SDGs, students can develop a sense of responsibility and the skills necessary to contribute for a healthy and sustainable future.

In relation to NCDs, is fundamental that students understand the patterns of risky behaviour, such as unhealthy diets, physical inactivity, tobacco use, alcohol abuse. By fostering awareness and promoting healthy behaviours in adolescents, schools can play a pivotal role in preventing the onset of NCDs later in life. Moreover, well-informed students can advocate for relevant resources in their communities (e.g., gardens, cycling routes), potentially reducing the global burden of these diseases. Since PAFSE project adopts an open-schooling framework, and parents, educators and the community are involved in the students' projects, rising their awareness about different NCDs is also a goal.

In relation to AI in public health, is essential that students understand the potential of technologies and their role in diagnosing diseases, predicting outbreaks, and personalizing patient care. Understanding the potentials and risks of AI is essential skill for future occupational profiles in healthcare. Incorporating education about AI in schools provides students with a foundational understanding of these technologies, enabling them to critically assess their applications and innovate in ways that can impact public health and healthcare.

Finally, understanding the role of the environment and animal health in zoonotic diseases is crucial, particularly in educational settings. Schools are ideal places to promote awareness and knowledge about how environmental factors and animal health may contribute to the spread of diseases to humans. By integrating this topic into school curricula, students can learn about the interconnectedness of natural ecosystems and the importance of maintaining them for disease prevention. Science education on this topic is important not only for raising awareness of related public health issues but also for promoting behaviours that contribute to the preservation diverse forms of life on land and below water.

The educational scenarios were chosen based on topics that are naturally incorporated in school curricula, making feasible for teachers to explore them with more detail in the context of implementation of PAFSE project.

The educational scenario on the topic "Sustainable Development Goals" tackles worldwide challenges and presents routes for individuals and groups to contribute to the SDGs. The educational plan concentrates on the integration of measures in schools to reinforce the SDGs, with an emphasis on SDG3 - Good Health and Well-being. The final aim is increasing the students understanding and empowerment towards a positive impact on the health and sustainability of the community. Students investigate socio-scientific issues via the implementation of projects, collating evidence before translating it into tangible actions at school level. Their efforts contribute towards the execution of the United Nations Sustainable Development Agenda 2030, promoting equality, health, and well-being in their communities with guidance given by teachers in school environment to assure full comprehension of such

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global development aims. The educational scenario commences by exploring the SDGs and their relevance for worldwide development. Subsequently, the emphasis is directed to SDG3, highlighting the significance of sound health and well-being for persons and societies, and the correlation between this objective and the other development goals. These actions are part of the teaching-learning sequence, which is the first part of the implementation of the PAFSE project within the classroom. Following this, students participate in structured research, are engaged in inquiry-based activities, collect, analyse, and interpret data. Utilizing guided research and classroom discussions, students are encouraged to investigate the impact of SDG3 on their community and identify socio-scientific issues. Furthermore, students collaborate to address distinct aspects of health and sustainability, identifying challenges and proposing solutions through collective actions. The students undertake a research project and use findings to implement concrete actions and initiatives in the school. As a culmination of this project, students create scientific posters that depict their findings and recommendations. These scientific posters are then presented during an open-school event, which serves as a platform for engaging with residents, organizations, and policy makers, facilitating debate, collaborations, and future initiatives. Throughout the teaching-learning sequence, students enhance their inquiry-based competences, digital literacy skills, and teamwork capabilities. As a result, they acquire a sense of responsibility towards their local school community and the wider, global aspirations of sustainable development. The expected learning outcomes are:

- Describe the SDGs and understand the importance of sustainable development.
- Explain how SDGs are interrelated.
- Use argumentation to connect SDG3 with other SDGs.
- Obtain and analyse data and scientific information regarding SDGs tracking.
- Propose evidence-based actions, at different levels, that help advance the SDGs.
- Find evidence, compilates data and information to help progress the SDGs at the local level.
- Use evidence to propose measures that contribute to the sustainability agenda at the community level and communicate them to the community leadership.

The Educational Scenario on the topic “non-communicable diseases” aims to bridge the knowledge, attitudes, and behaviours gap among students, by developing and implementing an innovative educational proposal, that seeks to empower students with the tools to understand, prevent, and mitigate NCDs, while recognizing the determinants shaping public health, and the active role they can play in positively influencing the health and well-being of their community. Cardiovascular diseases, cancer, diabetes, and respiratory disorders have emerged as leading causes of morbidity and mortality worldwide. There is extensive evidence that these major medical conditions are largely influenced by various determinants of health, including lifestyle choices, socio-economic status, environmental factors, genetics, and access to healthcare. NCDs have deep-rooted connections with socioenvironmental issues and preventing them requires a holistic and informed approach able to boost awareness on the related risks and undertaking concrete individual and community actions. Therefore, this educational scenario aims to facilitate teachers and the school community in examining societal issues relating to the prevalence of NCDs through the use of updated scientific evidence. The teaching -learning script aims to assist students in comprehending how STEM-based knowledge and occupational profiles can aid in preventing and avoiding exacerbations of NCDs. Additionally, it promotes students’ evidence-based decision-making and possible informative contributions to public policy. The scenario examines key factors that affect humans’ health and empowers students to prevent NCDs in their living environments. It additionally facilitates students’ involvement in civic initiatives and developing local responses

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to emerging issues. This involvement includes collaborations with the community and STEM professionals like researchers, public health specialists, data scientists and engineers. The scenario is based on the mandatory curriculum of natural sciences and promotes the following fundamental learnings:

- Distinguish health from quality of life.
- Understand the main determinants of health and well-being.
- Characterize the main non-communicable diseases, indicating the prevalence of associated risk factors.
- Interpret information on the determinants of individual and community health, analysing their importance in the quality of life of a population.
- Critically analyse action strategies in the promotion of individual, family, and community health, starting from issues framed in local, regional, or national problems.

The implementation of the PAFSE project in schools required integrated actions of teachers from multiple disciplines (e.g., science, mathematics, geography, citizenship) and followed a multidisciplinary approach. Teams of teachers were introduced to the challenge of working collaboratively to implement educational scenarios and integrate health promotion and disease prevention as a key subject in their lectures. Additionally, to follow science instruction through the use of advanced techniques, dynamic learning objects and educational resources provided by PAFSE researchers. Finally, in involving families in instructional pursuits and holding inquiry-led projects and open school events led by students.

The educational Scenario on the topic **"Artificial Intelligence in Public Health"** raises awareness on the role of AI systems in the effective delivery of healthcare. This involves comprehending the concept of AI, the development steps for an AI system, and stimulating classroom discussions on its use as an emerging technology. Creating awareness on the impact of emerging technologies, like AI, in everyday life and society, is established in the formal curriculum of Information and Communication Technologies (ICT). Hence, this educational scenario facilitates ICT teachers' role in exploring the social and ethical concerns surrounding the application of AI. The educational proposal enables young people to acquire a deep understanding on how STEM can provide effective solutions for public health issues, address ethical concerns regarding its use, facilitate evidence-based personal decision-making, and promote the uptake of academic syllabi and multiple possibilities in STEM careers. This educational scenario challenges educators in integrating health into the ICT syllabus/curricula whilst collaborating with other disciplines, including Sciences and Mathematics. It promotes the following fundamental learnings:

- Application of appropriate methods and techniques to develop simple AI systems for public health.
- Incorporation of Artificial Intelligence strategies in web applications.
- Identification of philosophic questions that can emerge from the use of AI.
- Identification of possible applications of AI in public health.
- Use of evidence-based argumentation to promote the use of AI in public health.
- Analysing possible consequences of inappropriate use of AI in public health.
- Use of evidence-based argumentation to discuss concerns around the use of AI in public health.

Finally, during the implementation of the educational scenario on **"The role of environment and animal health in zoonotic diseases and pandemics"** students investigate the captivating realm of zoonotic diseases and their repercussions on human health. They scrutinize the inception of these illnesses and comprehend how they are transmitted from

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animals to humans, whilst recognizing the components that give rise to their emergence. Students explore ONE HEALTH approach endorsed by the World Health Organization, which highlights the interdependence of human, animal, and environmental health. Students investigate the correlation between environmental degradation and human health from different perspectives, including human health itself, as well as the emergence of zoonotic diseases, which pose an increasing threat to global health and have caused significant economic harm in the last two decades, potentially impacting human health as well. The impact of phenomena such as climate change, pollution, and loss of biodiversity on the well-being of individuals and communities is explored, with an emphasis on gaining a deeper understanding of the significance of environmental protection for human health. Students comprehend the intricate effects of climate change on human and animal health, as it causes pathogens and vectors to develop adaptive mechanisms, resulting in diseases that are resistant to conventional treatments due to increased resilience and survivability. Furthermore, the scenario includes data analysis as an essential component of scientific projects. It enables the development of basic yet significant project management skills. Students learn how to gather, scrutinize, and decipher data regarding zoonotic diseases, environmental degradation, and their repercussions on human health. Students acquire crucial aptitudes in data analysis, effectively drawing conclusions from scientific data, and communicating their findings with clarity. Additionally, they formulate recommendations to be implemented in their respective communities. Overall, this educational proposal provides learners with in-depth comprehension of zoonoses, ONE Health and the role of preventive approaches in public health. Students also investigate the One Health approach, acknowledging the significance of interdisciplinary cooperation in tackling worldwide health issues. Through scrutinizing the connections between environmental decline and health, scholars cultivate a responsibility for safeguarding the environment and the contribution they can make towards championing a healthier world. Ultimately, their experience with data analysis endows them with advantageous scientific competencies for prospective research and handling intricate health dilemmas. Education that improves literacy in environment, climate, and One Health is essential for building consensus and strengthening communities' resilience. It provides the necessary foundation for acquiring the expertise required to develop evidence-based proposals and solutions for problems related to climate and environment. the expected learning outcomes are the following:

- Use online tools to plot tables, graphs, and maps, using updated data.
- Analyse the consequences of zoonotic diseases on human beings and the environment.
- Obtain, evaluate, and communicate data and scientific information about environmental determinants of health and zoonotic diseases.
- Use evidence to build argumentation on climate change.
- Give examples of environmental issues affecting the prevalence of zoonotic diseases in the community.
- Describe different approaches to protect, develop and influence global health.
- Use evidence to propose measures and methods to fight climate change and communicate them to the community leadership.

The four educational scenarios present a clear picture of global challenges and opportunities of the 21^{st} century and emphasise the need for collaborative interdisciplinary efforts to create a healthier, fairer, and more sustainable future for all.

Enactment(s) of the educational scenario

Overall, the implementation of the four educational scenarios developed by ENSP-NOVA followed PAFSE model and therefore similar phases. The enactment is briefly explained below.

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The process starts with teacher preparation for the implementation of the educational scenario. This training aims to improve teachers' skills in project-based and inquiry-based learning, with an emphasis on data collection, analysis, and communication of results. With new pedagogical techniques and resources at their disposal, teachers are ready to effectively integrate the educational scenarios into their teaching.

Following this phase, teachers bring scenarios to life in the classroom by linking the lectures to the mandatory curriculum and expected learning outcomes. Students engage in active learning through discussions, hands-on activities, and problem-solving tasks, fostering a deeper understanding of the subject matter. Teachers play a pivotal role in guiding these activities, encouraging critical thinking, and facilitating meaningful dialogue in the classroom. The student scientific project is the culmination of this process. At this phase students apply their newfound knowledge to conduct scientific investigations. They work in groups to formulate research questions, design experiments, gather and analyse data, and draw evidence-based conclusions. They participate in scientific activities provided by the partners of the educational network (e.g., research centres, enterprises, libraries, science centres). Ultimately, they present the findings and recommendations of their scientific project in the open schooling event and therefore in front of their peers, families, and school community.
In summary, the educational scenario implementation encompassed various methods: brainstorming, debate, collaborative learning, project-based learning, inquiry-based learning. Additionally, involved the organization of science education activities in formal and informal learning environments, both inside and outside the classroom, with the teacher and partners integrating the local educational network.

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Methods

A prospective case-control study was conducted to answer the research question and test the hypotheses. The target population of the project consisted of students aged between 12 and 15, which, in the Portuguese context, corresponds to lower-secondary education (7th, 8th and 9th grade). The students were from the five different pilot schools that were briefly described in the “context” section. The schools had different characteristics and sizes. Based on these alternating characteristics, a certain number of classes were selected from each school and assigned as cases or controls. Informed consent was obtained from the legal representatives because all students were minors. The following surveys were conducted:

1. The Student Interest and Choice in STEM (SIC-STEM) Survey, an instrument that operationalizes key constructs of Social Cognitive Career Theory (SCCT) to examine their interplay within students' experiences and their subsequent influence on STEM career aspirations (Roller et al., 2018).
2. Survey on knowledge and skills (specific for each educational scenario) based on: i. The theory of Planned Behaviour (Icek Ajzen, 1985), a recognized and widely-use theory across social and behavioral sciences, that rests on the assumptions that human behaviour is driven by a triad of considerations: perceptions of the behaviours’ outcomes (behavioral beliefs), beliefs about social pressure to perform the behaviour (normative beliefs), and perceived ease or difficulty of performing it (control beliefs) (Bosnjak et al., 2020); ii. Constructing a Theory of Planned Behaviour Questionnaire: Conceptual and Methodological Considerations (Icek Ajzen, 2006).

The questionnaires were administered at the same time to all students - cases and controls – before and after the educational enactments of PAFSE.

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RESULTS

1. SIC-STEM Survey.

This questionnaire includes 3 subscales: mathematics, sciences, and technology/engineering. Each subscale has 15 items. The response options consist of a 5-point Likert scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree. The scores of each domain were calculated through the mean of the 15 items. This way, each score can range from 1 to 5 – the higher the score, higher the attitudes and interest in Mathematics, Sciences and Technology/Engineering.

Sample. Data was collected from 423 students enrolled in the 2022/2023 school year at five schools in the Greater Lisbon area. The study analysed data from 257 student respondents who experienced one of the integrated educational scenarios (cases) and 166 controls.
Data Analysis. A mixed ANOVA was conducted to assess the effect of the scenario, with an interaction between the group (PAFSE vs. Control) and the phase (paired samples: pre-scenario vs. post-scenario). The group*phase interaction term was used to determine if the pre-post scenario evolution differed significantly between the groups. Within each group, a paired Student's t-test was used to compare pre-post scenario results.
Results.

Table 1 Scores of students' attitudes towards STEM - educational scenario on the topic "The role of environment and animal health in zoonotic diseases and pandemics."

Variable	Group	N	Pre-scenario		Post-scenario		Student's t-test (pre-post) p-value	Interaction time * group p-value
			Mean	SD	Mean	SD		
Mathematics	PAFSE	63	3.17	0.60	3.29	0.64	0.033	**0.031**
	CONTROL	54	3.47	0.68	3.42	0.70	0.353	
Sciences	PAFSE	63	3.34	0.52	3.49	0.52	**0.004**	**0.006**
	CONTROL	54	3.52	0.56	3.49	0.62	0.413	
Engineering and technology	PAFSE	63	3.05	0.48	3.13	0.53	0.223	0.232
	CONTROL	54	3.19	0.71	3.16	0.62	0.611	

Results in Table 1 show that the evolution pre-post scenario differed significantly between the PAFSE Group and the Control Group for the variables "Mathematics" and "Sciences" (interaction: $p < 0.05$):

- The mathematics mean score increased significantly in the PAFSE Group (pre-scenario: 3.17 ± 0.60; post-scenario: 3.29 ± 0.64; $p < 0.05$) but remained unchanged in the Control Group (pre-scenario: 3.47 ± 0.68; post-scenario: 3.42 ± 0.70; $p = 0.353$).
- The Sciences mean score increased in the PAFSE Group (pre-scenario: 3.34 ± 0.52; post-scenario: 3.49 ± 0.52; $p < 0.05$) but did not change in the Control Group (pre-scenario: 3.52 ± 0.56; post-scenario: 3.49 ± 0.62; $p = 0.413$).

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Table 2 Scores of students' attitudes towards STEM - educational scenario on the topic "Individual and socioenvironmental influences on humans' health and the burden of non-communicable diseases"

Variable	Group	N	Pre-scenario		Post-scenario		Student's t-test (pre-post) p-value	Interaction time * group p-value
			Mean	SD	Mean	SD		
Mathematics	PAFSE	102	3.45	0.62	3.52	0.63	0.047	0.431
	CONTROL	53	3.01	0.79	3.13	0.82	0.052	
Sciences	PAFSE	102	3.51	0.57	3.68	0.56	<0.001	**0.011**
	CONTROL	53	3.39	0.53	3.43	0.60	0.464	
Engineering and technology	PAFSE	102	3.23	0.61	3.21	0.64	0.753	0.729
	CONTROL	53	2.99	0.78	3.01	0.67	0.845	

Results in Table 2 show that the evolution pre-post scenario differed significantly between the PAFSE Group and the Control Group for the variable "Sciences" (interaction: $p < 0.05$):

- The Sciences mean score increased significantly in the PAFSE Group (pre-scenario: 3.51 ± 0.57; post-scenario: 3.68 ± 0.56; $p < 0.001$) but did not change in the Control Group (pre-scenario: 3.39 ± 0.53; post-scenario: 3.43 ± 0.60; $p = 0.464$).

Table 3 Scores of students' attitudes towards STEM - educational scenario on the topic "Sustainable Development Goals."

Variable	Group	N	Pre-scenario		Post-scenario		Student's t-test (pre-post) p-value	Interaction time * group p-value
			Mean	SD	Mean	SD		
Mathematics	PAFSE	51	3.62	0.53	3.72	0.68	0.058	0.387
	CONTROL	21	3.39	0.55	3.41	0.58	0.736	
Sciences	PAFSE	51	3.53	0.58	3.75	0.58	<0.001	**0.018**
	CONTROL	21	3.49	0.57	3.47	0.43	0.799	
Engineering and technology	PAFSE	51	3.44	0.49	3.42	0.48	0.777	0.252
	CONTROL	21	3.31	0.55	3.17	0.49	0.036	

Results in Table 3 show that the evolution pre-post scenario differed significantly between the PAFSE Group and the Control Group for the variable "Sciences" (interaction: $p < 0.05$):

- The Sciences mean score increased significantly in the PAFSE Group (pre-scenario: 3.53 ± 0.58; post-scenario: 3.75 ± 0.58; $p < 0.001$) but did not change in the Control Group (pre-scenario: 3.49 ± 0.57; post-scenario: 3.47 ± 0.43; $p = 0.799$).

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Table 4 Scores of students' attitudes towards STEM - educational scenario on the topic "Artificial Intelligence and Public Health"

Variable	Group	N	Pre-scenario		Post-scenario		Student's t-test (pre-post) p-value	Interaction time * group p-value
			Mean	SD	Mean	SD		
Mathematics	PAFSE	41	3.11	0.84	3.35	0.82	<0.001	**0.043**
	CONTROL	38	3.03	0.68	3.09	0.65	0.404	
Sciences	PAFSE	41	3.45	0.52	3.49	0.46	0.526	0.449
	CONTROL	38	3.30	0.61	3.27	0.63	0.661	
Engineering and technology	PAFSE	41	2.99	0.54	3.55	0.57	<0.001	**<0.001**
	CONTROL	38	3.00	0.68	3.00	0.46	0.947	

Results in Table 4 show that the evolution pre-post scenario differed significantly between the PAFSE Group and the Control Group for the variables "Mathematics" and "Engineering and Technology" (interaction: $p < 0.05$):

- The mathematics mean score increased significantly in the PAFSE Group (pre-scenario: 3.11± 0.84; post-scenario: 3.35 ± 0,82; $p < 0.001$) but did not change in the Control Group (pre-scenario: 3,03 ±0.68; post-scenario: 3.09 ± 0.65; $p = 0.404$).

- The Engineering & Technology mean score increased significantly in the PAFSE Group (pre-scenario: 2.99 ± 0.54; post-scenario: 3.55 ± 0.57; $p < 0.001$) but did not change in the Control Group (pre-scenario: 3.00 ± 0.68; post-scenario: 3.00 ± 0.46; $p = 0.947$).

2. **Survey on students' knowledge and skills** (specific to each educational scenario)**.** The assessment comprises of three subscales: knowledge, measured on a scale of 0 to 100 to represent the percentage of correct answers; skills1, also on a scale of 0 to 100 indicating the percentage of correct answers; and skills2, assessed on a Likert scale from 1 to 5, where a higher score reflects a more favourable attitude towards the desired behaviour.

Sample. Data from students enrolled in the 2022/2023 school year was collected from five lower secondary schools in Greater Lisbon. *Data Analysis.* A mixed ANOVA was conducted to evaluate the effect of the scenario, with an interaction between the group (PAFSE vs. Control) and the phase (paired samples: pre-scenario vs. post-scenario). The group*phase interaction term was used to determine if there was a significant difference in the pre-post scenario evolution between the groups. Within each group, a paired Student's t-test was used to compare the pre-post scenario.

Results.

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Table 5 Scores of students' knowledge and skills - educational scenario on the topic "The role of environment and animal health in zoonotic diseases and pandemics."

Variable	Group	N	Pre-scenario Mean ± SD	Post-scenario Mean ± SD	Student's t-test (pre-post)	Interaction time * group
Knowledge	PAFSE	73	61.1 ± 23.2	76.6 ± 19.8	p < 0.001	**p = 0.002**
	CONTROL	59	60.6 ± 21.3	64.3 ± 22.2	p = 0.168	
Skills 1	PAFSE	73	64.4 ± 27.7	78.1 ± 23.8	p < 0.001	p = 0.265
	CONTROL	59	56.6 ± 31.3	63.4 ± 29.5	p = 0.195	
Skills 2	PAFSE	73	3.61 ± 0.53	3.85 ± 0.56	p = 0.001	**p = 0.003**
	CONTROL	59	3.81 ± 0.58	3.74 ± 0.62	p = 0.304	

Results in Table 5 show that the evolution pre-post scenario differed significantly between the PAFSE Group and the Control Group for the variables 'knowledge' and 'skills2' (interaction: $p < 0.05$):
- The mean score for 'knowledge' increased significantly in the PAFSE Group (pre-scenario: 61.1 ± 23.2; post-scenario: 76.6 ± 19.8; $p < 0.001$), while it remained unchanged in the Control Group (pre-scenario: 60.6 ± 21.3; post-scenario: 64.3 ± 22.2; $p = 0.168$).
- The mean score for Skills2 significantly increased in the PAFSE Group (pre-scenario: 3.61 ± 0.53; post-scenario: 3.85 ± 0.56; $p= 0.001$), while it remained unchanged in the Control Group (pre-scenario: 3.81± 0.58; post-scenario: 3.74 ± 0.62; $p = 0.304$).

Table 6 Scores of students' knowledge and skills - educational scenario on the topic "Individual and socioenvironmental influences on humans' health and the burden of non-communicable diseases."

Variable	Group	N	Pre-scenario Mean ± SD	Post-scenario Mean ± SD	Student's t-test (pre-post)	Interaction time * group
Knowledge	PAFSE	108	59.8 ± 23.2	73.3 ± 20.1	p < 0.001	**p = 0.001**
	CONTROL	68	57.4 ± 24.4	58.2 ± 27.0	p = 0.743	
Skills 1	PAFSE	108	51.9 ± 25.5	66.4 ± 29.4	p < 0.001	**p = 0.007**
	CONTROL	68	47.5 ± 27.2	47.5 ± 30.6	p = 1.000	
Skills 2	PAFSE	108	3.90 ± 0.51	4.06 ± 0.54	p < 0.001	p = 0.117
	CONTROL	68	3.83 ± 0.50	3.89 ± 0.57	p = 0.247	

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Results in Table 6 show that the evolution pre-post scenario differed significantly between the PAFSE Group and the Control Group for the variables 'knowledge' and 'skills1' (interaction: $p < 0.05$):

- The mean score for 'knowledge' significantly increased in the PAFSE Group (pre-scenario: 59.8 ± 23.2; post-scenario: 73.3 ± 20.1; $p < 0.001$), while it remained unchanged in the Control Group (pre-scenario: 57.4 ± 24.4; post-scenario: 58.2 ± 27.0; $p = 0.743$).

- The mean score for Skills1 significantly increased in the PAFSE Group (pre-scenario: 51.9 ± 25.5; post-scenario: 66.4 ± 29.4; $p < 0.001$), but remained unchanged in the Control Group (pre-scenario: 47.5 ± 27.1; post-scenario: 47.5 ± 30.6; $p = 1.000$).

Table 7 Scores of Students' knowledge and skills - educational scenario on the topic "Sustainable Development Goals."

Variable	Group	N	Pre-scenario Mean ± SD	Post-scenario Mean ± SD	Student's t-test (pre-post)	Interaction time * group
Knowledge	PAFSE	70	33.0 ± 20.7	56.0 ± 21.6	p < 0.001	**p = 0.090**
	CONTROL	33	24.7 ± 20.7	39.6 ± 17.3	p < 0.001	
Skills 1	PAFSE	70	39.6 ± 29.6	56.4 ± 20.7	p < 0.001	p = 0.113
	CONTROL	33	31.1 ± 25.0	38.6 ± 25.8	p = 0.048	
Skills 2	PAFSE	70	3.61 ± 0.53	3.94 ± 0.49	p < 0.001	**p = 0.026**
	CONTROL	33	3.48 ± 0.63	3.60 ± 0.70	p = 0.203	

Results in Table 7 show that the evolution pre-post scenario differed significantly between the PAFSE Group and the Control Group for the variables 'attitudes and behaviours' (interaction: $p < 0.05$):

- The mean score for Knowledge increased significantly in the PAFSE Group (pre-scenario: 33.0 ± 20.7; post-scenario: 56.0 ± 21.6; $p < 0.001$) and changed in the Control Group (pre-scenario: 24.7 ± 20.7; post-scenario: 39.6 ± 17.3; $p < 0.001$).

- The mean Skills2 score significantly increased in the PAFSE Group (pre-scenario: 3.61 ± 0.53; post-scenario: 3.94 ± 0.49; $p < 0.001$) but did not change in the Control Group (pre-scenario: 3.48 ± 0.63; post-scenario: 3.60 ± 0.79; $p= 0.203$).

DISCUSSION AND CONCLUSIONS

The results of this case study offer valuable insights about the impact of educational scenarios following inquiry-based learning and open schooling approach on lower secondary school students' attitudes towards STEM. PAFSE researchers from ENSP-NOVA implemented an innovative STEM education program in five pilot schools to increase students' knowledge and attitudes towards public health, STEM subjects, and careers. STEM is an abbreviation of four

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closely connected areas of study: science, technology, engineering, and mathematics. These fields are often associated due to their similarities in theory and practice.
The research analysed the attitudes of students towards STEM subjects and careers in the context implementing the PAFSE educational proposal.
Students enrolled in the implementation of the educational scenario on the topic of zoonotic diseases and pandemics demonstrated a marked rise in enthusiasm for Mathematics and Science. This highlights the importance of data science connecting environmental health to humans' health to foster students' attitudes and interest in STEM. In a similar way, students engaged in the implementation of the educational scenario on the topic of non-communicable diseases showed an augmented interest regarding science. The results suggest that inquiry-based learning, in the context of a project that aimed at preventing disease in the community, can foster curiosity and passion for scientific topics, as well as careers in science and mathematics. Furthermore, the scenario on the topic of the Sustainable Development Goals piqued students' interest in science, highlighting the importance of aligning educational content with global challenges that are significant for pupils, such as climate change, ecosystem degradation, and the sustainability of life as a whole. Finally, students enrolled in the educational scenario on the topic of Artificial Intelligence demonstrated a significant increase in their attitudes and interest towards mathematics, engineering, and technology. These findings suggest the importance of interdisciplinary frameworks that combine technology and science to spark students' interest and attract them to STEM occupational profiles. Positive changes were also identified in students' knowledge and skills. The research findings have important implications for STEM education. Specifically, they demonstrate the effectiveness of Educational Scenarios that combine inquiry-based learning and open schooling principles in stimulating students' interest in STEM subjects. This educational proposal offers a practical approach to enhancing the appeal and relevance of STEM topics to students, especially when addressing real-world issues related to public health. Additionally, this study emphasises the significance of interdisciplinary scenarios that integrate the actions of teachers from multiple scientific areas/ disciplines in addressing topics related to public health. The educational proposal includes actions of formal educational providers in the classroom environment, as well as experiences of STEM providers (universities, research labs, enterprises) and a research project that benefits the health of the community. Therefore, it provides a comprehensive and practical perspective on complex issues that involve the combination/ integration of different, yet complementary fields of knowledge.

Although the findings suggest potential, further research is required with larger samples to investigate the enduring and long-term effects of these educational scenarios and their influence on career decisions. Additionally, a more in-depth exploration of the impact of teacher involvement and teaching techniques within these settings could facilitate a better understanding of efficacious STEM education approaches. Teachers play a crucial role in shaping students' perspectives of STEM subjects. The implementation of educational scenarios can be influenced by variations in educators' enthusiasm, expertise, and educational approaches. Institutions with engaged and competent teachers may design and implement scenarios more effectively, stimulating greater interest and understanding among students in related subjects. However, educational institutions with less committed or inexperienced instructors may struggle to coordinate or participate in the implementation of educational scenarios. This could result in weaker impacts on students' aptitudes and attitudes. Furthermore, these educational scenarios ask for collaboration between teachers from diverse disciplines. Schools that have previously had strong interdisciplinary collaboration may provide students with more comprehensive and enriched learning opportunities, which could lead to a greater impact on their attitudes and skills. This is especially important in situations that involve

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the integration of STEM subjects with other disciplines. Institutions lacking interdisciplinary teamwork may fail to fully utilise the potential benefits of interdisciplinary collaboration, resulting in suboptimal outcomes. The study also presented certain limitations: the study's use of questionnaires may introduce self-report bias, where participants may not accurately reflect their true feelings and instead respond in a manner they perceive as expected or socially acceptable. This bias can skew the data, leading to misinterpretations of the attitudes and behaviours being investigated. Furthermore, the integrity of the control group may be compromised due to the inadvertent communication of the PAFSE topics by teachers, which could potentially influence the outcomes. Additionally, establishing a clear temporal relationship between the educational interventions and shifts in student attitudes towards STEM poses a challenge, further complicating the analysis. The study's findings may not be generalizable beyond the narrow age range of 12-15 years, as attitudes and perceptions are likely to change with age. Finally, cultural influences, which can significantly impact students' perspectives on STEM and public health, may not have been adequately accounted for in the study, reducing its relevance across diverse populations. These limitations emphasize the importance of carefully considering methodology and demographic factors in educational research.
Further research will be conducted to investigate how external factors affect learning outcomes in the context of PAFSE implementation.

For instance, educational institutions located in affluent areas are more likely to possess better resources, such as high-quality technological equipment, well-stocked laboratories, and extracurricular activities. These facilities may enhance the implementation of educational scenarios and improve the quality and impact of the learning experience. However, by comparison, educational institutions in poor regions may face financial restrictions that hinder their ability to invest in the learning environment. Additionally, socioeconomic backgrounds can affect parental involvement in education. There is considerable evidence that individuals from lower-income backgrounds may face obstacles to obtaining educational assistance beyond the classroom. This may limit the extent to which their attitudes and abilities are positively influenced by the situations presented.

In summary, the implementation of the educational scenarios had a positive impact students' knowledge and skills in dealing with public health issues, as well as their interest and attitudes towards STEM. The PAFSE educational scenarios, which are firmly grounded in inquiry-based learning and open educational principles, have the potential to yield favourable effects on students' views, curiosity, and understanding of STEM subjects. These findings highlight the potential of STEM education to transform students, enabling them to address real-world issues and contribute to a more sustainable and technologically advanced future.

RECOMMENDATIONS

1. Encourage teachers work based on educational scenarios; promote the multidisciplinary implementation of educational scenarios - science teachers involving of teachers from different disciplines (e.g., ICT, English, Citizenship, Arts) in the educational enactments.
2. Promote an open schooling framework and project-based learning in the context of public health education; encourage knowledge transfer from students to society by the implementation of projects that benefit the school community.
3. Create educational clusters with epicentre in schools and in collaboration with local stakeholders (e.g.: universities, government bodies, companies, associations, foundations, civil society), committed to an interdisciplinary approach to public health education; promote learning activities in the classroom and informal education spaces (e.g., science clubs,

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libraries) that bring real problems and supports students' innovation and creativity in the development of solutions.
4. Encourage school collaborations with the local community and interactions of students with STEM professionals.
5. Encourage the use of digital learning objects in learning environments enriched by technology.
6. Elaborate policy briefs based on the results of this study.
7. Conduct a follow-up questionnaire to get valuable insights on the enduring and long-term impacts of the educational scenarios.

When considering these suggestions, it is important to evaluate their potential impact comprehensively, ensuring alignment with the context in which they are being implemented, and keeping in mind the individuals involved.

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3.4. University of Minho (Uminho) – Case Study Report

Fostering public health prosumer students through low code learning

INTRODUCTION
Public health awareness assumes a heightened significance in a post-pandemic world. The global crisis illuminated the critical role of informed, health-conscious communities in preventing the spread of infectious diseases and minimizing their impact. Within this context, it becomes evident that bridging the gap between scientific expertise and public understanding is paramount. Scientific texts, often cloaked in hermetic language and laden with specialized jargon, pose a formidable barrier to accessibility. Efforts to make scientific literature more accessible represent a significant step toward demystifying complex subjects (Ermakova et al., 2023; Araújo & Aguiar, 2023a). Still, this alone is insufficient. To address public health challenges, we must equip middle school students with the skills to navigate, interpret, and communicate this information effectively. By cultivating a generation of students who can decipher and translate scientific knowledge into accessible resources, we empower them to serve as vital conduits for disseminating public health information to their communities. In the contemporary landscape characterized by an increasingly technologically-driven world and by the growing influence of Artificial Intelligence (AI), juxtaposed with the proliferation of content creation and consumption platforms like Instagram, TikTok, and YouTube (Prensky, 2004; Rosenthal, 2018), which hold considerable sway among younger generations and have altered how information is both consumed and disseminated, it is essential to recognize the shifting information dynamics. Within this evolving context, as part of the European PAFSE project, the UMINHO partner has focused on integrating public health themes and low-code development environments, thereby promoting both public health and digital literacy. This chapter presents the pilot case study conducted across six schools located in Braga, Portugal. This study involved the formulation of educational scenarios that integrate low-code programming with key public health topics, as well as the training of educators to facilitate these scenarios within their classrooms. Subsequently, these scenarios were put into practice, engaging students in a learning experience at the intersection of technology and public health.
CONCEPTUAL FRAMEWORK
The concept of "prosumer," encapsulating the merging of "producer" and "consumer" roles, is not a novel idea (Toffler & Alvin, 1980). However, the specific focus on the "prosumer student" approach, which emphasizes active student engagement and knowledge co-creation, is a relatively underexplored concept within the realm of education. The existing body of research primarily pertains to the teacher-prosumer relationship (Burlea & Burdescu, 2016; Triviño-Cabrera et al., 2021; Zavyalova & Galvin, 2022). When applying the concept of prosumption to students, Dusi and Huisman (2021) emphasize Ritzer's (2014) notion of the prosumption continuum. Ritzer's (2014) framework posits that activities can be situated along a continuum that spans from prosumption-as-production (simultaneously consuming and producing) to prosumption-as-consumption (simultaneously producing and consuming). Dusi and Huisman (2021) contend that the concept of

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prosumption holds relevance in the context of higher education, as it provides valuable insights into the diverse roles and behaviors of students. By situating students' activities, such as crafting a thesis, engaging in group study sessions, or participating in decision-making processes on the prosumption continuum, a more comprehensive understanding of their multifaceted roles and positions within higher education can be attained.

Although the literature on prosumer learning scenarios remains somewhat limited, studies within this framework offer compelling insights. For example, in second language learning, Engin's (2014) study illustrates a prosumer learning scenario where students actively engage in creating and consuming digital video tutorials related to various aspects of academic writing. While students still leaned towards favoring teacher-led explanations, the study shows that these videos contributed positively to language learning. Another instance, this time within the realm of computer science, can be found in the work of Vasilchenko et al. (2020). Their research illustrates a pedagogical experience in which students assume the role of prosumers, engaging with knowledge generated by their peers. Students majoring in computing science were assigned the task of conducting interviews with experts in the field. Subsequently, they were required to create succinct video reports, along with written summaries, based on these interviews. The purpose of these reports was to enhance students' understanding of various facets and stages of the life cycles of Information Technology (IT) systems. Although student responses varied, resulting in a dichotomy of either loving or disliking this approach, the teaching staff remained steadfast in their belief in the educational advantages of this method and expressed their intent to continue implementing it in future teaching endeavors. These insights suggest that prosumption can potentially enhance learning outcomes, even if it demands students to step beyond the familiar and into the realm of the unfamiliar.

Navio-Marco et al. (2022) draw a link between prosumerism, the concept of "learning by practice," and the evolving landscape of digital education, aligning this perspective with Cullen's (2020) idea of student participation and co-production knowledge. In the digital realm, "learning by practice" translates to active participation in the digital arena, which includes the consumption of content and the creation and dissemination of knowledge. In the context of our case study's scenario, prosumer students will not only be consumers of public health information but also actively engaged in creating and sharing knowledge related to public health using low-code learning techniques. Low-code is a software development approach with high potential (Varajão, 2021), facilitated by a low-code platform, which empowers developers to create mobile or web applications with minimal to no traditional hand-coding (Araújo & Varajão, 2023), primarily utilizing a graphical user interface (GUI) for tasks such as dragging and dropping application components and connecting them seamlessly (Prat, 2021; Trigo et al., 2023; Varajão et al., 2023). In the pedagogical context, low-code learning has proven to be a valuable tool for enhancing the computer skills of both students and teachers (McHugh et al., 2023). This approach enables them to acquire fundamental programming skills while simultaneously developing practical and functional applications. Indeed, Matook et al. (2023) emphasize that a low-code platform provides students with real-world ISD (Instructional Systems Design) experiences while facilitating technology-mediated learning.

RESEARCH QUESTIONS

This case study aims to devise a workflow that uses low-code learning to nurture public health prosumer students, with a specific emphasis on promoting interdisciplinary collaboration

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between science and technology classes. Our central research question is as follows: "How can we foster public health prosumer students through low-code learning?"

METHODS AND CONTEXT

A workflow consisting of three key stages was designed to address the research question.

1. Developing the learning scenarios: The initial stage involves incorporating and adapting health-related subjects from the science curriculum into the ICT syllabus, accompanied by creating learning scenarios.
2. Teacher training program: Following this, training courses are conducted with teachers to familiarize them with the new content and provide training on effectively implementing these learning scenarios.
3. In-school application & Revisions: In the final stage, teachers apply the scenarios presented during the workshops in their classrooms, and students are encouraged to engage actively in creating and later presenting their own content. The teaching scenarios were refined following their implementation, incorporating valuable feedback from both the experiment participants and educators.

1. Developing the learning scenarios

The structure of the learning scenarios is founded on the fundamental tenets of active methodologies. Active methodologies encompass a range of methods, practices, strategies, and instruments designed to engage students directly in the teaching and learning process (Moya, 2017). In developing the scenarios, particular emphasis was placed on three key active learning concepts: project-based learning, collaborative learning, and the flipped classroom approach.

Project-based learning (PBL) is an interactive, student-centric instructional approach that is rooted in the beliefs that learning is most effective when situated in real-life contexts, students are active participants in their learning journey, and collaborative interactions and knowledge sharing drive their success (Kokotsaki et al.; 2016). What sets PBL apart is the creation of a tangible end product that directly tackles the unit's guiding question, serving as both a concrete representation of student learning and a valuable educational artifact (Krajcik & Shin, 2014).

Helle et al. (2006) contend that Project-based learning represents a variant of collaborative learning, which entails students working collectively within groups and in cooperation with the teacher (Davidson & Major, 2014). In such a setting, the group collaboratively determines the distribution of tasks, either by assigning collective responsibilities to all members or by assigning specific roles based on individual skills and strengths (Araújo & Aguiar, 2023b).

A flipped classroom is an instructional approach where the traditional model of classroom instruction is reversed (Bergmann & Sams, 2012). In a traditional classroom, students listen to lectures and receive direct instruction from the teacher during class time, and then they complete homework or practice exercises outside of class. In a flipped classroom, students engage with the instructional content before class, typically through pre-recorded video lectures or reading materials (Sohrabi & Iraj, 2016). Class time is then used for more interactive and collaborative activities, such as discussions, problem-solving, and hands-on exercises, where students can apply the knowledge they gained from the pre-class materials (Akçayır & Akçayır, 2018).

Based on these active learning concepts, three progressively challenging learning scenarios (basic, intermediate, and advanced) were designed for the seventh, eighth, and ninth-grade

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levels, promoting interdisciplinary collaboration between the ICT and Science disciplines. The scenarios were structured to span around five/six lessons, each lasting 40 minutes. Students are challenged to design a mobile application using the MIT App Inventor, centered around a health topic chosen by their Science teacher. In the subsequent discussion, we provide an overview of how MIT App Inventor operates, along with an exploration of block-based visual programming languages. But, for the present moment, it is crucial to underscore that using this platform has been shown to contribute significantly to the enhancement of students' computational thinking skills (Xie & Abelson, 2016; Pérez-Jorge & Martínez-Murciano, 2022). The learning scenarios are integrated within the broader context of the Ciência Viva school clubs (see Figure 1).

Figure 1. Poster for the Maximinos school group's Ciência Viva Club.

The Ciência Viva club network, a project led by the National Agency for Scientific and Technological Culture in partnership with the Directorate-General for Education, is dedicated to promoting hands-on science education and disseminating scientific and technological knowledge. These clubs serve as community hubs, engaging families and the local population in innovative scientific applications, aiming to instill a passion for science, lifelong learning, and establishing connections between schools and the local community through partnerships with scientific institutions, local authorities, educational centers, businesses, museums, and cultural organizations (Ciência Viva, 2023).

2. Teacher training program

Upon the development of the learning scenarios, a teacher training program titled "Low-code development to promote STEM in gamified and multimodal environments" (in the original Portuguese, "Desenvolvimento low-code para promoção das CTEM em ambientes gamificados e multimodais"), was designed, spanning a total of 15 hours and divided into four sessions, complemented by a preliminary introductory session.
An invitation to engage in the activities within the PAFSE project was extended to eight schools. Out of the eight schools that were invited to participate in the activities developed

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within the PAFSE project, six of them endorsed the declaration of commitment as external partners supporting the project. The remaining two schools opted not to partake due to the unavailability of Information and Communication Technology (ICT) teachers. This training initiative successfully engaged teachers from six school groups situated in Braga (A.E. Real; A.E. Alberto Sampaio 1 e 2, A.E. Maximinos; A.E. Trigal de Santa Maria; A.E. André Soares).

Following the training courses, feedback surveys among the participating teachers were conducted. The responses indicated a generally positive perception of the workshop, with many highlighting the collaborative efforts between the Science and Technology disciplines as a key positive aspect. One teacher, in particular, noted, "As a natural sciences teacher, I found the workshop provided me with valuable insights into an area I was previously unfamiliar with. The collaborative work between ICT and Natural Sciences was particularly engaging and enlightening."

3. In-school application & Revision

Thirty-two classes (sixteen PAFSE classes and sixteen control classes) from six schools in Braga actively participated in the implementation of the learning scenarios, with each scenario lasting approximately 5 to 8 sessions. In the first scenario designed for 7th-grade students, 95 participants took part, while the second scenario, tailored for 8th-grade students, involved 105 students. The third scenario saw participation from 112 students. Table 1 shows the participating classes and respective schools per level.

Level	**School Group**	**PAFSE Class**	**Control Class**
Level 1 (Basic)	Agrupamento de Escolas De Real	7_D	7_A
	Agrupamento de Escolas De Maximinos	7_4	7_1
	Agrupamento de Escolas André Soares	7_F	7_I
	Escola Secundária Alberto Sampaio (Alberto Sampaio 1)	7_I	7_H
	Agrupamento de Escolas de Trigal de Santa Maria	7_A	7_D
	Escola Básica 2 e 3 de Nogueira (Alberto Sampaio 2)	7_F	7_G
Level 2 (Intermediate)	Agrupamento de Escolas De Maximinos	8_1	8_2
	Escola Secundária Alberto Sampaio (Alberto Sampaio 1)	8_I	8_H
	Agrupamento de Escolas de Trigal de Santa Maria	8_A	8_C
	Escola Básica 2 e 3 de Nogueira (Alberto Sampaio 2)	8_E	8_D
Level 3 (Advanced)	Agrupamento de Escolas De Real	9_A	9_B
	Agrupamento de Escolas De Maximinos	9_6	9_1
	Agrupamento de Escolas André Soares	9_H	9_A
	Escola Secundária Alberto Sampaio (Alberto Sampaio 1)	9_H	9_I
	Agrupamento de Escolas de Trigal de Santa Maria	9_A	9_B
	Escola Básica 2 e 3 de Nogueira (Alberto Sampaio 2)	9_F	9_E

Table 1. Participating schools, PAFSE classes and control Classes, divided into three levels (Basic, Intermediate and Advanced).

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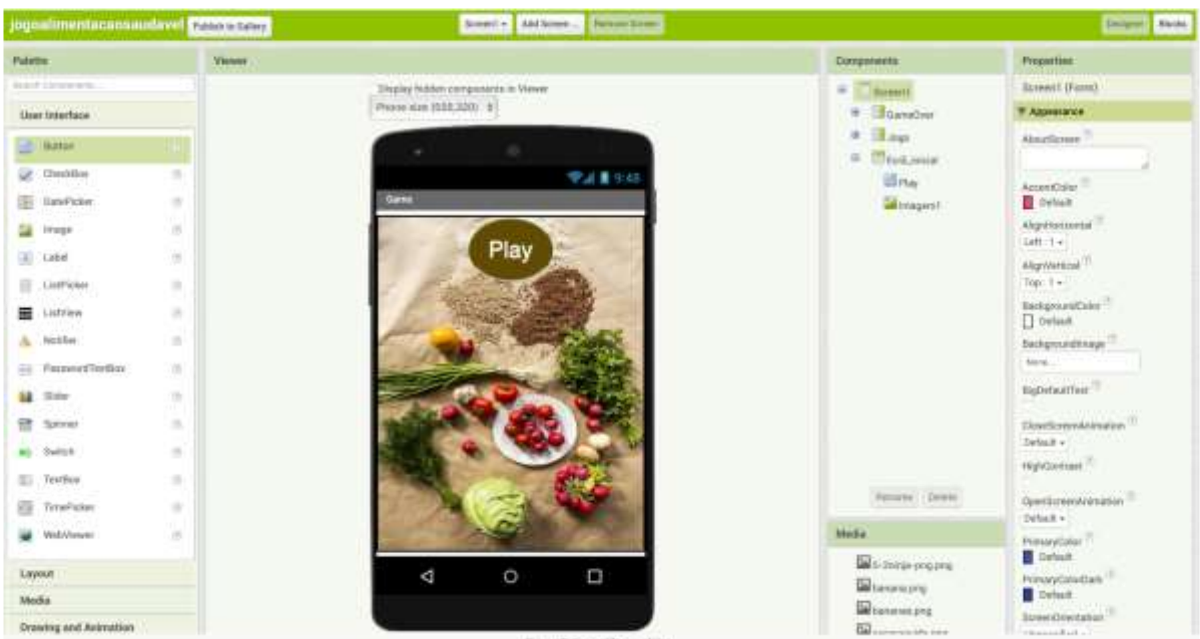
RESULTS
To create the application, the students used the low-code platform, MIT App Inventor, which is built on the concept of block programming. MIT App Inventor, which originated as an endeavor within the now-ended Google Labs, is an online development platform for building mobile phone applications and has garnered immense popularity and acclaim on a global scale. Block-based programming languages offer a user-friendly approach that eliminates the need for users to manually type complete programming statements (Papadakis et al., 2016). Instead, users select blocks from categorized menus, making it unnecessary for beginners to memorize or type code names (Turbak et al., 2014). This dimension is pivotal for block languages, primarily aimed at reducing syntactic errors in traditional text-based programming. As noted by Vasek (2012), block languages fall within the category of visual programming languages, where blocks are differentiated by color-coding according to their collections, and the shapes of these blocks dictate that they can only be linked in ways that adhere to proper syntax, resembling a jigsaw puzzle where pieces naturally interlock. In block-based coding, a user constructs interactive narratives, games, and multimedia content by simply dragging and dropping pre-designed code blocks. The MIT App Inventor user interface incorporates two fundamental editors. The design editor streamlines the arrangement of mobile app interface elements through drag-and-drop functionality. Figure 2 displays the interface of the design editor, presenting a student project, with a thematic emphasis on healthy eating.  Figure 2. MIT App Inventor design editor's interface, displaying a student's group project focused on healthy eating. The blocks editor provides a visual platform for app creators to define their app's logic (Patton et al., 2019). Figure 3 showcases identical content to that depicted in Figure 2, albeit within the block editor.

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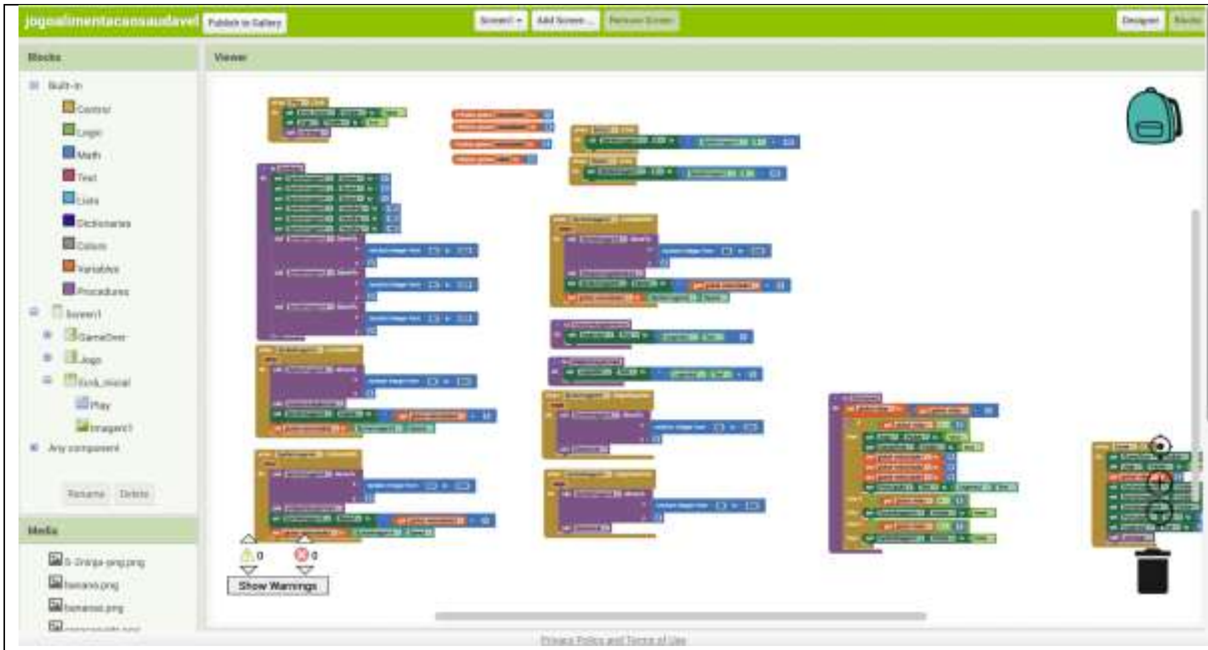

Figure 3. MIT App Inventor block editor's interface, displaying student's group block programing.

In addition to featuring the two essential editors, MIT App Inventor offers a feature known as the AI Companion — a mobile application that enriches the app development experience. The AI Companion serves as a dynamic tool, granting app developers the ability to conduct live testing of their applications while they are still in the construction phase. This real-time testing capability streamlines the development workflow and allows for immediate feedback and troubleshooting, ensuring that the app functions as intended and meets the desired user experience. Figure 4 provides a visual of the design editor and the AI Companion in coordinated action.

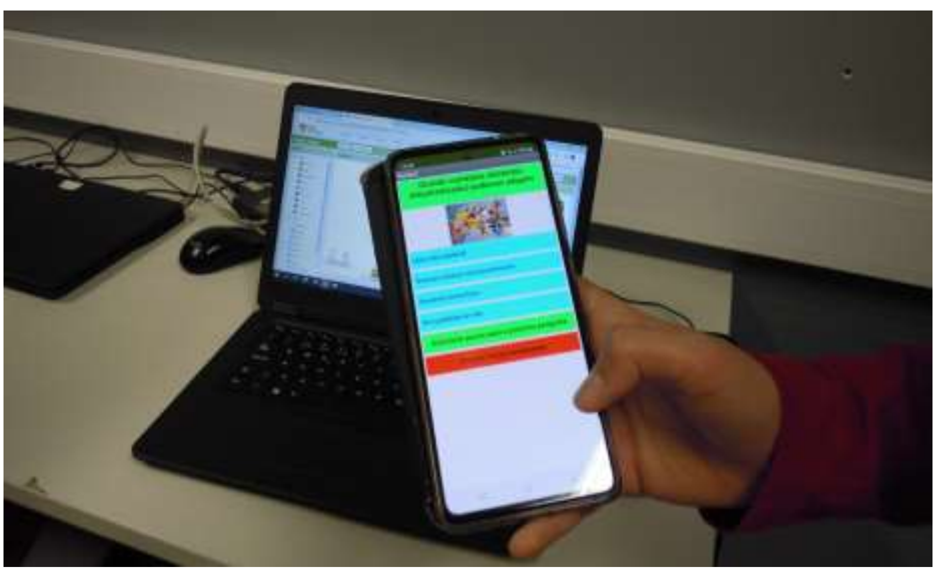

Figure 4. The Mit App Inventor's AI Companion and Design Editor working in concert.

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The MIT App Inventor platform provides an introductory level of computational thinking, offering a visual alternative to text-based coding. Consequently, it not only makes learning more captivating but also more accessible for students, as it eliminates the initial hurdles often associated with traditional coding in text, making it a highly suitable educational resource.
In the context of health-related topics, students explored the potential of MIT App Inventor to create applications that cater to a range of health-related concerns. The application examples presented in Figures 5, 6, 7 and 8 offer a glimpse into the diverse landscape of innovative solutions they devised.

Figure 5 displays an app which is designed to assess a user's physical profile by collecting and analyzing their responses to specific questions. Such an application can find utility in various health and fitness contexts, such as helping individuals determine their fitness level or recommending suitable exercise and dietary routines.

Figure 5. User's Physical Profile Assessment app.

Figure 6 presents an example of an engaging application that combines creativity and health education. Users are encouraged to color images that depict wholesome foods, thereby not only enhancing awareness of nutrient-rich dietary choices but also providing a calming and meditative experience through the act of coloring. This application serves as an educational tool and promotes mindfulness and relaxation.

Figure 6. Healthy Eating Coloring app.

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Figure 7 showcases an application that functions as a Body Mass Index (BMI) calculator, which enables users to calculate their BMI by inputting their height and weight.

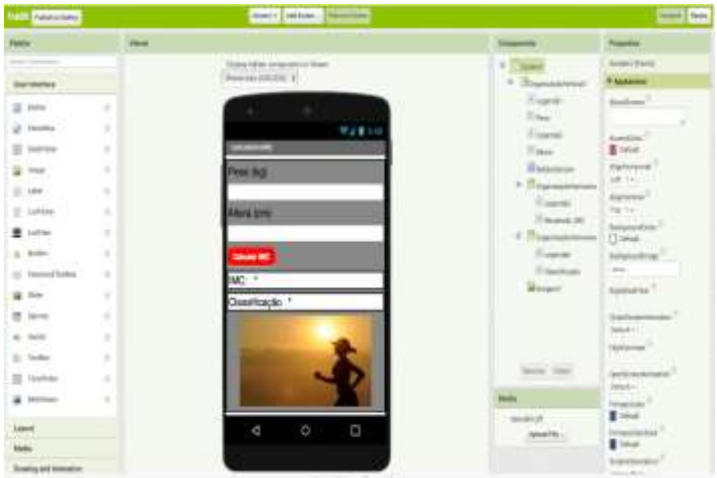

Figure 7. BMI Calculator app.

In Figure 8, we observe an application functioning as a virtual assistant. The development of this particular app showcases the students' adept use of AI tools, including text-to-speech and speech recognition functionalities. Text-to-speech technology enables the application to audibly render text, providing users with a dynamic audio interface. Simultaneously, speech recognition capabilities enable the app to comprehend and respond to the user's voice commands. This interaction via voice commands facilitates communication with the virtual assistant, making the application remarkably user-friendly and accessible.

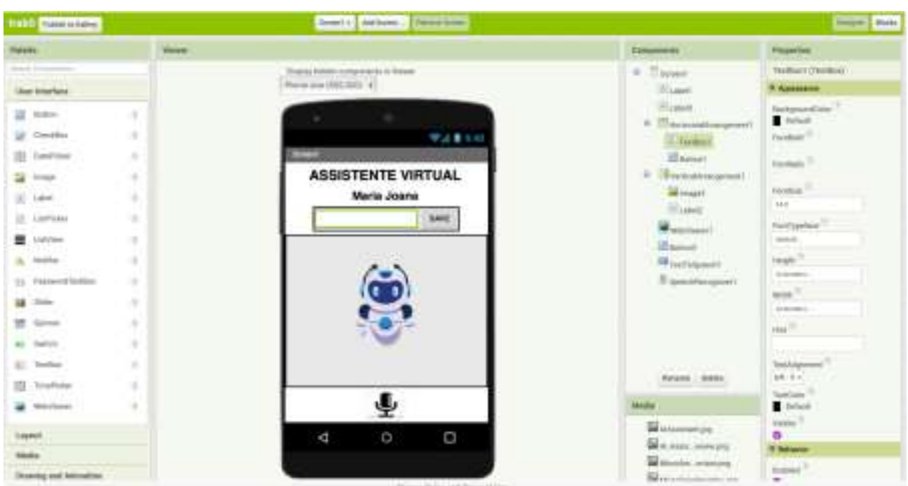

Figure 8. Virtual Assistant app with voice command integration.

Upon the conclusion of the scenarios, the students had the opportunity to present their applications at a school-organized public event (see Figure 9). This event brought together students who participated in different level scenarios. The event also garnered substantial attendance from educators and parents, underscoring the importance of involving all stakeholders in the students' learning experiences. According to Condliffe (2017), there is consensus among several authors that the public showcasing of the outcomes resulting from

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project-based learning experiences underscores the authenticity of the projects and their real-world applicability.

Figure 9. Photo of a student presentation at a public event organized by the André Soares School Group.

Feedback questionnaires were administered to the participating educators. The feedback from educators was uniformly positive regarding the learning scenarios and PAFSE activities. They also reported that students exhibited enhanced abilities in analyzing problems related to public health, viewing science as a valuable tool for the betterment of their community, and ultimately, contributing to heightened public health awareness.

DISCUSSION AND CONCLUSIONS

After receiving feedback from experiment participants and teachers, we have made substantial improvements to the teaching scenarios. These include a refined duration to address time constraints and provide clearer guidance, optimized resource utilization by consolidating materials into a centralized digital location, streamlined content delivery to eliminate unnecessary information, a shift in focus towards practical applications aligned with real-world challenges, and enhanced versatility for teachers to customize scenarios based on specific learning objectives. These amendments aim to create a more focused, efficient, and impactful learning experience for all parties involved, addressing concerns and aligning the scenarios more closely with the needs and preferences of both teachers and participants.

In examining the results of our case study, we find a compelling alignment with our primary research question: "How can low-code learning foster public health awareness among prosumer students?". The integration of low-code learning has provided students with an opportunity to actively engage in their learning process. Through the creation, sharing, and practical application of public health knowledge, students have moved beyond the traditional roles of passive learners. The feedback from teachers, which indicates improvements in students' problem-solving skills in public health and a greater appreciation for science's role

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in community well-being, highlights the potential of this educational approach. This case study underscores the positive impact of low-code learning in cultivating public health awareness and equipping students to become informed and engaged contributors to their communities.

RECOMMENDATIONS

In light of the results of our case study, we recommend the integration of low-code learning into educational curricula, with a deliberate emphasis on fostering interdisciplinary collaboration, as it is a vital step toward equipping students with the skills and perspectives necessary for success in an interconnected world. Self et al. (2018) have pointed out the emergence of a modest yet increasingly expanding body of research dedicated to the exploration of interdisciplinary pedagogical approaches. And, indeed, among the most praised qualities of the learning scenarios was their ability to bridge the gaps between different subject areas, encouraging students to approach problems and projects holistically.

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3.5. Institute for Systems and Computer Engineering, Technology and Science (INESC-TEC) – Case Study Report

A project-based learning approach on 3D printing for public health:

a case study on three schools of the northern interior of Portugal

INTRODUCTION
Recent advances on 3D printing in healthcare have led to lighter, stronger and safer products, reduced lead times and lower costs (Debnath et al., 2021; López-Ojeda & Hurley, 2023). Custom parts and objects can be tailored to each patient and each situation. Medical applications for 3D printing are expanding rapidly and this technology is expected to revolutionize health care. The application of 3D printing in the medical sector can provide several benefits, such as the customization and personalization of medical products or equipment (Jin et al, 2022). Speccifically, the COVID-19 pandemics increased awareness of the population modest health literacy (Mheidly & Fares, 2020), and this fact, highlighted the need for public health education. Thus, is crucial to promote science education to help communities be ready and better manage public health risks, in collaboration with stakeholders, schools, students and their families. In this context, research has demonstrated that project-based learning is a valid approach to the development of critical thinking. Project-based learning may help students address these themes. Indeed, by motivating students with hands-on projects, we can inspire students at low secondary level make informed choices regarding their health and, in the process, strengthen the schools' capacity to promote Science, Technology, Engineering, Mathematics (STEM) learnings with a focus on public health. In partnership with community stakeholders, such as local companies or laboratories, students may feel more integrated in their surroundings, thus advocating for an open schooling framework. In this context, INESC TEC provided a case study that focused on the importance of 3D printing in public health. In this chapter, it is presented this pilot case study conducted in three schools, in Portugal' s northern interior, aspiring at promoting both public health and digital literacy themes, through the districts of Vila Real. Speccifically, our goal is to develop and implement an educational scenario regarding 3D printing that uses project-based learning to address these topics, strengthening the capacity of students in low secondary level and their schools to promote Science, Technology, Engineering, Mathematics (STEM) learning with a focus on public health issues. The scenario supports 9th grade science and ICT teachers in exploring 3D printing using updated scientific/technical evidence. The learning experience supports youths in understanding and reaching high-level comprehension on how STEM may contribute to address these issues, contributing to evidence-based personal decision-making, and public policy. Finally, we find it important to understand if students and schools, when challenged, take a role in their community preparedness for major health problems. By implementing an educational scenario with a focus on 3D printing, and thus potentiate the use of this technology, we intend to help raise awareness on the public health theme.
CONCEPTUAL FRAMEWORK
Additive manufacturing is the process of creating an object by building it one layer at a time. Technically, additive manufacturing can refer to any process where a product is created by building something up, such as molding, but it typically refers to 3D printing.

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3D printing, in full three-dimensional printing, is the process of layering two-dimensional cross sections sequentially, one on top of another. The process is analogous to the fusing of ink or toner onto paper in a printer (hence the term printing) but is actually the solidifying or binding of a liquid or powder at each spot in the horizontal cross section where solid material is desired (Jandyal et al., 2022).

The most common additive manufacturing techniques for 3D printing is the fused deposition modeling (FDM), which is largely used for printing of metal/thermoplastic materials with ease of design flexibilities. It has been utilized in the automobile industry, ranging from testing models, lightweight tools to final functional components. Also, 3D printing is highlighted by the literature to have had a strong impact on the combat against COVID19, and its importance in the medical product supply chain (Belhouideg, 2020; Tino et al., 2020), which reinforces the significance of such technique in today's world.

Particularly, COVID-19 pandemic has shown that scientific research and innovation can be a complex and slow process, with fundamental unpredictability in research findings and its own adoption by society. The collective challenges caused by the COVID-19 pandemic, amplified by the population modest health literacy (Mheidly & Fares, 2020), puts public health education in the spotlight, as it can boost awareness about risk factors, individual behaviors, determinants of health, and their relationship with living environments.

Furthermore, research has demonstrated that project-based learning is a valid approach to the development of critical thinking. When students are able to partake in problem-solving activities in real-world challenges, they present a high degree of responsibility, autonomy, and unsupervised work time when engaging in the projects (Thomas, 2000). This approach embraces a driving question, collaboration among students, communication skills, and interdisciplinary learning, continuously highlighting the importance of critical thinking (Unaizahroya et al., 2022; Shahrizoda, 2022).

Indeed, teachers have an important role in motivating the students, launching focused queries but always providing a suitable distance for students to work freely. Through this goal-directed process for problem resolution, the tasks are carried out by students autonomously, having continued feedback from not only their peers, but also from experts (Thomas, 2000).

Evidence suggests that project-based learning is capable of engaging and motivating middle grades learners (Yetkiner et al., 2008). In fact, when students are allowed to choose a topic of their interest or relevance to their personal lives, they become naturally driven to commit to the work and aim for high quality results (De Vivo, 2022). Even when compared to traditional educational approaches focused on long-term knowledge retention, project-based learning proves to be more effective (Strobel & van Barneveld, 2009), positively influencing students' performance, recollection, awareness and self-efficacy across different educational levels (Bilgin et al, 2015).

Also, for STEM-related disciplines, project-based learning is considered a powerful approach for learning due to the inclusion of realistic tasks (Capraro & Slough, 2013). This brings some challenges, e.g.: students taking responsibility for the learning process by setting goals and sustaining their motivation, the need of positive interdependence, individual accountability, equal participation, and social skills (Kagan, 1994; Johnson et al., 1993).

RESEARCH QUESTIONS

The goal of this case-study is to understand if and how a project-based learning approach on 3D printing methods and techniques can positively impact the learning process of children attending the 9th grade. Our main research question is: what is the impact of a project-based learning approach on 3D printing for public health regarding 9th graders' knowledge, skills, attitudes and behaviour?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006468.

METHODS AND CONTEXT

Three stages were designed to address the research question.

1. Learning Scenario's Development;
2. Teachers' Training Program;
3. Schools' Participation and Revision.

We implemented the educational scenarios in 3 different schools located in the city of Vila Real, an interior territory of Portugal with about around 52,000 inhabitants, covering an area of around 370 km^2. The schools selected to participate in the pilot phase of the PAFSE project are all located in an urban area, in the city center, embracing students from different parishes. This situation is of great value as to provide us with information regarding students of dissimilar social and economic contexts. Also, they embrace distinctive degrees of education, from the 7th to the 12th grades, with students ranging from 12 to 17 years old.

To address the research question, our intention is to understand if the students, by the end of the learning scenario implementation, can:

1. Use online tools to open and print 3D models.
2. Analyze pre-designed models.
3. Identify the printers' basic features.
4. Identify the proper materials for printing different objects for different contexts of use.

The scenario enactment was led by the ICT's teachers, but other teachers were also involved, mainly in the fields of mathematics and computer science.

1. Learning Scenario's Development

The educational scenario presented clear objectives regarding the process of 3D printing. Our goal was to provide students with means to experience the whole process and understand its importance for public health. 3D printing, in full three-dimensional printing, in manufacturing, any of several processes for fabricating three-dimensional objects, is the process of layering two-dimensional cross sections sequentially, one on top of another. The process is analogous to the fusing of ink or toner onto paper in a printer (hence the term printing) but is actually the solidifying or binding of a liquid or powder at each spot in the horizontal cross section where solid material is desired.

With this curriculum in mind, different digital learning objects were created exploring distinctive themes:

- Introduction of types of printers (video and PowerPoint).
- 3D printing tutorial (PowerPoint).
- Printers' basic features: the HARDWARE (video and tutorial).
- Printers' basic features: the MATERIALS / SUPPLIES (infographic and tutorial).
- Tutorial of how to handle the materials (PowerPoint tutorial).
- Introduction of the printing process (video and tutorial).
- 3D post-printing techniques (PowerPoint with video)
- Introduction of the post-printing process (infographic and tutorial).

Also, digital educational resources were developed to aid in the scenario enactment:

- Introduction of the different printing methods (video).
- Examples of printers (video).
- Pedagogical glossary for technical terms and definitions (infographic).
- Different basic objects printable in 3D (infographic).
- Models of 3D printers (video).

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- Key factors and features of 3D printers (video).
- Scenarios of use for the materials (infographic).

Aiming at a clear path for the teaching-learning dynamic, a specific set of lessons and teaching -learning activities were defined, with a learning trajectory focused on 3D printing. The principal target were Science and ICT classes, with 9th graders (+/- 15 years old students), where ICT teachers, accompanied by other colleagues, participate in the enactment of the scenario (e.g., Visual Education, Mathematics and English teachers), as it aims to be interdisciplinary.

The lesson plan was outlined as follows:

Lesson 1: Introduction of types of printers

Lesson 2: Introduction of the different printing methods

Lesson 3: Printers' basic features: the HARDWARE

Lesson 4: Printers' basic features: the MATERIALS / SUPPLIES

Lesson 5: Introduction of the printing process

Lesson 6: Introduction of the post-printing process

Lesson 7-forward: After building and presenting the printing process map, students are challenged to print other 3D objects in groupwork.

Supplementary learning resources and educational activities were also defined:

- Teleconference with STEM professionals (e.g., Engineers, Designers Medical Doctors, or researchers of PAFSE consortium): Students make questions to experts with a particular focus on: a) future academic choices and career paths; b) identifying new professions in new fields of industry 4.0.
- Visit to FABLAB: Students make questions to experts with a particular focus on tools and materials to create 3D scenarios. These activities are relevant for students' connections with possible STEM curriculums and careers. Students are shown the working environment and dynamic of a FABLAB.

2. Teachers' Training Program

Upon the development of the learning scenarios, an online workshop for the teachers was implemented, with the main goal of providing the teachers with information and data regarding 3D printing. The workshop gathered the 3 schools that participated in the case study. This teacher training program had a total of 15 hours and divided into four sessions with synchronous and asynchronous contact. This initiative successfully engaged teachers from the three school groups situated in Vila Real, and feedback surveys among the participating teachers offered a generally positive perception of the workshop. Afterwards, the scenario was implemented in the three schools. In order to answer our research question, a final questionnaire was executed in the scenario enactment at schools, aimed at assessing 3 domains:

<u>Knowledge:</u>

- 3D printing concepts:
- 3D technical principles and workflows. ü Tools for printing 3D models.
- Hardware for 3D printing.
- Supplies and materials for 3D printing.
- Knowledge - outcome assessment:

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- Understands the importance of printed 3D artifacts to address pandemic challenges.
- Recognizes the 3D printing process.
- Recognizes 3D printer's main features.

Skills (abilities/competences)

- General: 3D basics, Imagination, creativity
- Specific: Printing 3D models by combining process knowledge and application requirements; Technical usage of 3D printing hardware, supplies and software; Post-process knowledge of 3D printing.
- Skills – outcome assessment:
- Recognizes hardware basic features.
- Recognizes printer's materials and supplies.
- Recognizes post-printing processes.
- Is able to identify the differences of multiple 3D printers.
- Can print specific 3D objects.
- Is able to print artifacts that improve public health.

Affective /Attitudes/Behaviour (beliefs)

- Using imagination for designing real tools and materials, focusing on the printing of artifacts.
- Using creativity skills on new technologies in the development process of the solution.
- Affective, Attitudes and behavior - outcome assessment:
    a. Believes that is important to raise awareness on how 3D printing can help the community.
    b. Believes that is an important tool during a pandemic.
    c. Has intention to continue extending the skills and knowledge regarding 3D printing.
    d. Is aware of the democratization of 3D printing for public health.
    e. Attitude towards 3D printing.
    f. Believes that is important to improve one's own personal capabilities.

A pre- and post-questionnaire regarding STEM awareness was also implemented in each class, which was able to access the students' awareness concerning mathematics, sciences, engineering and technology.

A practical component of the scenario was also implemented, having the students print different objects using 3D printing equipment.

3. Schools' Participation and Revision

Three schools from Vila Real participated in the case study, with students from the 9th grade, namely: Escola São Pedro; Escola Camilo Castelo Branco, Escola Morgado Mateus. Each school selected 1 class that would actively participate in the study (PAFSE Group) and a control group (1 class) who did not participate in the scenario enactment (Control Group). Hence, in total 6 classes were accounted for. All the classes answered two sets of questionnaires, in the same period, before (pre-scenario) and after (post-scenario) the scenario enactment: a STEM questionnaire and a 3D printing-related questionnaire. Only the students who answered both the pre- and the post-scenario questionnaires were included in the analysis. Also, the students were asked to print specific sets of items regarding public health. They were given the chance to search, find and use the ones of their choosing, having the opportunity to print the models resorting to FDM printing equipment. The goal was to observe they dexterity using the equipment and understand their motivation towards the task at hand.

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RESULTS

Overall, 202 students participated in the educational scenario and answered the pre- and post-scenario questionnaires.

Results in Table 1 and Fig. 1 clearly show a significantly improvement on the students' awareness concerning STEM disciplines. The control group did not present any progress regarding the subject, even demonstrating worst results when comparing the first pre-scenario enactment and the post-scenario questionnaire.

Table 1: Results of the questionnaires (pre- and post-scenario) of the three schools combined.

Variable	**Group**	**N**	**Pre-scenario**		**Post-scenario**		**Student's t-test** (pre-post) *p-value*	**Interaction time * group** *p-value*
			Mean	SD	**Mean**	SD		
Mathematics	PAFSE	34	3.50	0.62	3.65	0.59	*0.009*	*0.077*
	CONTROL	46	3.42	0.58	3.45	0.64	*0.459*	
Sciences	PAFSE	34	3.44	0.70	3.47	0.64	*0.704*	*0.299*
	CONTROL	46	3.44	0.67	3.37	0.74	*0.232*	
Engineering and technology	PAFSE	34	3.31	0.42	3.44	0.53	*0.029*	*0.095*
	CONTROL	46	3.13	0.63	3.12	0.59	*0.837*	

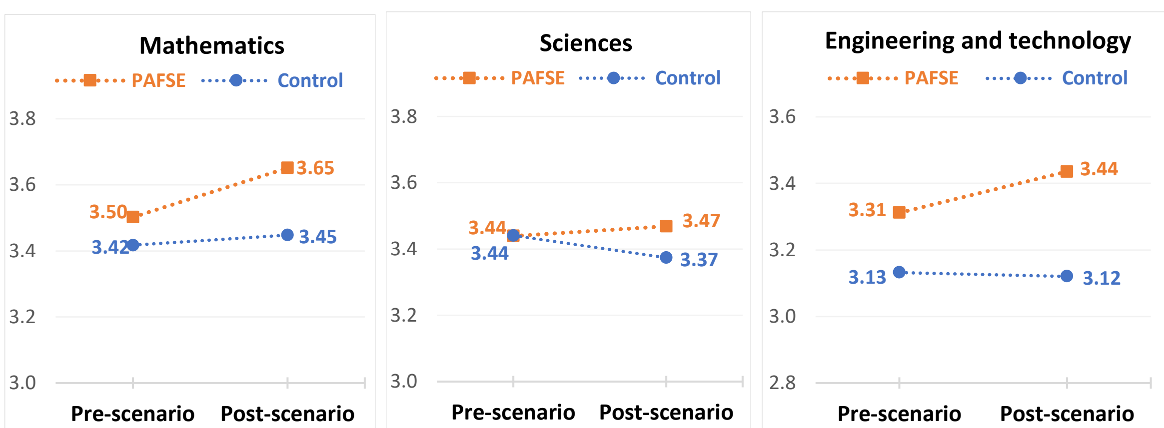

Figure 1: Results of the questionnaires (pre- and post-scenario) of the three schools combined

When considering the 3D printing-related questionnaire, results also encourage the proposal that a project-based learning approach concerning 3D printing is promising. Students' from the three schools demonstrated, even during the classes, their improvement in the knowledge of the field and skills, being able to identify different printing techniques and equipment, and even being able to provide examples for each situation. In terms of attitudes and behaviour, most students agreed / strongly agreed that they were more confident about the subject and were motivated to spread their knowledge in their community, understanding its importance for not only public health, but also the benefits that this paradigm shift brings to the world's communities and their own personal capabilities.

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Furthermore, questionnaires were administered to the participating teachers's. Feadback were positive regarding the learning scenarios and the overall Pafse activities. Also, affirmed the enhanced abilities observed from the students in the use of 3D printing tools and public health.

Also, the INESC TEC group had the chance to print public health related items using an FDM printing equipment. Illustrative examples of the printed objects can be found in Fig. 2, showcasing photographs of some students' projects.

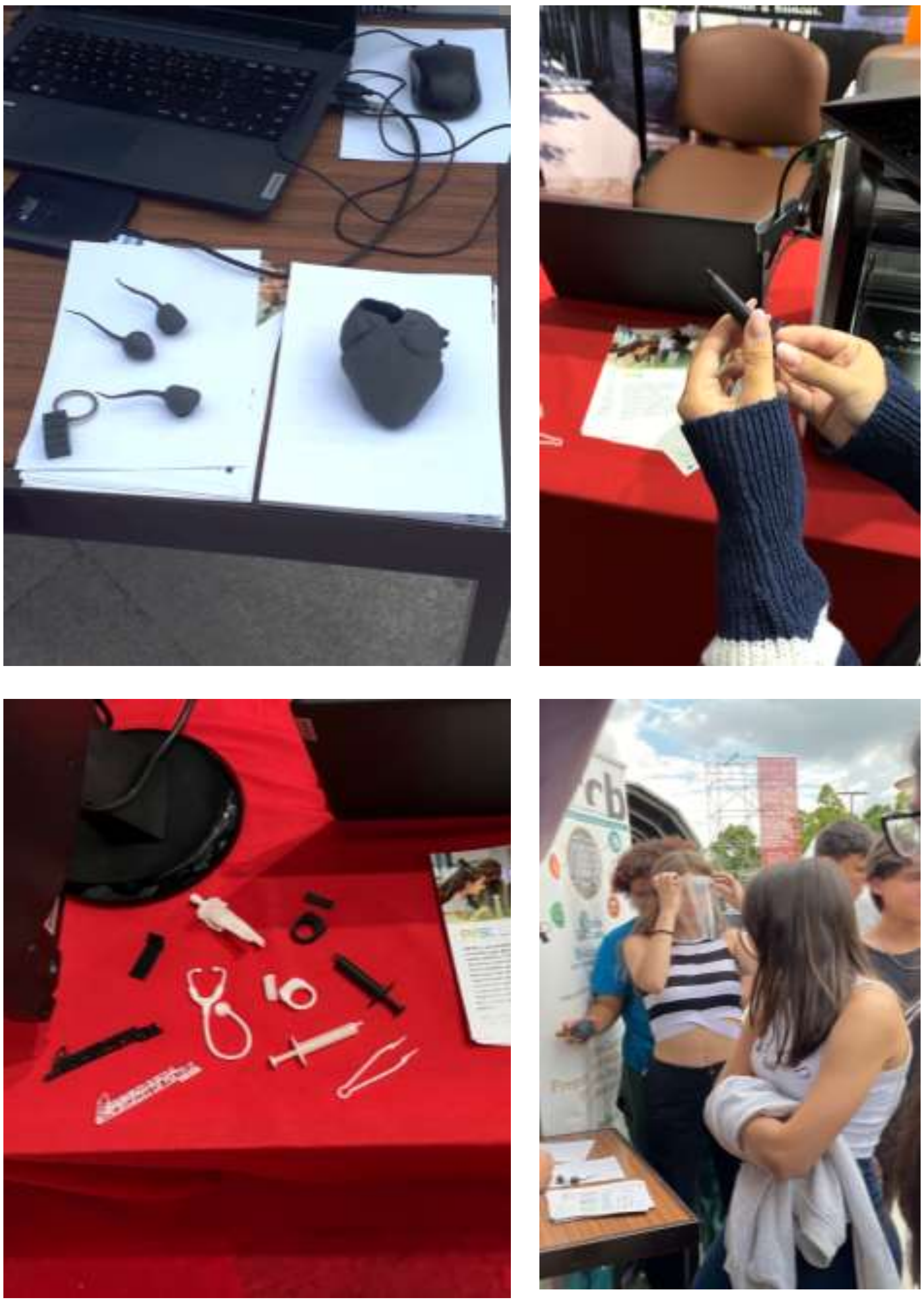

Figure 2: Photographs of students' projects

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These students' 3D printing results were presented at a school-organized public event (see Figure 2). These events promote the students works and brought together other attendances from educators, parents and the community of Vila Real.

DISCUSSION AND CONCLUSIONS

After feedback from students and teachers participants, considerable improvements were made to the teaching scenarios. Mainly, the ammedments made intended to provided a more efficient, effective and satisfactory learning experience to participants involved.

Particularly, the approach to provide clearer guidance was refined, with the optimization of resources and creation of specific accessible materials joint in a centralized digital location; also, provide a time management strategy for 3D printing projects; and, improved adaptability to customize scenarios based on specific learning objectives.

Results have shown that the involvement in the educational scenario and the activities originated in it increased the knowledge, skills attitudes and behaviour regarding the topic at hand. In examining the results of our case study, we find a compelling alignment with our primary research question: What is the impact of a project-based learning approach on 3D printing for public health regarding 9th graders' knowledge, skills, attitudes and behaviour?

The students did improve their awareness on 3D printing and transmitted their enthusiasm for the field to their own community and family members, that actively participated in a final open-schooling event. The direct feedback we received from the students was very positive, having said that a practical hands-on approach was extremely positive to apprehend the contents of the educational scenario. Also, with the respect to the analysis and interpretation of the quantitative results, we find it important to highlight the scenario's positive impact on raising awareness on 3D printing towards public health, and also getting students to be more informed and engaged in this problematic, even in their own communities.

However, it is also worth noting that not all types of 3D printing were tested with the students. The most popular technique (FDM printing) was the one selected, as the equipment is more accessible. Indeed, it would be important to also demonstrate other printing techniques in real time.

RECOMMENDATIONS

Considering the results of our case study, we understand it would be important to implement this topic in the school year's curriculum. It is known now that students take interest in this subject, and it shows great potential to be spread to the community, enhancing the awareness of public health related issues. Moreover, we recommend promoting an open schooling framework and project-based learning in the context of public health education, given its positive results in the classroom environment.

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3.6. Instituto Superior de Engenharia de Lisboa (ISEL)– Case Study Report

Potential of a project-based learning in terms of its ability to capture students' interest in the study of STEM areas: A Case Study on the implementation of Educational Scenarios focusing on Public Health

INTRODUCTION
The increasing concern that the curriculum heavily emphasizes memorization of facts and has insufficient importance on problem solving or self-directed study skills necessary for a practice is not new. One of the areas that caught attention from the beginning was the medical schools, concentrating the learning process on problem-based, self-directed learning and other teaching-learning methods specifically designed to emphasize the needed skills and to increase the retention of facts and their recall in the clinical practice. This approach, built on research into the problem-solving skills of physicians and principles of educational psychology, is applied by several medical schools and serves as an antidote to the many educational abuses seen in more traditional approaches [1]. A European Union (EU) Special Report provides an overview of education approaches across the EU and points out the EU's educational objectives [2]. The EU's educational objectives, set out in Education and Training 2010, Education and Training 2020 and Europe 2020 strategic frameworks, are as follows: • reduction of the number of early schools' leavers; • increase in tertiary education attainment; • increase in participation in lifelong learning; • reduction of the number of low achievers in basic skills; • increase in participation in early childhood education; • increase in participation in higher education in the field of mathematics, science and technology; • increase in upper secondary education attainment. The above-mentioned report also emphasises that the achievements and surplus are so important that similar programs should additionally start to be available to even younger students [2]. Wolk advocated basic school level on child-chosen creating projects, given that when children are allowed to choose what to explore, they become intrinsically motivated to work hard and strive for the highest quality [3]. Meyer et al. studied 5th and 6th grade students' learning challenge during project-based mathematics instruction in a classroom on five areas of research: academic risk taking, achievement goals, self-efficacy, volition, and affect [4]. Students' responses to a tolerance for failure survey, an adaptive learning pattern survey, and individual interviews about their actions during a math project, were the basis for qualitative and quantitative analyses. Butzin compares standardized test scores in reading and mathematics for 2nd and 5th grade students from two similar technology-rich elementary schools in Miami-Dade County, Florida [5]. Some studies go beyond their analysis on knowledge acquisition going until the link with the labour market. For example, Schoon and Parsons investigate the formation and realization of teenage career aspirations in a changing sociohistorical context, in a follow-up study of over 17,000 individuals born 12 years apart (in 1958 and 1970) [6]. Two types of analytical models, a mediating model and a contextual systems model were used to analyse the processes by which the effects of social structure influence teenage aspirations and subsequent occupational attainment. Both models suggest that teenage aspirations in combination with educational attainments are a major driving force in the occupational development of young people and that they mediate the effects of socioeconomic background factors.

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The contextual system model is an elaboration of the mediating model, providing additional insights into the effects of distal and proximal contexts. Differences in the experiences of young people growing up 12 years apart indicate that the sociohistorical context plays a key role in shaping occupational progression. For the later born cohort the importance of educational credentials has increased, both in influencing teenage aspirations and predicting adult occupational outcomes.
Educational approaches are thought to have facilitative or hindering effects on students' critical thinking development. For four decades, researchers have demonstrated that project-based learning (PBL) can be an effective way to engage and motivate middle grades learners [7].

Although definitions vary in the specificities, PBL is typically considered an approach to teaching in which students respond to real-world questions or challenges through an extended inquiry process. PBL often involves peer collaboration, a strong emphasis on critical thinking and communication skills, and interdisciplinary learning [8-10]. When PBL is thoughtfully designed and implemented, evidence suggests that it can be more effective than traditional instruction for teaching concept mastery in core academic disciplines, supporting long-term knowledge retention, improving mastery of 21st century skills, and preparing students to synthesize and explain concepts [11-13]. Additionally, there is some evidence that PBL can be more effective than traditional instruction in increasing student performance on standardized tests and that it can be especially effective with lower-achieving students. Tiwari et al. performed a study to compare the effects of PBL and lecturing approaches on the development of students' critical thinking. Methods on undergraduate nursing students at a university in Hong Kong were randomly assigned to one of two parallel courses delivered by either PBL or lecturing over one academic year [14].

The integration of science, technology, engineering, and mathematics content (STEM) has become a mainstream topic within educational systems. Clark and Ernst discuss the technology integration model for education and the factors to be considered when contemplating technology education as a focal point of integrated curricula [15]. These factors are: (1) academic collaboration; (2) hands-on approaches; and (3) the use of creativity and problem solving. Considering that technology can be the driving force behind integration, the authors suggest cohorts of teachers from all academic areas, including technology education, work together to provide a comprehensive integrated curriculum, with technology leading the process and content.

Han et al. explore whether participating in science, technology, engineering, and mathematics (STEM) project-based learning (PBL) activities affected students who had varied performance levels and to what extent students' individual factors influenced their mathematics achievement [16]. Teachers in three high schools attended sustained professional developments provided by a STEM centre based in a Southwestern university and were required to implement STEM PBL once in every six weeks for three years (2008 through 2010). Hierarchical linear modelling was used to analyse the data and results implied that STEM PBL in schools benefitted low performing students to a greater extent and decreased the achievement gap.

CONCEPTUAL FRAMEWORK

There is a need to enhance the readiness of communities in the public health perspective, thus strengthening the level of responsibility and proactiveness of young people and citizens in participating in public health-related measures. This will also improve the collaboration between stakeholders, schools and their communities to the benefit of education and wellbeing.

Project-based learning may help students address these themes. Indeed, by motivating students with hands-on projects, we can inspire students at low secondary level make informed choices regarding their health and, in the process, strengthen the schools' capacity to promote Science, Technology, Engineering, Mathematics (STEM) learnings with a focus on public health. In partnership with community

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stakeholders, such as local companies or laboratories, students may feel more integrated in their surroundings, thus advocating for an open schooling framework.

In particular, PAFSE open schooling model for socio-scientific inquiry and project-based learning in the context of public health education aims to:

- Improve community public health and well-being by raising awareness, prevention and co creating solutions to both personal and socially relevant public health socio-scientific issues that have a direct impact at a personal and community level;
- Enhance STEM education, a school curriculum, and a pedagogical framework by incorporating a variety of viewpoints and expertise from both educational and non-educational agents and institutions. This approach aims to facilitate meaningful learning and the development of competence among students;
- Empower all stakeholders, including students and their families, both within and outside the school, by involving them in continuous inquiry, knowledge generation, creative initiatives, and communication. This collaborative effort aims to tackle public health socio-scientific challenges that are relevant not only to the local community but also extend beyond its boundaries.

In the case of PAFSE partner, ISEL, our goal is to develop and implement three educational scenarios, regarding droplets and the physics of viruses' transmission, energy sources and public health impact, and noise pollution and quality of life, that use project-based learning to address these topics, strengthening the capacity of students in low secondary level and their schools to promote Science, Technology, Engineering, Mathematics (STEM) learning with a focus on public health issues.

The first educational scenario regarding droplets and the physics of viruses' transmission aims to prepare 9th grade students and the school community to reduce the risk of airborne diseases through the study of a computational tool named Computational Fluid Dynamics (CFD). It is important to raise awareness among students and the school community on the subject, and to reflect on possible measures which could be implemented, both individually or at the school community level, as long as they can mitigate the spread of respiratory droplets, with the scope of avoiding the swift proliferation of airborne diseases. The learning scenario increases students' understanding of how airborne transmission of respiratory droplets works, and how STEM can contribute to anticipating, mitigating and solving public health threats by exploring simulations obtained from a CFD tool.

The second educational scenario, regarding energy sources and public health impact, prepares 7th grade for a heightened awareness of energy sources and the importance of renewable energy to ensure the sustainability of the planet as a viable ecosystem. The impact of the consumption of different energy sources will be discussed, with a focus on the topic of energy rationalization, and respective economic and environmental impacts. With this scenario, teachers will be raising awareness about the implications that energy choices have on problems such as air pollution, the planet and public health.

The third educational scenario, regarding noise pollution and quality of life, provides for students a tool that supports upload of audio files and displays histograms, spectrograms, frequency, and amplitude values. Based on scientific studies, a table of identified and expected risks will be developed for each frequency, amplitude, and duration time. Therefore, the learning experience prepares youths to measure noise levels and become aware of risky environments, sources of noise pollution, and how this threat can affect the health and quality of life of the community.

RESEARCH QUESTIONS

Limited research on students, parents, teachers and other stakeholders' views and perspectives on an open schooling model for socio-scientific inquiry and project-based learning in the context of public

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health education gives rise to related research questions. Accordingly, a set of questions was prepared to address, mainly to teachers, to help understand how PBL can influence students' interest in the study of STEM areas.

Therefore, the main research question of this case-study is:

- What could be the potential of the PBL (project-based learning) in terms of its ability to capture students' interest in the study of STEM areas?

To have a deeper understanding of the issue addressed in the main question, we created a series of research questions focusing on the following:

- What are the main constraints that teachers identify when adapting the school conditions and preparing colleagues to the hands on?
- How to cope the curriculum and the time constraints to the PBL in STEM?
- How do teachers use Digital Learning Objects for the aims of PAFSE?
- Do teachers use Digital Learning Objects of PAFSE to adapt for their practices in other teachers?
- How to engage parents to cooperate with their children and with school?
- What are the contingency plans available?
- Having control class and PAFSE class responses to questionnaires are sufficient to evaluate the impact of the present project?

METHODS AND CONTEXT

Context

We implemented the educational scenarios in five different schools located in the city of Lisbon, the capital city of Portugal. The schools were selected to participate in the pilot phase of the PAFSE project, to ensure that the implementation of the educational scenarios and their effects could be measured in different (social and economic) contexts. Also, they embrace distinctive degrees of education, from the 7^{th} to the 9^{th} grades, with students ranging from 12 to 15 years old.

To address the research question, our intention is to understand if the students, by the end of each learning scenario implementation, can:

1. Understand the difference between facts and opinions, understands how to find dubious information, assesses the credibility of health-related information based on several factors that influence the credibility of information;
2. Understands the relevance of scientific facts to explain phenomena related to public health, airborne diseases, energy sources, noise pollution and produce argumentation;
3. Evaluate both individual and community risks, as well as behaviour patterns of risk and protection;
4. Describe different approaches to protecting, developing and positively influencing public health;
5. Identify the importance of the use of computational tools to help solve problems involving STEM areas related to public health.

The scenario enactment was led by the physics' teachers, but other teachers were also involved, mainly in the fields of mathematics and computer science (e.g.: biology and ICT teachers).

The educational scenarios designed and developed by the ISEL PAFSE team were already briefly presented in the conceptual framework, and the titles of the educational scenarios are the following:

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- *Droplets and the physics of viruses' transmission.* This educational scenario is related to the PAFSE topic: looking out for my community.
- *Energy sources and public health impact:* This educational scenario is related to the PAFSE topic: looking out for my community.
- *Noise pollution and quality of life:* This educational scenario is related to the PAFSE topic: looking out for my community.

Our rationale for the choice of these scenarios was the following:
For the first scenario, the study and prediction of the spread of respiratory droplets is relevant because it can mitigate the dissemination of diseases that spread by air, thus promoting a healthier life and well-being for everyone of all ages. The creation of the scenario was influenced by the Sars-Cov-2 pandemic. It is accepted in the scientific community that the virus spreads essentially through the air. With the technological advances achieved, it is possible and relevant to explore with students a Computational Fluid Dynamics (CFD) tool that simulates and predicts the propagation of respiratory particles in different breathing regimes and in environments with different configurations (e.g.: rooms with or without ventilation, natural or power ventilation, rooms with tables, chairs, occupants). This allows to estimate the risk of transmission of respiratory disease between individuals.

For the second scenario, the study on the different sources of energy on the planet, as well as the study of the ways of obtaining and using them is relevant, essentially at a time when the problem of climate change is as strong as ever, and it is necessary to increasingly raise awareness, not only among younger generations, but also to the community in general, to the problems arising from the excessive exploitation of energy and the waste of energy resources. Therefore, the scenario prepares students and the school community to efficiently use existing energy sources, thus helping to combat problems such as air pollution or climate change. This scenario will allow teachers to address, simultaneously, in an interactive and scientific way, the need to efficiently rationalize available energy, as well as to promote the idea of energy transition to more carbon-neutral environments.

For the third scenario, the study of noise in its various aspects, such as environmental noise, neighbourhood noise or work noise, the respective physical concepts and the impact that this problem has on the quality of life is relevant, fundamentally, because it is a problem often ignored or disregarded, but that can have a great impact on people's lives, such as affecting concentration during work, disturbing a night's sleep, or, in extreme cases, leading to premature death. This scenario will allow teachers to address, simultaneously, in an interactive and scientific way, the problem of noise, through a tool that supports the upload of audio files and that displays noise spectrograms (frequency analysis over time). The tool will also have a table where the public health risks associated with each frequency band, range, and exposure time will be identified.

Additionally, the socio-scientific issues related to the educational scenarios are complex and multidimensional, have different scientific, economic, political, cultural and ethical aspects, and are related to public health challenges that the local society of Lisbon has to address. Moreover, the educational scenarios are related to PAFSE topics, and the educational scenarios are related to Portugal's Biology, Physical-Chemistry, Natural Sciences and Health Education Curriculum for lower secondary school. Furthermore, the educational scenarios can promote students' public health conceptual understanding, higher-order thinking skills, epistemological understanding and general understanding about the complexity and multidisciplinary of public health socio scientific issues, as well as interest in STEM education, responsible citizenship, and health literacy.

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Development of the educational scenarios

The educational scenarios were implemented with the intent of providing students the interaction with different computational tools to help solve problems involving STEM areas related with several public health issues such as airborne diseases, noise pollution, air pollution and climate changes. Each educational scenario was designed to provide opportunities to promote understanding of fundamental concepts, phenomena, models and mechanisms of biological sciences and health education, epistemological awareness and understanding, critical STEM literacy, critical health literacy and critical scientific literacy, aspects in STEM instruction with a view to promote active responsible citizenship. Additional objectives of each educational scenario are to highlight the role of science for the establishment of public health, the conduction of authentic socio-scientific research by students (formulating hypotheses and specific research questions, collecting data from a variety of inquiry-based sources, analysing, making inferences, synthesizing, drawing conclusions, and presenting appropriate research project) to promote the multidisciplinary implementation of health educational scenarios and effective health education. Another semantic objective is to create purposeful collaborations between schools and their broader communities. They have to work together to address local challenges, contribute to community public health.

In the first scenario, students analysed CFD simulations in the form of videos and observed the influence that the variation of the parameters that characterize the process of propagation of respiratory particles has on their behaviour for different breathing regimes.

In the second scenario, students were challenged, through the application of an interactive game to combine the different primary energy sources they already knew. In the game, students had at their disposal a series of energy sources and had to choose which ones best met the needs of electricity consumption for each time of the day. Each selection of the best combinations of energy sources to meet energy needs corresponded to a "mission" that students had to complete. In each "mission", students had a series of indicators that allowed them to analyse whether they were making the best decision in choosing that certain energy or amount of energy.

In the third scenario, students carried out a series of sound and noise measurements in their school, in various locations, including their own classroom through the use of a sound measurement tool. Shortly, the application allowed the user the record of a couple of sound measurements per smartphone and for each measurement, the application itself generated an audio log report of the main parameters of the measurement, such as the range of frequencies obtained, the sound intensities (minimum, maximum, peak, average intensity), among others.

Using a socio-scientific issue related to the PAFSE topic, teacher and students should discuss the complexity and multidimensionality of each socio-scientific issue, the social risks, and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders. In addition, it is important to be discussed that many health issues have social dimensions, that cannot be addressed only by science and are considered socio-scientific issues. The inquiry-based learning activities include adequate provisions for identification of students' preconceptions and alternative ideas (misconceptions) on concepts related to each health topic.

Additionally, the activities allow students to work collaboratively in a guided inquiry approach, to investigate specific concepts and problems related to each topic and obtain a deep conceptual understanding about concepts, related mechanisms, and processes of each topic, as well as epistemological understanding about several aspects of nature of science, operation mode of science, and history of science. The learning activities are supported by Digital Learning Objects (DLOs) and other Digital Open Educational Resources (DOERs), as well as by pieces of scientific information, which

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is provided in the form of text, diagrams, models, infographics, historical reports, biographies, conceptual maps, geographical maps, etc.

With this curriculum in mind, the following digital learning objects (DLOs) were created in order to explore each educational scenario:

First educational scenario:
1. Computational Fluid Dynamics Tool (CFD);
2. Repository of simulation results obtained with the CFD tool (images, videos);
3. PowerPoint presentation of the essential concepts of the scenario;
4. For teachers, learning guide of a PowerPoint presentation with the introductory concepts;
5. PowerPoint presentation on how to build and analyse a scientific document;
6. Explanatory document on the logic of applying CFD simulations;
7. Learning guide, for teachers, with the sequence/explanation of the analysis of the videos of class 3 and the respective completion of the worksheet;
8. Learning guide, for teachers, with a sequence of analysis of the videos of class 3 and the respective completion of the worksheet;
9. PowerPoint presentation, exclusively for teachers, with the detailed explanation of the videos to be analysed in classes 3 and 4;
10. Learning guide, for teachers, with a sequence/explanation of the analysis of the videos of class 4 and the respective completion of the worksheet;
11. Learning guide, for teachers, with a sequence of analysis of the videos of class 4 and the respective completion of the worksheet;
12. PowerPoint presentation on how to build a poster;
13. Worksheets (including a resolution version for each sheet).

Second educational scenario:
1. Interactive game about primary energies: Respective energy consumption and rationalization;
2. PowerPoint explaining, for teachers and students, the sequence/explanation of the analysis of the game on primary energies;
3. PowerPoint presentation on how to build and analyse a scientific document;
4. Worksheets (including a version with answers for each);
5. PowerPoint presentation on how to build a poster;

Third educational scenario:
1. Online tool that allows the creation and interpretation of a spectral density graphic;
2. PowerPoint presentation on how to build and analyse a scientific document;
3. Learning guide, for teachers, with the explanation of how the online sound recording tool works;
4. Learning guide, for students, with the explanation of how the online sound recording tool works;
5. PowerPoint presentation on how to build a poster;
6. Worksheets (including a resolution version for each sheet).

Both PAFSE educational scenarios and related Learning Objects and activities used by the PAFSE school students can be found at the "Photodentro" open repository of the project, https://photodentro.pafse.eu/ . Table 1 shows the URL of final versions of the educational scenarios, as well as related learning objects and activities used for this case study.

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Table 1. The educational scenarios and related learning objects and activities used for this case study.

	Title of educational scenario	URL
1.	Droplets and the physiscs of viruses' transmission	https://photodentro.pafse.eu/handle/8586/445 https://photodentro.pafse.eu/handle/8586/460 https://photodentro.pafse.eu/handle/8586/461 https://photodentro.pafse.eu/handle/8586/463 https://photodentro.pafse.eu/handle/8586/462 https://photodentro.pafse.eu/handle/8586/464 https://photodentro.pafse.eu/handle/8586/465 https://photodentro.pafse.eu/handle/8586/450 https://photodentro.pafse.eu/handle/8586/452
2.	Energy sources and public health impact	https://photodentro.pafse.eu/handle/8586/447 https://photodentro.pafse.eu/handle/8586/469 https://photodentro.pafse.eu/handle/8586/467 https://photodentro.pafse.eu/handle/8586/473 https://photodentro.pafse.eu/handle/8586/475 https://photodentro.pafse.eu/handle/8586/471
3.	Noise pollution and quality of life	https://photodentro.pafse.eu/handle/8586/453 https://photodentro.pafse.eu/handle/8586/476 https://photodentro.pafse.eu/handle/8586/483 https://photodentro.pafse.eu/handle/8586/479 https://photodentro.pafse.eu/handle/8586/481 https://photodentro.pafse.eu/handle/8586/485

The educational scenario on the PAFSE topic: Droplets and the physics of viruses' transmission
This Educational Scenario is an integrated learning module in Public Health Education related to the PAFSE topic: Looking after my community: *airborne diseases* and it is integrated in Portugal Biology Curriculum for 9th - grade students.

A socio-scientific topic related to biological, social and cultural, economic, dimensions of airborne diseases provide the context for the inquiry-based primary research questions related to the learning topic: Looking after my community: *airborne diseases.*

Socio-scientific issue:
Although it is still uncertain how the Sars-Cov-2 virus spreads in highly vaccinated populations, it is widely accepted in the scientific community that the virus is transmitted through the air. In this sense, it is important to raise awareness among students and the school community on the subject, and to reflect on possible measures which could be implemented, both individually and at the school community level, as long as they can mitigate the spread of respiratory droplets, with the scope of avoiding the swift proliferation of airborne diseases. The strategy to counter the Sars-Cov-2 pandemic worldwide was based on the containment of the population at home, the restriction of contacts between people, the promotion of the rule of "two meters of social distance" and the recommended or mandatory use of face masks. With the technological advances currently achieved, it is possible and relevant to explore with students a Computational Fluid Dynamics tool (CFD), which simulates and predicts the propagation of respiratory particles in various environments, not only in different configurations, different number of occupants, different number of tables and chairs, various types of breathing regimes, such as coughing, sneezing, normal breathing, wheezing, among others, but also the distance between regimes, or even the use or non-use of mask, hence, having a perception of the transmission risk of respiratory diseases between individuals in each space.

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Using the example of the socio-scientific issue related to airborne diseases, teacher and students discussed the complexity and multidimensionality of socio-scientific issues, the social risks, and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders.

The primary research questions of this educational scenario are the following:

- How do airborne diseases spread?
- Is it possible to predict how airborne diseases spread through the air?
- What can be done by the school community to prevent and mitigate airborne transmission?

The evaluative tasks for the educational scenario on the PAFSE topic: Looking after my community – airborne diseases are the following:

- Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment).
- Worksheets evaluation (for each lesson that composes the educational scenario).
- Analysis and interpretation of a series of 3D CFD simulation videos where an occupant in a room either speaks, coughs or sneezes.
- Evaluation of a scientific presentation and a poster on the topic airborne diseases: concept physics of transmission, how can it be predicted and suggestions to mitigate airborne diseases transmission.
- Post-test (Final/ summative assessment).

Parents and other stakeholders were encouraged to become real partners in school projects and activities through answering questionnaires, giving interviews, or sharing their experiences and expertise.

The educational scenario on the PAFSE topic: Energy sources and public health impact
This Educational Scenario is an integrated learning module in Public Health Education related to the PAFSE topic: Looking after my community: *energy sources and public health impact* and it is integrated in Portugal Biology and Natural Sciences Curriculum for 7th and 8th - grade students.

A socio-scientific topic related to biological, social and cultural, economic, dimensions of energy sources and public health impact provides the context for the inquiry-based primary research questions related to the learning topic: Looking after my community: *energy sources and public health impact.*

Socio-scientific issue:
Air pollution is a global problem with effects on public health. While some of the consequences of pollution are unpredictable in terms of climate change, others, such as heat-induced stress, chronic respiratory and cardiovascular diseases, cancers, among others, are supported by considerable facts and arguments. The energy supply system contributes on a large scale to air pollution, which annually causes more than seven million deaths worldwide, with more than four million deaths being caused by indoor (household) air pollution and more than three and a half million due to outdoor (environmental) air pollution. Given the nature of planet Earth as an energy-dependent system, the educational landscape supports physics teachers in organizing classroom debate on the energy transition to more carbon-neutral environments.

Using the example of the socio-scientific issue related to energy sources and public health impact, teacher and students discussed the complexity and multidimensionality of socio-scientific issues, the social risks, and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders.

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The primary research questions of this educational scenario are the following:

- What is a primary energy?
- How are energy sources distributed around the world and what is the level of energy consumption in the different regions of the world?
- What are the advantages and disadvantages of using renewable energy source instead of fossil fuels?
- How does energy consumption can influence the spread of problems like climate changes or air pollution?
- What can be done by the school community to prevent and mitigate public health issues due to energy consumption such as air pollution or climate changes?

The evaluative tasks for the educational scenario on the PAFSE topic: Looking after my community – energy sources and public health impact are the following:

- Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment).
- Worksheets evaluation (for each lesson that composes the educational scenario).
- Learn interactively, by playing a computer designed game on how can we combine different primary energies in a sustainable way to satisfy energy consumption needs in different times of the day.
- Evaluation of a scientific presentation and a poster on the topic energy sources and public health impact: definition of primary energies, identification of primary energy sources available in the planet, advantages and disadvantages of using renewable energies and fossil fuels, and individual and community measures to take place to mitigate public health problems like air pollution or climate changes that can occur due to energy consumption.
- Post-test (Final/ summative assessment).

Parents and other stakeholders were encouraged to become real partners in school projects and activities through answering questionnaires, giving interviews, or sharing their experiences and expertise.

The educational scenario on the PAFSE topic: Noise pollution and quality of life
This Educational Scenario is an integrated learning module in Public Health Education related to the PAFSE topic: Looking after my community: *noise pollution and quality of life* and it is integrated in Portugal Physical-Chemistry Curriculum for 8th - grade students.

A socio-scientific topic related to physical, social and cultural dimensions of noise pollution and quality of life impact provides the context for the inquiry-based primary research questions related to the learning topic: Looking after my community: *noise pollution and quality of life.*

Socio-scientific issue:
Noise is a social problem, particularly observed in urban environments and in the workplace, with well-documented public health impacts. People's exposure to noise can negatively affect a full day's work, or even a night's sleep, leading to problems such as reduced day-to-day productivity and loss of health and quality of life. According to the World Health Organization, noise pollution is one of the main drivers of health. Moreover, according to the European Environment Agency (EEA), noise is responsible for 16,600 premature deaths and more than 72,000 hospitalizations every year in Europe. For the preservation of wildlife, and the health and well-being of humans, public debates on the subject should be held frequently, and actions to monitor noise levels in specific situations, contexts and environments should

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also be recommended, comparing the recorded values of measurements with the limits recommended and imposed by the current legislation.

Using the example of the socio-scientific issue related to noise pollution and quality of life, teacher and students discussed the complexity and multidimensionality of socio-scientific issues, the social risks, and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders.

The primary research questions of this educational scenario are the following:

- What are the main differences between noise and sound?
- How can noise affect our lives?
- What are the main noise pollution sources in our day-to-day life?
- What can be done by the school community to prevent and mitigate public health issues due to noise pollution?

The evaluative tasks for the educational scenario on the PAFSE topic: Looking after my community – energy sources and public health impact are the following:

- Evaluation of the preconceptions of students on the subject (Initial/ diagnosis assessment).
- Worksheets evaluation (for each lesson that composes the educational scenario).
- Usage of a sound recording app to perform a series of measurements around the school facilities and then analysis the results identifying which measurements can be considered noise and the main reasons on why noise occurred in those places.
- Evaluation of a scientific presentation and a poster on the topic noise pollution and quality of life: definition of noise and main differences between noise and sound, identification of noise pollution in our day-to-day, identification of several public health issues that occur due to noise pollution, and individual and community measures to take place to mitigate public health problems that can occur due to noise pollution.
- Post-test (Final/ summative assessment).

Parents and other stakeholders were encouraged to become real partners in school projects and activities through answering questionnaires, giving interviews, or sharing their experiences and expertise.

Teacher training courses – workshops and implementation of educational scenarios

Before the implementation of each educational scenario in the classroom, teacher training was conducted. Teacher training lasted fifteen hours in four online workshop sessions and were discussed the following topics:

- Pedagogical framework and PAFSE digital educational platforms.
- Development of PAFSE educational scenarios: Pedagogical approaches and strategies for each educational scenario.
- PAFSE digital educational platforms.
- Planning and enactment of educational scenarios.
- Planning and enactment of School Research Projects and open schooling event.

The workshop gathered the 5 schools that participated in the case study. This initiative successfully engaged teachers from the five school groups situated in Lisbon, and feedback surveys among the

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participating teachers offered a generally positive perception of the workshop. Afterwards, the scenarios were implemented in the five schools. In order to answer our research question, a final questionnaire was executed in the scenario enactment at schools, aimed at assessing 3 domains for each scenario:

Droplets and the physics of viruses' transmission scenario:

1. Knowledge:
    - Explains, on the whole, the process of spreading viruses by air.
    - Identifies factors that influence the spread of respiratory droplets.
    - Identifies sources of risk in the environment.
    - It identifies measures and proposes general actions to combat airborne diseases.
    - Understands how ventilation systems can help mitigate the spread of airborne viruses.

2. Skills (abilities/competences):
    - Finds, analyses and interprets scientific data, texts and dynamic graphic representations to understand the public health impact of airborne diseases.
    - Understands the difference between facts and opinions, understands how to find dubious information, assesses the credibility of health-related information based on several factors that influence the credibility of information.
    - Understands the relevance of scientific facts to explain phenomena related to public health and airborne diseases, and produces argumentation.
    - Evaluates both individual and community risks, as well as behaviour patterns of risks and protection.
    - Sets out appropriate strategies to reduce the risk of infection of airborne diseases, both at individual and at community level.
    - Understands the importance of using a computational tool in assessing and predicting risks of infection of airborne diseases, taking into account the configuration of space.

3. Affective/Attitudes/Behaviour (beliefs):
    - Adopts general risk perception attitudes.
    - Adopts attitudes to minimize the risk of airborne diseases (e.g., raising awareness to keep shared spaces well sanitized).
    - Promotes the communication and debate of measures for risk reduction, specifically public policies with an impact on the health of the school community and the community in general.
    - Uses computational tools to solve complex mathematical problems related to public health.

Energy sources and public health impact scenario:

1. Knowledge:
    - Recognizes that carbon dioxide production is the main factor driving anthropogenic climate change.
    - Defines the concept of primary energy and its sources.
    - Identifies various forms of energy production and transfer.
    - Recognizes the difference between renewable and non-renewable energy sources.
    - Identifies the advantages of using renewable energy and the challenges associated with using this type of energy.
    - Identifies measures and proposes general actions to combat climate change.

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2. Skills (abilities/competences):
    - Finds, analyses and interprets scientific data, texts and dynamic graphical representations to establish the relationships between energy sources, air pollution and extreme weather events.
    - Analyses the overall energy production process.
    - Analyses the consequences of air pollution in terms of damage to the environment, global warming and extreme weather events.
    - Analyses the public health consequences of air pollution.
    - Understands strategies to reduce energy waste, such as more frequent use of renewable energy sources and minimizing the ecological footprint.
    - Obtains, evaluates and communicates facts related to energy sources and their implications in terms of indoor and outdoor air pollution.

3. Affective/Attitudes/Behaviour (beliefs):
    - Adopts general attitudes towards the rationalization of energy consumption.
    - Adopts actions to minimize the ecological footprint, reducing energy needs and transitioning to more sustainable energy sources.
    - Builds argumentation and debates measures to reduce environmental and domestic risks, with a special focus on public policies related to SDG 7 (affordable and clean energy).

Noise pollution and public health impact:

1. Knowledge:
    - Distinguishes noise from sound.
    - Characterizes the units and parameters of noise.
    - Characterizes the impact of regular exposure to noise in humans' health.
    - Identifies ways and equipment that reduce or mitigate exposition to noise.
    - Identifies relevant action to address challenges related with harmful noise exposition at the community and societal level.

2. Skills (abilities/competences):
    - Finding, analysing , and interpreting spectral density diagrams.
    - Researching, discussing, and communicating evidence on effects of harmful noise exposition to wildlife and humans' health.
    - Analysing practical strategies to reduce exposure to noise.
    - Analysing scientific evidence to explain phenomena related to noise pollution and produce argumentation.
    - Understanding the importance of using a computational tool to solve day-to-day problems.

3. Affective/Attitudes/Behaviour (beliefs):
    - Noise pollution perception attitudes, measures towards limiting the increase, intellectual curiosity, respect for plurality of viewpoints.
    - Adopting general risk perception attitudes.
    - Adopting attitudes towards minimizing the risk of noise exposure, specially identified damaging frequencies and tones.
    - Engaging public speaking and debate of measures to reduce risks.

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A pre- and post-questionnaire regarding STEM awareness was also implemented in each class, which was able to access the students' awareness concerning mathematics, sciences, engineering and technology.

Implementation of the educational scenarios

Aiming at a clear path for the teaching-learning dynamic, a specific set of lessons and teaching-learning activities were defined for each scenario. The principal target of each scenario were Science and ICT classes, with 7th, 8th and 9th graders (+/- 15 years old students), where physics' teachers, along with other colleagues, participate in the enactment of the scenario (e.g., ICT, visual education, mathematics, English teachers), as it aims to be interdisciplinary.

Estimated duration of scenario implementation is:

- 6 lessons of 40-45 minutes for the development of each teaching-learning activity proposed for each scenario.
- 4 to 6 lessons of 40-45 minutes for school research project.
- Open Schooling Event.

For the first scenario the lesson plan was outlined as follows:

Lesson 1: Presentation of the scenario and its introductory concepts.
Lesson 2: Explore concepts of the physics of airborne virus transmission.
Lesson 3: Analyse CFD simulations of an initial case study.
Lesson 4: Analyse CFD simulations of a more complex case study.
Lesson 5: Presentation and debate of the results achieved in the analysis of the simulations.
Lesson 6: Conclusion of class 5 and discussion of the school research project.

First, students study problems related to the spread of respiratory particles through the air and human infection in a given room and under pre-defined conditions. They explore and explain the problem by understanding how particle/virus airborne transmission works by seeking scientific information about respiratory particle flow, research in trusted sources and share ideas with teachers and colleagues.

Then students explore a computational tool that simulates the flow of particles into enclosed spaces and understand the complexity of the process (airborne particle spreading), but with the support of a computer tool the phenomena are easier to predict, characterize and analyse. In this phase students understand that simulators are relevant computational tools for real-life problem solving and generally understand the principles of physics and mathematical equations that explain the spread of particles and the functioning of a computational tool. They will analyse and study results obtained from computer simulations, explain the behaviour of particles inside the room, and the differences observed between simulations.

Finally, during the school research project students understand how particle flow develops in different environments and propose measures and recommendations to prevent or to mitigate the propagation of particles through the air in school and in community spaces. Based on computer simulations and the entire teaching-learning process, proposals and recommendations for community health are prepared by the students and presented to the community at the open school event, in the form of a poster, constituting the creation of this element as the school research project.

For the second scenario the lesson plan was outlined as follows:

Lesson 1: Presentation of the scenario and study and comparison of primary energy sources.
Lesson 2: Explore the consumption of various energy sources worldwide.

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Lesson 3: Explore the differences, advantages and disadvantages of renewable and non-renewable energy sources.
Lesson 4: Implementation of the interactive game of primary energy combinations to meet energy consumption needs.
Lesson 5: Presentation and debate of the conclusions obtained from the activities of the previous classes.
Lesson 6: Impacts of energy consumption on public health and preventive solutions.

First, students explore/study concepts related to the primary energies and sources available on the planet and how energy consumptions vary over the years by researching and analysing credible data and scientific bases.

Then students discuss and explore how we can efficiently meet the consumption needs of families, interactively, through a game, where students combine different primary energy sources to solve the problem at hand and explain the reasons why they chose one source over another. Students analyse how excessive energy consumption, as well as its waste, impacts society at different levels (from a social, health, environmental and economic perspective), some of the problems being soil and water contamination, air pollution, among others.

Finally, students present a series of measures and recommendations to prevent/mitigate the exploitation and excessive consumption of energy, as well as the waste of it in school and community spaces and present the results of the school research project (facts, proposals and recommendations to the community) at the open school event.

For the third scenario the lesson plan was outlined as follows:
Lesson 1: Sound and Noise: generic concepts.
Lesson 2: Noise: causes, types of exposure and impacts to public health.
Lesson 3: Practical activity of noise and sound measurements.
Lesson 4: Analysis of noise and sound measurements.
Lesson 5: Presentation and debate on the conclusions taken from the practical activity. Identify measures and behaviours to adopt to reduce noise generation with the focus on improving public health.
Lesson 6: presentation of the school research project.

First study analyses the main differences between noise and sound and the main physical parameters used to characterize noise and then study and analyse problems related to noise exposure through a research work of science-based information on the subject (concept of noise and distinction of the concept of sound, standards, recommended limits, sources of noise pollution, how to measure, among others). Students analyse and describe different sources of noise and identify those most harmful to human health through science-based data and information research.

Then students analyse and discuss real cases of various types of noise through the recording of sounds, using an audio recording application, and through the recording of noise level measurements, in decibels, at their school, with an acoustic meter, and then characterize the noise recorded, in terms of level of impact on public health. Students discuss in the classroom environment the main causes of noise at different levels (e.g.: wildlife, environment, health).

Finally, students find solutions to mitigate the identified problems, based on research and practical activities carried out in class, considering the consequences of noise for public health. Based on the entire teaching-learning process, proposals and recommendations for community health are prepared

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by the students and presented to the community at the open school event, in the form of a poster, constituting the creation of this element, the school research project.

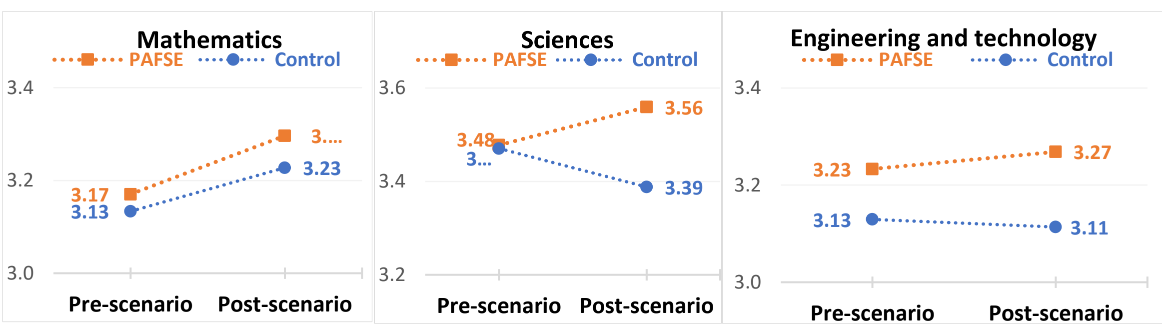
Methods

Five schools from Lisbon participated in the case study, with students from the 7th, 8th and 9th grades each addressed their respective educational scenario. Each school selected one class that would actively participate in the educational scenario (PAFSE Group) and a control group (one class) who did not participate in the scenario enactment (Control Group). Hence, in total 30 classes were accounted for. All the classes answered two sets of questionnaires, in the same period, before (pre-scenario) and after (post-scenario) the scenario enactment: a STEM questionnaire and a questionnaire regarding the contents of the educational scenario they addressed. Only the students who answered both the pre- and the post-scenario questionnaires were included in the analysis.

RESULTS

Within this project there were three different scenarios. A questionnaire was handed to a class before and after the implementation of the respective scenario. This class will be called PAFSE class. To be able to compare it, the same questionnaire was also handed to a control class in the same school (control class), in which the project was not implemented. Although different results were shown for each scenario, the main conclusion (which will be further developed in the next topic) was the fact that in general, the classes where the project was implemented had an increase in the student's interest in studying STEM areas. More specifically, the results for each scenario were:

- **Scenario 1:** in the PAFSE class, the interest in studying every STEM area increased after the implementation of the scenario, mainly in Mathematics, where the control class also increased. However, in the areas of Science and in Engineering and Technology, the PAFSE class also increased (significantly, in the area of Sciences), whereas the control class declined. Supporting graphs for this scenario can be seen below:



- **Scenario 2:** before the implementation of the scenario, the control class had a bigger interest in studying these areas. However, after the implementation, the interest was boosted in the Mathematics and Sciences areas. On the other hand, it declined slightly in the Engineering and Technology area. In the control class, the interest in every area strongly declined, mainly in Mathematics and in Science. Supporting graphs for this scenario can be seen below:

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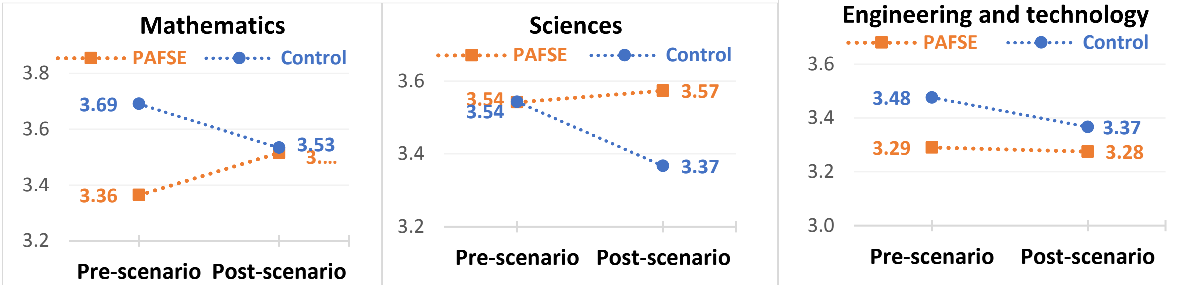
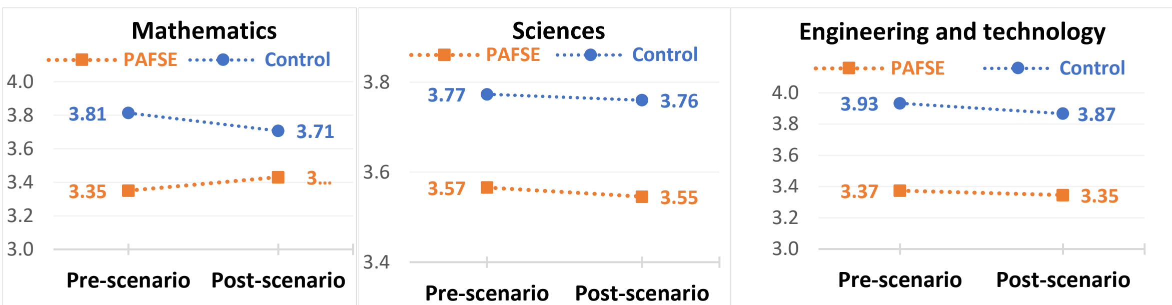


- **Scenario 3:** this scenario had the interest rates more balanced through the first time answering the questionnaire and the second. Before the implementation of the scenario, the control class also had a bigger interest in studying these areas, such as in scenario 2. Almost every statistic declined slightly, with the exception of the interest in the area of Mathematics in the PAFSE class, which increased. In the control classes, the interest in every area dropped, such as the interest in Science and Engineering and Technology in the PAFSE classes. Supporting graphs for this scenario can be seen below:



However, it should be taken into consideration that this sample size was small, only including one class that implemented the project per school, and that these conclusions should be taken with a grain of salt. Furthermore, this questionnaire main objective was to get a perception about the topic at hand.

DISCUSSION AND CONCLUSIONS

The aim of the present case study was to investigate Portugal lower secondary school students' (at urban schools) views and perspectives on an open schooling model regarding public health education, through the implementation of specially designed educational scenarios based on an open schooling model for inquiry-based learning in the context of public health socio-scientific issues. The Portuguese students presented and debated three different public health socio-scientific issues, namely: (1) Airborne diseases transmission, (2) Public health impacts due to energy consumption (3) Public health impacts due to noise pollution.

As mentioned in the topic above, although different results were shown for each scenario, the main conclusion was the fact that in general, the classes where the project was implemented had an increase in the student's interest in studying STEM areas, and that PAFSE classes had a bigger interest in studying these areas than the control classes. Moreover, in the control classes, after the implementation of the process, the interest always decreased. In terms of specific scenarios, the first scenario was clearly the one with better results. However, scenarios 2 and 3 still showed an overall increase of interest from students in studying said areas, and had a global evolution from students, mainly in the area of Mathematics, which had an increase in every PAFSE class and also in one control class.

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Nevertheless, it should be reminded that the questionnaire does not include soft skill learnings, such as time management, teamwork, data organization, public presentation, debate, among others. Moreover, it does not take into account the levels of scientific alphabetization and preparedness of the community about the possible public health challenges. Lastly, it does not consider the level of preparation of the students to be involved with project-based learning.

RECOMMENDATIONS

After the conclusion of the 2022/2023 school year, meetings with every participating school in the project were held. From these meetings with school directors and with the professors from the classes where the project was implemented, a lot of feedback was received. Some of it may be related to the interest of students with the STEM areas, such as:

- the possibility to innovate even more when presenting the topics of each scenario. Some schools with more "creative" teachers proposed the use of a more dynamic methodology, to stimulate the research environment;
- the potentiality of not always using a question-search-answer methodology during the research and the completion of worksheets, as it may turn classes boring for the students;
- create more dynamic and interactive worksheets so that students are always challenged and interested in what is being discussed;
- the possibility of further stimulating students into pursuing studies of a STEM area, and the potential of inviting experts of each area to talk to the students;
- The creation of more support documents for students and teachers such as learning guides to help them better understand what is required in each learning activity;
- Include the PAFSE project in the club science of each school.

We believe these recommendations, among others, from school professors, the ones who implement the scenario after all, can lend a very helpful hand on the increase of student's interest in studying STEM areas, as it makes classes more interesting.

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3.7. Adam Mickiewicz University (AMU)– Case Study Report

Students' developed arguments for nutrition as a public health issue in Biology education in Polish schools – case study.

Abstract
Nutrition is an important element of human health, and healthy eating habits developed in childhood and adolescence can last a lifetime. Therefore, it is extremely important to shape conscious nutritional decisions from an early age. Schools should support this process as a critical environment for implementing strategies that shape healthy dietary patterns. Argumentation is one example of active learning that can be used in schools because it allows students to use information and make evidence-based decisions when constructing an argument. The study involved 126 students from Polish schools aged 12-16. All the participants took part in classes focused on argumentation. The presented study is a qualitative exploratory study using content analysis. We were interested in students' choices, ways of thinking, and reasoning when constructing an argument in favor or against the idea of selling fast food at schools. The analysis of students' arguments for selling fast food in the school canteen allowed for the selection of themes such as restricting freedom of choice is a threat to autonomy, restricting freedom of choice is a threat to the autonomous choice of the hierarchy of values, the belief that such food also has benefits - arguments reducing cognitive dissonance maintain anti-health behaviors (minimizing harmfulness, finding additional cognitive elements, that serve as an excuse). The themes emerging from the arguments against the sale of fast food included a general attitude toward our own health, school as a place for shaping a healthy lifestyle, the quality of food we eat, and physiological mechanisms underlying health problems. As is shown in the presented article, engaging students in solving everyday dilemmas that affect their own lives reveals what is essential to the students in their choices. It also enriches our perception about introducing argumentation into the school environment or about possible designs of educational interventions.

Keywords: nutrition, argumentation, students, school canteen, fast food

Introduction

Nutrition as-public health and socio-scientific issue

What is health The U.S. government's Healthy People 2030 initiative in 2020 has redefined a definition of Health literacy. According to that initiative there are two levels of health literacy – personal and organisational. Personal health literacy "is the degree to which individuals have the ability to find, understand, and use information and services to inform health-related decisions and actions for themselves and others. Organizational health literacy is the degree to which organizations equitably enable individuals to find, understand, and use information and services to inform health-related decisions and actions for themselves and others." They highlight the fact that new definition instead of understanding the information stress usage of it. And that ability to make "well-informed" decisions is better than "appropriate decisions."

Nutrition researchers decided that a similar definition can be adopted for nutrition as a critical element of health. Nutrition literacy is defined as 'the degree to which individuals have the capacity to obtain, process, and understand nutrition information and skills needed in order to make appropriate nutrition decisions' (Silk et al., 2008).

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Nutrition is a crucial part of human life and health. What we consume and how we do it influences our bodies and well-being. It involves providing an organism with adequate nutrients, vitamins, minerals, and water. It is also a very biological process in which biochemical and physiological reactions occur and by which an organism uses food to support its life. It provides organisms with nutrients that can be metabolized to release energy stored in organic compounds or build up our cells. Failure to obtain sufficient nutrients causes malnutrition. Because of its role, what we eat impacts our health - since it becomes part of our body. Most of the studies about nutrition are dedicated to humans. There is a link between nutrition and diet. Diet refers to all the foods a person consumes, while nutrition is the process of using foods to promote muscle growth, metabolism, and repair. The relationship between diet, nutrition, and health is two-sided; nutrient deficiency can affect health status and vice versa. The dietary guidelines are designed to provide the public with evidence-based food and drink recommendations, support food consumption to meet dietary needs and prevent eating disorders such as tooth decay and obesity (Zohoori, 2020).

Shaping healthy dietary patterns at schools

While nutritional education is a lifelong process, the most critical period is childhood and adolescence. During this time, dietary preferences and habits are formed, which can be challenging to change later in life (Wojnarowska, 2017). Schools are identified as a critical environment for implementing strategies to shape healthy dietary patterns among students since children spend more time at school than in any other environment away from home and consume food there (Story et al., 2009; Khan et al., 2009). Children and adolescents are particularly vulnerable to developing bad eating habits and subsequent consequences. Young age is conducive to shaping and consolidating eating behaviors that may have consequences felt throughout life. The developmental age population reacts exceptionally sensitively to nutritional errors, leading to disorders in mental and physical development.

Typical irregularities in the structure of food consumption of school-age children and adolescents are:

– lack of variety and monotony of nutrition

– too high consumption of sugar and sweets, meat and meat processed foods, sweetened carbonated drinks, fats, fast food

– too low consumption of fruit, vegetables, products dairy products, whole grain products, and fish (Gawęcki & Roszkowski, 2009).

As Wanat and co-workers indicated in their research (2011), an increasing problem among young Polish people is skipping main meals in favor of snacking on foods that suppress hunger but have low nutritional value and high-calorie content, such as sweets, fast food (eating on the street), sweetened carbonated drinks. Among junior high school students, 33% said they eat fast food several times a week, and 60% consume fast food several times a month.

Improper diet affects the development of chronic diseases. Dietary patterns are an essential risk factor for many diseases; they also influence their course, the treatment process, and patients' quality of life. Dietary patterns are associated with lifestyle diseases, i.e., cardiovascular diseases, obesity, cancer, and diabetes (Synowiec-Piłat et al., 2017). The nutritional situation in many countries requires attention and calls for action. Education has been recognized as a possible and promising way of preventing future disasters.

Goals of Nutrition Education

Depending on the goal, there are three primary approaches in nutritional education, represented in Figure 1. These approaches are intervened and can and should be taken in tandem.

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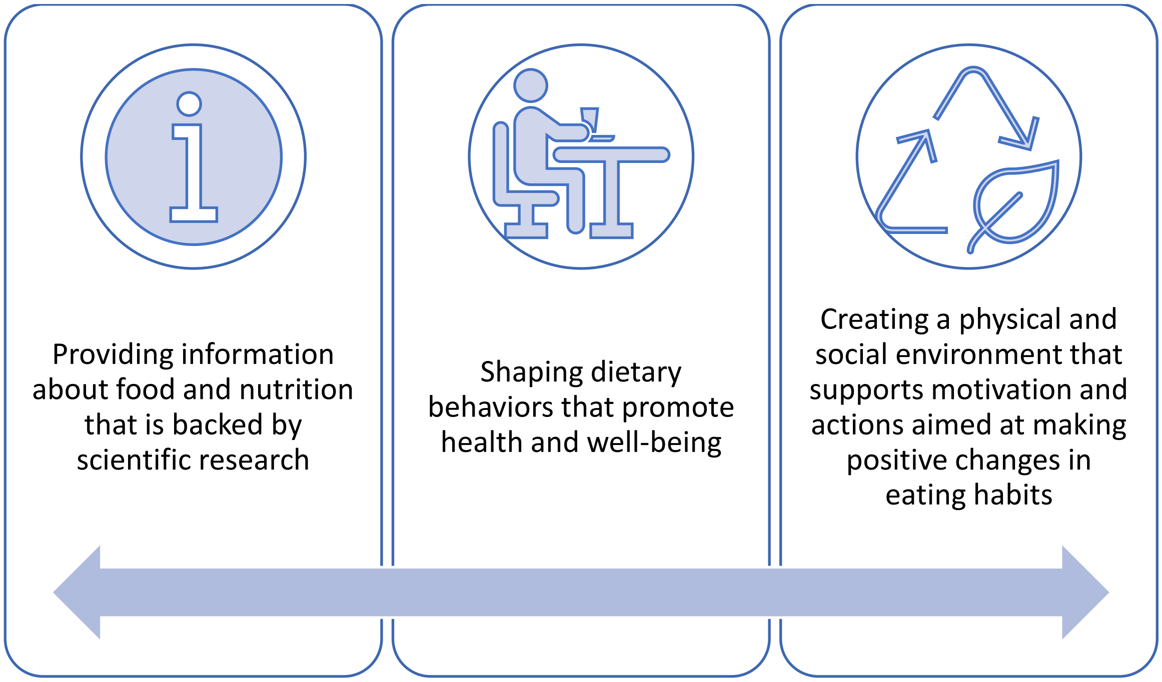

Figure 1. Three main approaches in nutritional education (after Contento, 2011).

Adapting all three approaches seems to be the most promising strategy. It is also well known that just informing somebody or providing facts alone is not a sufficient strategy to facilitate changes in human behavior. Food and Agriculture Organization of the United Nations reports that unhealthy diets remain one of the main contributors to the global burden of malnutrition and disease. They also recognized school-based food and nutrition education as a key component of holistic nutrition education and one of the four areas of FAO's main interest (FAO, Nutrition Education, 2021). The other three are:

i) promoting the integration and value of school meals;
ii) creating a political, legal, economic, and institutional environment;
iii) promote a healthy school environment and adequate and safe school meals.

The main points of the FAO model for school food and nutrition education are:

i) Involvement of the whole school community to promote healthy and more sustainable practices (creating an open-school environment where besides teachers and students, parents, communities, and local authorities are involved);
ii) Children are active participants in the communities, and they take responsibility for the food education process and become agents of change in local food;
iii) Active learning methods are applied (FAO, Nutrition Education, 2021).

Contento (2011) also believes that nutritional education is a combination of educational strategies supported by the environment aimed at facilitating people in making voluntary food choices and adopting dietary behaviors that promote health and well-being. She recognizes the role of individuals, as well as groups and decision-makers, in the nutritional education process.

Arguments and argumentation competences (Connections with argumentation)

Following recommendations from FAO we have created a learning unit that allows students to actively participate (shows also consequences of their own actions) within active learning methods applied. Argumentation is one of the examples of active learning.

Argumentation allows students to use information and make evidence-based decisions while constructing an argument

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The argument is seen as part of an interactive dialogue between two (or sometimes more) people who infer about a phenomenon based on premises (Walton, 1989). Argumentation is an integral part of the construction of scientific knowledge, thus, it has to be a part of science education if the latter is supposed to reflect the nature of science (Pilar Jiménez-Aleixandre & Erduran, 2007).

It can be said that the argument is a tool in discussion; it is used in discourse in the construction of scientific knowledge (Kitcher, 1988; Pilar Jiménez-Aleixandre & Erduran, 2007). Also, from the sociocultural perspective (Vygotsky, 1978; Wertsch, 1991), which points to the role of social interaction in learning and thinking processes, argumentation feeds learning.

The argument can be perceived on two levels – individual and social. From that perspective, an argument can be either an inner chain of reasoning (individual level) or a tool during the debate between people opposing each other with contrasting ideas (social level) (Jiménez-Aleixandre & Erduran, 2007). These two levels, as Kuhn (1993) points out, are linked and interfere with each other since social dialogue offers a possibility to externalize internal thinking strategies, ideas, reasoning, and values that are then embedded in argumentation. Puig, Torija, and Jiménez-Aleixandre(2012) add that argument is an assessment of knowledge in the light of the available evidence. Additionally, the argument can be revised, i.e., it can be discussed by itself. An argument may itself be an element of scientific inquiry - especially the process of its construction and evaluation.

Context

Polish educational system (eg. need to introduce more on argumentation and more on nutrition

In Poland, the compulsory formal educational system before 18 years of age consists of two types of school: primary and high school. According to the Education Law Act, Article 35, compulsory education concerns the requirement to undergo the general education process and reads as follows: Compulsory Education: Education is compulsory until the age of 18. Education commences in the calendar year when the child turns 7.

Forms of Implementing the Obligation of Education: The obligation of education can be fulfilled through:

Attending a primary and high school.

Participating in continuing education activities in non-school forms in accredited institutions.

Completing vocational training at an employer.

Pursuing education at a higher education institution (not necessarily as a student) – this applies to individuals who have completed other schools before turning 18.

Thus core curriculum for biology is written for primary and high school education.

It is worth mentioning that the current core curriculum for biology education is rich in content knowledge, but missing many skills and values (Chyleńska et.al., 2022). In the general aims of this document, a statement appears that a student is supposed to be able to present opinions and arguments regarding the discussed biological issues. But in objectives, arguments are only mentioned twice, when can we read that a student:

- should be prepared to formulate arguments based on modern science regarding the consequences of using genetic engineering techniques for human health and the environment, as well as to develop the ability to critically receive information in the field of genetics and genetic engineering available in the mass media.
- presents arguments for the endosymbiotic origin of mitochondria and chloroplasts.

Both topics are presented in a form that is not very close to the student's everyday life.

Nutrition in the core curriculum for biology

Nutrition in the biology core curriculum is perceived mainly from the perspective of the digestive system – its structure, functions, diseases, and diagnostic examinations. Nutrients are described in one point: The

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student: Presents the role of inorganic and organic nutrients in nutrition, especially complete and incomplete proteins, essential fatty acids, fiber, and vitamins. The word diet does not appear in the curriculum. Neither fast food.

Argumentation in Core Curriculum

As Pilar Jiménez-Aleixandre and Erduran (2007) point out across the world, there is an increasing tendency to “incorporate ideas about how scientific knowledge construction occurs and how argument can contribute to the process of scientific knowledge construction” (pp. 17). Countries such as the USA and the United Kingdom released documents highlighting the role of argumentation in science education. The emphasis on the relevance of using evidence and argumentation is also present in the Spanish National Curriculum but is also reflected in documents prepared in South Africa, Turkey, Israel, Australia, Taiwan, and others. Although argumentation is widely recognized worldwide as an important element of knowledge creation and a key component of the curriculum, in the current Polish curriculum, argumentation as a skill or competency does not exist. In the core curriculum for primary education, argumentation is mentioned once in general aims of biological education in the statement The student presents opinions and arguments related to the discussed biological topics. The core curriculum for high school biology also presents the same main aim. Arguments also appear in detailed objectives:

- The student presents arguments in favor of the endosymbiotic origin of mitochondria and chloroplasts.

The third place in which argumentation appears is in the introduction part. In the "Conditions and Method of Implementing the Curriculum" section, there is an indication regarding argumentation, which recommends: "Great emphasis should be placed on preparing students to formulate arguments – based on contemporary science – concerning the consequences of using genetic engineering techniques for human health and the environment, as well as on developing the skill of critically receiving information in the field of genetics and genetic engineering available in the mass media." *(https://cke.gov.pl/images/_EGZAMIN_MATURALNY_OD_2023/podstawa_programowa/biologia.pdf)

The mere inclusion of a goal in the curriculum or other educational documents, of course, does not guarantee the actual achievement of these goals. As Pilar Jiménez-Aleixandre and Erduran (2007) note, “Despite efforts at the level of international policies about the science curriculum, the systemic uptake of argumentation work in everyday science classrooms remains minimal One of the key challenges to implementing argumentation in everyday classrooms is the lack of transformation of policy recommendations to educational practice. ” (pp. 20).

Teaching approach

All the participants took part in classes focused on argumentation. In the first part of the classes, their personal knowledge about what an argument is and when to use it was activated. Then, fundamental concepts related to the structure of arguments and their role in education and teaching were presented. An example of an argument concerning smoking in public places was presented. Subsequently, students collectively attempted to create an argument regarding the impact of owning a dog on the owner's mood. Further on, they were asked to create their own argument regarding whether it is worth going on a class trip by ship in the Baltic Sea during the summer vacation. In order to support students in building their own argument and fulfilling its structure, students received a worksheet with elements of an argument to be filled in. This template is presented in the figure below (Figure 2).

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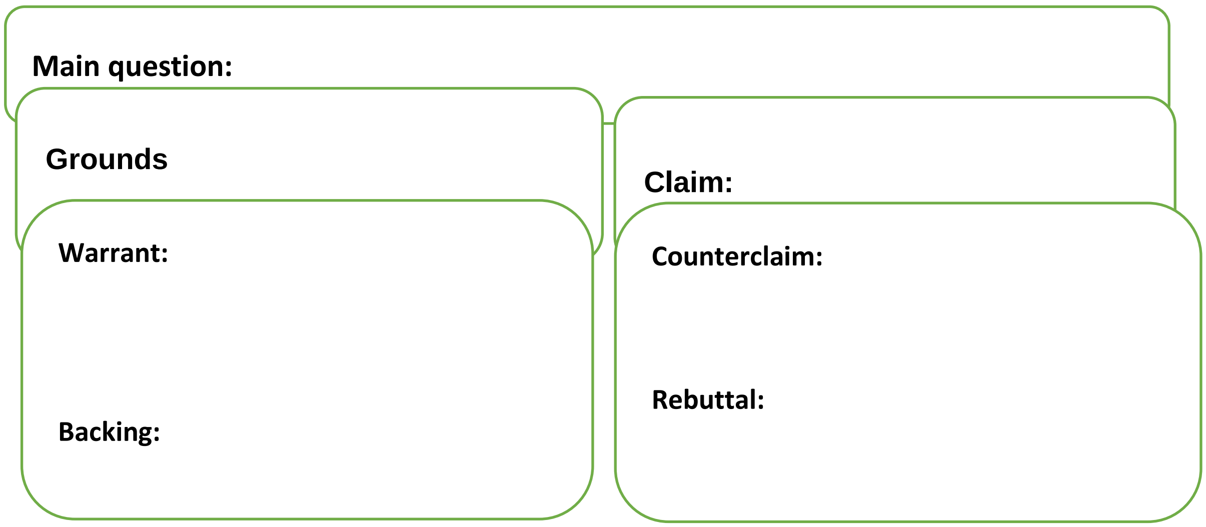

Figure 2. Template for argument construction given to students during the intervention.

After independently constructing their arguments, students presented them on a forum and provided each other with feedback regarding the structure of the arguments, the logical coherence of their statements, and so on. The next part of the class was devoted to solving a problem related to fast food consumption. Students received cards with information about research findings and various opinions on the effects of consuming fast food. After reviewing the materials, a brief discussion took place regarding what might be in favor of consuming such products and what might be against them. Part of the discussion focused on which information could be considered credible and which less credible or potentially manipulative (e.g., a hypothetical statement from a marketing executive of a well-known fast-food restaurant). The final part of the class was about students individually creating an argument in response to the problem question: "Should fast food be sold in schools?" The class concluded with a discussion where students exchanged the arguments they had prepared. The aim of the educational intervention was to create conditions in which all three assumptions described by Contento (2011) are met. We provided students with information about the effects of consuming fast food, and we created conditions for making a choice about the environment (whether fast food should be sold in the school cafeteria). Through discussion, we also aimed to establish a physical as well as a social environment where it would be possible to shape students' motivation for engaging in health-promoting actions.

Argumentation competence

Research question: What issues guide high school students' thinking when they are challenged to respond to a structured argumentation in task on what food should be available in a school canteen?

What issues do students raise when exposed to such task?

Methodology

- **Data collection**

The study involved 126 students from Polish schools aged 12-16. Almost half of the cohort were students at the primary level (61 participants), and the remaining part (65 participants) were from the high school level. All the schools are located in Poznan (big city in Poland). All of the students participated in the intervention described above. We were interested in the student's responses, and particularly the issues

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they raised when they were exposed to the challenge of constructing their own arguments regarding the problem of whether or not fast food should be sold in the school canteen. Students received worksheets with boxes to be filled in (fig. 2). Their answers were collected and analyzed.

Data analysis

The presented study is a qualitative exploratory study. We are interested in students' choices, way of thinking, and reasoning when constructing an argument in favor or against the idea of selling fast food at schools.

To discern qualities in students' reasoning revealed in their arguments, we used the framework of qualitative content analysis (QCA; Graneheim & Lundman, 2004; Graneheim et al., 2017). We performed a QCA in four steps, including: 1) discerning meaning units; 2) condensing codes; 3) creating categories; 4) formulating themes across students' discussions.

Findings

Four steps of the qualitative analysis framework were applied (Graneheim & Lundman, 2004) and are shown in Table 1.

Table 1

Arguments given by students in favor of selling fast food in the school canteen			
1. Meaning units	2. Codes	3. Categories	4. Themes
A ban on selling fast food in schools would limit my freedom and the freedom to choose whether I want to be healthy Or Taking away your freedom is also a disease Or A person is limited by many orders and prohibitions and may fall into a state of depression and feel like a slave. Or education and awareness-raising will lead to limiting the choice of other foods in schools	Restriction of freedom	Anti-health behaviors and attitudes as risk behavior	Restricting freedom of choice is a threat to autonomy
This food is tasty, increases my mood, and I prefer to be happy than healthy	Tastiness	Value related, hierarchy of values	Restricting freedom of choice is a threat to the autonomous choice of the hierarchy of values
even though fast food has a lot of sugars and fats, it does not harm us because young people have a high demand for energy, which	high demand for energy allows to burn fats and sugars/ are needed	minimizing harmfulness	This food also has benefits - arguments reducing cognitive dissonance maintain anti-health behaviors

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allows them to burn fats and sugars or even though it has a lot of calories, they (calories) are needed for proper development			
when you eat them rarely, in small amounts, they are not harmful or Americans also eat it for many years now, and they are still alive Or our diet should be based on a variety of products. no food will harm us when eaten in moderation. And prohibiting food can lead to eating disorders	A small amount is not harmful	minimizing harmfulness using	This food also has benefits - arguments reducing cognitive dissonance maintain anti-health behaviors
fast food is fast and cheap, and I want to eat quickly and cheaply during my break	Fast and cheap	Finding additional cognitive elements that serve as an excuse	This food also has benefits - arguments reducing cognitive dissonance maintain anti-health behaviors
such food should be sold in schools because it is willingly bought by young people, which will increase profits and is quick - which will reduce queues in the school store.	Willingly bought Increase profits, fast -smaller queues	Finding additional cognitive elements that serve as an excuse	This food also has benefits - arguments reducing cognitive dissonance maintain anti-health behaviors
Fast food should be sold because I like it, Sugar and fat stimulate the brain and trigger the feeling of reward, it stimulates reward, and then I am happy at school. I'd rather be happy than healthy	They are tasty, and feel of reward I'd rather be happy than healthy	Finding additional cognitive elements that serve as an excuse	This food also has benefits - arguments reducing cognitive dissonance maintain anti-health behaviors
Yes, they should because fast food is fast and cheap. Schools are ideally suited to selling fast food, early morning hours make it impossible to prepare a	Fast and cheap, Schools are ideally suited to selling fast food, it doesn't matter	Finding additional cognitive elements that serve as an excuse	This food also has benefits - arguments reducing cognitive dissonance maintain anti-health behaviors

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fresh breakfast, and short breaks force you to eat something high in calories. fast food restaurants are everywhere and close - that's why it doesn't matter.			
Arguments given by students against selling fast food in the school canteen			
1. Meaning units	2. Codes	3. Categories	4. Themes
Fast food should not be sold at school because it negatively affects our health and brain function OR It should not be sold at school because it is unhealthy Or Health is more important than taste	Negatively affects our body/ unhealthy	The general influence of the food we eat and values	The general attitude toward own health
fast food is unhealthy, and schools should not set a bad example Or At school, we should learn, and fast food interferes with our learning Or Schools should not promote unhealthy food or unhealthy eating habits Or This causes spikes in blood glucose, leading to concentration problems, causing fatigue and apathy, which in turn results in poorer academic performance or Just as the school does not promote bad behavior or inappropriate attire, it should not promote unhealthy eating. A student always has a choice outside of school premises, but when entering the school grounds, they are obliged to adhere to the rules.	Unhealthy, Bad examples interfere with learning/poorer academic performance Schools should not promote bad example	Values	School as a place for shaping a healthy lifestyle

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Or school should be an authority and promote healthy lifestyle, should be shaping good eating habits or behaviours, thus it should not sell "junk food" that can lead to diseases			
the food we prepare ourselves can also be tasty, or Healthy food can be prepared tasty and does not have a negative impact on our health Or Taste is not more important than health	Taste	Properties of self-made food	Quality of food we eat
fast food is a type of processed food most often prepared using old, low-quality products, e.g. old fat is often used in fast food restaurants	Processed, low-quality	Properties of fast food	Quality of food we eat
Eating healthy food is more efficient and we don't feel hungry again so quickly	Efficiency	Properties of fast food	Quality of food we eat
Healthy food can be prepared just as quickly (like fast food) and does not cause sugar spikes and concentration problems Or you can prepare (healthy food) at home and take it with you to school, thus you would not have to hurry up at school and buy fast food	As quickly as fast food	Properties of self-made food	Quality of food we eat
frequent consumption of such food leads to addiction, which further leads to serious diseases and obesity or Frequent consumption of such food leads to a decrease in immunity, which may make us more susceptible to diseases	Addiction More health problems	Caring for your own health	Physiological mechanisms underlying health problems

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this type of food causes glucose spikes, which cause problems with focus and concentration. Or Too much sugar causes fluctuations in blood sugar levels, which negatively affects concentration and mood	Glucose spikes and problems with concentration	Caring for your own health	Physiological mechanisms underlying health problems
Fast food has very little fiber, which has a negative impact on intestinal function and may lead to diseases	Little fiber, intestinal function, diseases	Caring for your own health	Physiological mechanisms underlying health problems
Fast foods have a negative impact on our health as they contain high amounts of sugar, which can lead to tooth decay, fluctuations in blood sugar levels, and subsequently result in concentration issues or even diabetes. Due to their high-fat content, fast foods can also contribute to atherosclerosis, neurodegenerative diseases, obesity, heart diseases, circulatory issues, high blood pressure, and many other health problems. Or Dietary fats clog blood vessels, leading to atherosclerosis.	High sugar, rich in fat tooth decay concentration problems, neurodegenerative diseases, circulatory issues	Health consequences, caring for your own health	Physiological mechanisms underlying health problems

Discussion

Lucan, Barg, and Long (2010), in their study, have distinguished Promoters and Barriers to, among others, fast-food consumption. As strong promotors for fast food consumption, they described taste or flavor, Availability and convenience, Time constraints, and Cravings or taste. All of these categories were also noticeable in the presented research. Less important promoters in Lucan et al. work (2010) were preparation or cost. Both these were mentioned as issues related to fast food consumption at school by participants of the presented study. The categories that did not appear in the presented research are No energy or desire to cook, cheat on diet, or weekend or day of a week.
As barriers to fast food consumption Lucan and co-workers (2010) mentioned health or nutrition, cost or finances, and Weight concerns. Less important in their research were Fat or grease content, cholesterol,

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or sugar content. All of these could also be reflected in the arguments given by participants. The categories that did not appear in the presented research are discipline or Same old stuff, tired of it.
Interestingly and differently from the work of Lucan and co-workers (2010), many of the arguments constructed by students in the presented research represent a bigger picture of their attitudes, values, or reasoning.

An analysis of the students' arguments for the sale of fast food in the school canteen has highlighted categories and themes that are strongly rooted in the developmental period that young people are currently in. The issue of freedom of choice of diet (even an unhealthy one) emerged strongly in the young people's statements, which allowed themes to emerge concerning a sense of threat to one's autonomy and the self-establishment of a value system. Such arguments refer to the basic tasks of adolescence, which are the achievement of autonomy and identity (Erikson, 1994; Cicchetti, Rogosch, 2002). According to Jessor's concept of risk behaviour, adolescents may engage in anti-health behaviours, for example, unhealthy eating, as their way of achieving developmental tasks if they cannot do so otherwise (Jessor, 1991; Jessor, Turbin, Costa, 1998). Thus, the actions of young people, including anti-health activities, have a well-defined function, as they can serve to achieve personal and socially meaningful goals of growth during adolescence (Jankowiak, 2017; Bonino Cattelino, Ciairano, 2005). Preventive interventions targeting adolescents should therefore take into account the characteristics of this period and enable young people to explore identity and feel independent in their own decisions.

Furthermore, the categories and themes that emerged indicate the mechanisms students use to reduce cognitive dissonance (McGrath, 2017; Festinger, 1962). Students justified fast food consumption by adding new cognitive elements such as energy requirements during the growth period, using economic arguments (cheapness) or tastiness, and denying its harmfulness. It is worth noting that the theory of cognitive dissonance can also form the basis of efforts to change attitudes towards health-promoting ones when an individual's behaviour is modified due to beliefs about its negative consequences for health. It is worth emphasizing that, in accordance with the selected categories, young people clearly indicate that they are harmful to health, are low in quality, and believe that school should be a place that shapes a healthy lifestyle. As the available research results show, during adolescence, individuals are susceptible to such changes, which may persist throughout their lives (Ong, Frewer, Chan, 2017). Our research shows that cognitive defense should be taken into account when learning argumentation. In situations where young people engage in anti-health behaviors, they can reduce cognitive dissonance to reduce the anxiety resulting from the awareness of engaging in such behaviors. Therefore, it is necessary to discuss with students their cognitive ways of denying the negative consequences of their anti-health behaviors.

Moreover, when we take a closer look into arguments given by students who argue in favor of selling fast food in the school canteen, we might notice moral/ethical considerations related to the value of freedom, or freedom of choice. There were also some that could be described as examples of non-scientific reasoning. The phenomenon recently described as denialism (Hoofnagle & Hoofnagle, 2007) can be spotted in presented students' responses as well. We defined denialism as “the employment of rhetorical arguments to give the appearance of a legitimate debate where there is none” or an approach that has the ultimate goal of rejecting a proposition on which a scientific consensus exists (Diethelm & McKee, 2009). As Diethelm & McKee, (2009) stated that there are five strategies used by denialists. They also highlighted that it is not necessary to use all of them in their reasoning. One of the denialistic mechanisms/strategies is selectivity (cherry-picking), which can be described as citing individual articles or one argument that challenges prevailing beliefs or highlighting the flaws of the weakest articles that form the basis of the agreement in order to undermine the credibility of all the others – eg, examples from category minimalizing harmfulness or Finding additional cognitive elements, that serve as an excuse.
The other denialistic strategy that can be observed here is the use of misrepresentation and logical fallacies – like in the example, *Americans have also eaten it for many years now, and they are still alive.*

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The planned intervention aimed at supporting argumentation skills about fast food consumption. Fast food consumption is one example of a socio-scientific issue, and by that related to students' everyday lies and, at the same time, requires some understanding of science in order to solve it. The SSIs are usually controversial or at least raise discussion about the topic (Sadler, 2004; Zeidler et al. 2005). As it was visible in some situations, science was not the basis for solving this problem. Students preferred to address the values systems instead of their own health. They created personal constructions of a socio-scientific dilemma, where decision-making does not have to be scientific in their perspective, even if they are faced with scientific facts. At the same time, the participants of the presented study did engage with the problem and, in most cases, formulated an argument. Considering that none of them participated before in any intervention that included the construction of a scientific argument, it can be assumed that such a strategy can be recommended. When we consider the ability to construct scientific arguments with counter-claims and rebuttals as one of our educational goals, this was achieved during the described intervention. As Sadler claims:

“if our goal is to help students become better able to contribute to debates and decisions about important societal issues with links to science and technology, then we need to create learning contexts, such that learners actually confront some of these issues and gain experience negotiating their inherent complexities.” (Sadler, 2011, pp.4).

Simonneaux (2011) reflects that argumentation on SSI poses particular challenges, starting with controversy. SSI has also an interdisciplinary nature, thus requiring students to bring together different domains. Various objectives exist when addressing SSI, including enhancing comprehension, fostering citizenship education, enabling students to make informed choices, empowering their participation in discussions, equipping them to navigate complexity, and promoting a deeper understanding of the Nature of Science (NOS). Teachers, when designing a learning environment, can choose different aspects of it. He or she can also use different teaching methods and approaches – from project-based, through debate to role play, and many more. Described intervention is just one of the examples of first attempts in introducing argumentation into the classroom to students who have never constructed complete arguments before. It can be claimed that introducing argumentation within the first social context (creating an argument on whether it is worth going on a class trip by ship in the Baltic Sea during the summer vacation) and then quite simple socio-scientific issues (selling fast foods in the school canteen) seems to be a possible fruitful approach. Usually, teachers focus their professional development on science content, and such development serves as an indication of their acquired pedagogical content knowledge (PCK) (Tidemand & Nielsen 2017). On the other hand, research done by Bayram-Jacobs and co-workers (2018) suggests that considering science content and SSI skills goals equally important is an indicator of the strong development of PCK for SSI teaching. Hence, both elements are important in professional development - especially since experiences and well rooted in content teachers make strong connections between knowledge and pedagogical skills, including pedagogical aspects of SSI.

Implications for the effectiveness of the educational scenarios:

1) include in learning argumentation possible ways for students to reduce cognitive dissonance when the topic directly concerns them and may confront them with fear for their own health
2) Educational interventions aimed at young people should, therefore, take into account the specificity of this period and enable young people to discover their identity and feel independent in making their own decisions.

General implications of the presented research:
1) In any discussions about issues that can possibly raise cognitive dissonance, subsequent interventions should include an analysis of methods used by students to reduce cognitive dissonance and a discussion on health-promoting ways of shaping autonomy and the place for health in the students' value system.

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2) It is recommended to introduce argumentation (its structure, role and ways of assessment) into the biology core curriculum in Poland as well as to teacher professional development training.
3) It is recommended to introduce socio-scientific issues to the core-curriculum to make science more meaningful for students.

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3.8. Portuguese Road Safety Association (PRP)– Case Study Report

The impact of a research project-based learning approach on secondary school students' knowledge, risk perception, attitudes, and behaviour in relation to road safety

INTRODUCTION
Road traffic crashes cause approximately 1.3 million deaths, and 20 to 50 million non-fatal injuries worldwide every year. More than half of all road traffic deaths and injuries involve vulnerable road users, such as pedestrians, cyclists, motorcyclists, and their passengers. Young people are particularly vulnerable in the world roads – road traffic injuries are the leading cause of death for children and young adults aged 5-29 (WHO, 2018). The European Commission defined the goal to move to close to zero deaths in the European Union roads by 2050 (“Vision Zero”) and to halve the number of serious injuries by 2030 from a 2020 baseline. To reach these goals, the European Commission based its road safety policy framework for the decade 2021 to 2030 on the Safe System approach, whose core elements are ensuring safe vehicles, safe infrastructure, safe road use (speed, sober driving, wearing safety belts and helmets) and better post-crash care. The European Commission also stated that the mindset of “Vision Zero” needs to take hold both among policy makers and in society (European Commission, 2020). The traffic safety and mobility education play an important role in strengthening and/or changing attitudes and intrinsic motivations towards risk awareness, personal safety, and the safety of other road users in order to contribute towards a safety-minded culture. It is considered an essential part of an integrated approach to traffic safety, as education provides the possibility for people to learn how to participate in traffic safely. The aim of traffic safety and mobility education is to positively influence behaviour patterns that result in safer traffic. The transfer of knowledge and gaining an understanding of traffic rules and situations are the basis of traffic safety and mobility education (ETSC, 2020). The scenario “Road traffic crash risk factors” aims to contribute towards a safety-minded culture in traffic. Its content endorses teachers to play a key role in developing knowledge and skills for incorporating road safety as a central topic in their classes and in teaching public health science using high-level methods, high-quality learning objects, and updated evidence. It challenged the students to contribute to the community road safety by engaging families in educational activities and reaching the local community with inquiry-based projects and open schooling events led by students. It was expected that the learning experience leads the young students to understand that road traffic crashes are major public health threats, the influencing variables and how to move to less risky patterns of behaviour in the road, and reach high-level comprehension on how STEM (Science, Technology, Engineering, Mathematics) may contribute to address these issues, contribute to evidence-based personal decision-making, and public policy. The scenario supported mainly 9th grade teachers in exploring with students the factors contributing to outcomes of road crashes in terms of injury, severity and fatality. The learning activities prepared students to follow a data-driven approach in addressing and mitigating risks, and so contribute to the reduction of burden from road traffic crashes at the community level. It provided an opportunity to develop a real-world data-driven research project in which students developed and applied knowledge and skills learned in classes. The project involved data collection, data manipulation, data analysis and communicating/discussing results based on scientific evidence in the open school event.

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CONCEPTUAL FRAMEWORK

The educational scenario was designed with a focus on project-based learning, inquiry-based learning, and open schooling approach, following the methodology and goals of PAFSE project. The goal was to carry out a data-driven science study that would lead the students to address a public health challenge in the community – road safety.

The PAFSE project aims to increase scientific literacy and the interest of young individuals in Science, Technology, Engineering, and Mathematics (STEM) careers. This is achieved by involving 15-year-old students in addressing public health challenges through immersive teaching-learning scenarios. PAFSE adopts a participative approach to science education, fostering robust collaboration between schools and stakeholders. At its core, the project empowers students as pivotal contributors, assigning them principal roles, and designs educational activities that not only enhance their understanding but also enhance communities' capabilities in managing public health issues, like road safety. The PAFSE project follows a project-based learning (PBL) and open schooling approach to make learning more meaningful and relevant, encouraging students to analyze authentic challenges. It combines face-to-face teaching with e-learning activities to improve learning experiences. The use of digital interactive educational scenarios is emphasized to provide detailed pathways for teachers and involve them in defining educational goals.

Project-based learning (PBL) stands out as a pedagogical approach with substantial potential to enhance meaningful learning experiences, increase motivation, and increase the relevance of educational engagement. Educational research consistently highlights the effectiveness of PBL in fostering a deeper understanding of concepts and facilitating skill development. PBL is most effective when it involves students in the analysis and resolution of authentic challenges, particularly those relevant to their personal lives (Thomas, Mergendoller, & Michaelson, 1999). By immersing students in real-world problems, PBL provides them with the tools to gather information, analyze evidence, and apply critical thinking skills, thereby making their learning experience more practical and applicable. Moreover, PBL creates an environment where students receive peer feedback and engage in constructive critique with experts, including teachers, mentors from civil society, and professionals from research organizations (Barrows & Tamblyn, 1980). This collaborative aspect not only enriches the learning process but also exposes students to diverse perspectives, fostering a holistic understanding of the subject matter. The joy and pleasure derived from co-creating solutions within a PBL framework contribute to a positive and motivational learning experience (Hmelo-Silver, 2004). Students find satisfaction in actively participating in the study of authentic challenges, creating a sense of ownership in their learning journey. Furthermore, PBL facilitates powerful connections between academic disciplines, real-world workplace scenarios, and societal challenges, particularly in the context of public health (Gijbels et al., 2005). This interdisciplinary approach helps students to understand the broader implications of their knowledge and skills, emphasizing the importance of collaborative efforts in generating solutions that address societal and entrepreneurial needs. In conclusion, PBL emerges as a robust educational strategy that not only enhances academic learning but also instills in students a sense of responsibility and capability to contribute meaningfully to societal challenges.

Project-based learning (PBL) also significantly influences and enhances interest in Science, Technology, Engineering, and Mathematics (STEM) areas. The authentic learning experiences offered by PBL immerse students in real-world scenarios, fostering a deeper understanding and appreciation for STEM disciplines (Hmelo-Silver, 2004). The collaborative nature of PBL not only nurtures teamwork and communication skills essential in STEM professions (Johnson et al., 2014) but also cultivates long-term interest in science (Osborne et al., 2003). Recognizing the career

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relevance of PBL, the National Research Council (2012) emphasizes its role in preparing students for the demands of STEM professions. Fredricks *et al*. (2004) reinforce the connection between increased engagement and academic achievement, positioning PBL as a catalyst for elevating students' interest and participation in STEM education.

Throughout the project preparation, inquiry-based learning was the main approach employed, which actively engaged students in the exploration of digital educational resources developed within the framework of the PAFSE project. Inquiry-based learning is a pedagogical approach that involves students in learning activities where they actively practice different scientific inquiry skills. This method encourages students to use these skills to address scientific questions, either formulated by themselves or by their teachers. This process often involves the handling of authentic data, which can be either experimentally collected by the students or provided in pre-collected form. Common inquiry skills involve constructing and utilizing models, conducting experiments, collecting and organizing data, handling variables, making data-driven conclusions, and effectively communicating about scientific issues (Bell, Smetana, & Binns, 2005; Windschitl, Thompson, & Braaten, 2008).

The school project allowed students to be actively involved with the community, not only during the preparation of the project, but also in the school event open to the community. The concept of open schooling, characterized by collaborative endeavors among schools, universities, research centers, local communities, civil society organizations, and industry agents within a specific geographical context, has been identified as a promising avenue for producing impactful outcomes in education. While evidence supports the potential benefits of such collaborations, the incorporation of workable arrangements for open schooling remains limited within many educational systems. Research suggests that open schooling allows organizations to make significant contributions to formal education providers while simultaneously preparing future citizens for real-world challenges and lifelong learning competences (Sotiriou & Cherouvis, 2017). In the context of the PAFSE project, there is an effort to address the possible connections between curricular disciplines, real-life challenges, professions, and organizational workplace cultures. This is achieved by strengthening relationships between schools, families, universities, research centers, civil society organizations, and other relevant community and public health partners. The project emphasizes a holistic approach to education that extends beyond traditional classroom boundaries. Furthermore, PAFSE actively promotes teacher professional development, recognizing the crucial role of educators in fostering effective open schooling practices. The project seeks to introduce teaching-learning innovations that engage community stakeholders in partnerships that support schools. This approach aligns with the broader goals of open schooling, aiming to create a collaborative ecosystem where various entities contribute to the educational process.

Besides the development of educational skills and knowledge in the students, the project aimed to improve road safety in the community, by contributing towards a safety-minded culture in traffic and reducing risky behaviours. Education plays a pivotal role in enhancing road safety by raising awareness, encouraging responsible behaviour, and giving the necessary knowledge and skills to intervene safely in road environments. Educational interventions have been proven effective in reducing risky behaviours and improving road safety outcomes. For instance, a study by Mohan, Tiwari, and Tsimhoni (2009) emphasized the positive impact of educational programs on enhancing road safety knowledge and fostering safer behaviour among school children. Educational measures, when appropriately designed and targeted, contribute to reducing accident rates and improving road user behaviour. Furthermore, education serves as a critical tool for promoting a culture of safety and responsibility among drivers, pedestrians, and cyclists. By providing individuals

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with a deep understanding of traffic rules, risk factors, and the potential consequences of unsafe behaviours, education contributes to the development of a safety-conscious mindset (OECD/ITF, 2008). In the context of road safety improvement, education is not only limited to formal classroom settings but extends to public awareness campaigns, community engagement, and the integration of safety education into broader curricular frameworks.
Following the methodologies described above and aiming at the goals described, students were challenged to carry out a data-driven science project, with data collected through a questionnaire in the local community, that addressed the public health issue of the consequences of road traffic crashes. Over the developed of the project students contacted with researchers and experts in road safety, performed inquiry-based activities, administered the data collection instruments, analysed results, extracted conclusions, and proposed priorities for promoting a safety-minded culture in traffic in an open schooling event.

RESEARCH QUESTION

The goal is to assess if the involvement in the data-driven science project as part of the educational scenario “Road traffic crash risk factors” increased the knowledge of road safety and lead to safer behaviours in traffic. Research question: “What effect does a data-driven science study on road traffic safety have on student’s knowledge, risk perception, attitudes, and behaviour?”

METHODS AND CONTEXT

Context
The educational scenario “Road traffic crash risk factors” was implemented in a school in the center of Lisbon, Portugal, to students of the 9th grade. The school is located in a multicultural community that includes students from different backgrounds and different nationalities, counting with more than 30 nationalities, such as Spanish, English, Chinese, Indian, Nepalese and French, in addition to Portuguese students. The school has approximately 65 teachers and 740 students in 40 primary and secondary classes. There are 302 students aged between 12 and 15 divided into 16 classes, the target group that the PAFSE project aims to reach. The school has a students' association and a parents' association which, in addition to defending and promoting the interests of their members they jointly promote important activities, such as exhibitions of students' work, get-togethers between students, families and teachers, outings, end-of-year parties or events of interest to the community. The PAFSE project is one of the many initiatives that the school actively promotes to engage not only the students but also their families and local organizations.
The scenario enactment was leaded by the Physics teacher, but other teachers were also involved as teachers of mathematics, information technology, visual and technological education, science, citizenship and English. The planning and execution of the school project was preceded by 6 lessons in which the students explored several educational resources to understand the risk factors in traffic in a close link to topics taught in Physics lessons. The project aimed at developing a data-driven science study with data collection trough questionnaire to assess opinions, attitudes and behaviours concerning road traffic crash risk factors in the community (self-declared behaviours, risk perception of unsafe behaviours and attitudes towards risky behaviour). Students should identify the topics to include in the questionnaire, build the questionnaire and instruments for data collection, plan the data collection (define a population, a sample, and sampling methods), collect the data, analyse the data, and build posters and infographics with the results. In the end, students should present the findings to the community in the open schooling event (students, residents, citizens, researchers, organizations, policy makers), aware for risky behaviours in traffic, and propose measures to improve road safety in the community.

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Development and enactment of the project

The project was based on guided research on road traffic crash risk factors and data obtained through a questionnaire. To address the challenge, students drawn their first ideas about topics to explore from the lessons discussed in the classroom and the supplementary educational activities. Throughout a comprehensive series of six lessons, students were guided to understand the substantial health and societal burdens imposed by road traffic injuries. The educational journey involved identifying main sources of risk and recognizing patterns of risky behaviours in traffic. An important goal of the learning process was to aware for the consequences associated with both safe and unsafe behaviours on the road. Moreover, the educational approach focused on identifying and deconstructing prevailing beliefs and myths linked to each specific crash risk factor. This was achieved through the application of evidence-based thinking, emphasizing the importance of critically evaluating information and assumptions associated with road safety. This multifaceted learning experience aimed not only to give knowledge but also to cultivate a reflective mindset, empowering students to assess and challenge commonly held beliefs with a foundation in evidence. Through this process, students not only acquired knowledge about road safety but also developed critical thinking skills essential for making informed decisions in real-world situations. The main pedagogical approach adopted in these lessons centered around inquiry-based learning, emphasizing student-driven exploration. The educational strategy involved exploring digital educational resources specifically developed for the scenario "Road Traffic Crash Risk Factors". This approach aimed to actively engage students in self-directed discovery, fostering a deeper understanding of the complexities surrounding road safety issues and crash risk factors. Through inquiry-based learning and the use of tailored digital resources, students were encouraged to question, investigate, and critically analyze information, promoting an enriched and participatory educational experience.

After understanding the importance of adopting safe behaviours in traffic, students were challenged to brainstorm about how they could contribute to improving the road safety levels in the school community and what steps they should follow. With the teacher's support, students concluded that to improve road safety and identify specific road safety countermeasures, they first need to identify and understand the problem. This led to the need to collect data. In the next phase, students, working in groups, elaborated with the teacher on the main research questions, goals, data collection methods and instruments, following the steps of the scientific method. At this stage, students were challenged to explore an educational resource that included all the information needed for the different phases of the project development: the steps of the scientific method; definitions and examples of dataset, population, sample, and sampling; data collection instruments; examples of questions for risky traffic behaviours for several road users (pedestrians, cyclists, e-scooter riders, car drivers, car passengers, motorcyclists/moped riders). The decision of the road traffic crash risk factors to assess (speed, safety equipment, distraction, fatigue) in the scholar community was discussed in the class and different topics were addressed by different groups. In the phase of data analysis and preparing the outcomes, students had the support of mathematics, informatics, and citizenship teachers.

The findings of the project were presented and discussed in the "Road Safety Day" – an open schooling event with the presence of the scholar and local community, experts in road safety and parents for a broad discussion about how to improve road safety at community level. The objectives of the event were to raise awareness for the consequences associated with risky behaviours in traffic, highlight the importance of safe practices on the road, and promote discussions on proactive measures to improve overall road safety within the community. Beyond the insights provided by the

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students, the event also benefited from the contributions of road safety experts and local stakeholders, ensuring a well-rounded and informed discussion that involved a variety of perspectives and expertise.

Methods

A case-control study was conducted to answer the research question: "What effect does a data-driven science study on road traffic safety have on student's knowledge, risk perception, attitudes, and behaviour?". The group of students who participated in the educational scenario (PAFSE Group) and a control group, from the same school, who did not participate in the scenario (Control Group) answered a questionnaire, in the same period, before (pre-scenario) and after (post-scenario) the scenario enactment. The questionnaire aimed at assessing 4 domains:

- **Knowledge** – included 14 questions related to road safety and research with 4 answering options (one correct option, two wrong options, and one option "do not know"):
  1. According to the World Health Organization, what is the leading cause of death for children and young adults aged 5-29 years worldwide?
  2. How many people died in car accidents each year around the world?
  3. How much do road accidents cost?
  4. A road system can be intervened to increase road safety. Which elements should be considered?
  5. The performance of the 3 road system elements can be improved to reduce the risks of an accident. In which situation?
  6. A person is walking, riding or driving. Which tasks can be affected by risk factors?
  7. Which of the following conditions increase the risk of a road crash most?
  8. What is the effect of speeding, driving after drinking alcohol, driving when tired, and using the mobile phone while driving, in the reaction time?
  9. How is field of view affected by speed?
  10. Seat belts, airbags and helmets create conditions to:
  11. What kind of distraction is the most dangerous?
  12. Which of the following sentences is correct?
  13. Which of the following options shows the steps of a data-driven science study in a correct order?
  14. Which of the following sentences is correct in the context of a statistical study?

  A variable representing the percentage of correct answers was created to assess the knowledge.

- **Risk perception in traffic** – included 7 items with answer options in a 5-point Likert scale that assessed the risk perception as a car passenger, pedestrian, and cyclist – "What level of risk do you perceive in…" (Answer options: Likert scale from 1 = low risk to 5 = high risk):
  1. Travelling as a car passenger without wearing the seatbelt.
  2. As a pedestrian, using the mobile phone while crossing the road.
  3. As a pedestrian, crossing the road when the pedestrian light is red.
  4. As a pedestrian, crossing the road outside a crosswalk.
  5 Cycling without a helmet.
  6. Not respecting the traffic rules while cycling (e.g. don't stop when the traffic light is red or before the "STOP" sign).
  7. Using the mobile phone while cycling.

  A score resulting from the mean of the 7 items was used to assess the risk perception (score from 1 to 5 – the highest the score, the highest the risk perception).

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- **Intentions towards safe behaviours in traffic** – included 5 items in a 5-point Likert scale that assessed the intention of safe behaviour in the future as a car passenger, pedestrian, and cyclist – "Select the option that best reflects how true or false you consider each of the following statements." (Answer options: Likert scale from 1 = definitely false to 5 = definitively true):
    1. I will never use the mobile phone while crossing the road.
    2. I will never cross the road when the pedestrian light is red.
    3. I will always use the seat belt while travelling as a passenger in a car.
    4. I will always use the helmet while cycling.
    5. I will never use the mobile phone while cycling.

  A score resulting from the mean of the 5 items was used to assess the intentions towards safe behaviours (score from 1 to 5 – the highest the score, the highest the intention towards safe behaviours in traffic).

- **Self-declared behaviours as a pedestrian** – included 3 items in a 5-point Likert scale that assessed the self-declared risk behaviour as a pedestrian in the past 30 days – "During the last 30 days, how often did you…?" (Answer options: Likert scale from 1. never to 5. (almost) always):
    1. as a pedestrian, use the mobile phone while crossing the road.
    2. as a pedestrian, cross the road when the pedestrian light was red.
    3. as a pedestrian, cross the road outside a crosswalk, when there was a crosswalk nearby.

  A score resulting from the mean of the 3 items was used to assess the self-declared behaviours (score from 1 to 5 – the highest the score, the most frequent the behaviour).

The questions on risk perception, intentions, and self-declared behaviours were adapted from the E-Survey of Road users' Attitudes – ESRA (Meesmann et al., 2022).

Only the students who answered both pre-scenario and post-scenario questionnaires were included in the analysis (paired samples): 15 in the PAFSE Group and 14 in the Control Group. A Mixed ANOVA with interaction between the group (PAFSE vs. Control) and the phase (paired samples: pre-scenario vs. post-scenario) was used to assess the effect of the scenario. The interaction term group*phase was used to assess if the evolution pre-post scenario differed significantly between the groups. Paired Student's t-test was used for the comparison pre-post scenario within each group. A significant level of 5% was considered.

RESULTS

The sample included 29 9th grade students, aged 14-15 years old, who answered both pre-scenario and post-scenario questionnaires: 15 students who participated in the educational scenario (PAFSE Group) and 14 students who did not participate in the scenario (Control Group). The distribution by gender was similar in both groups ($p = 0.682$): 66.7% females and 33.3% males in the PAFSE Group; 64.3% females and 35.7% males in the Control Group.

The results of the effect of the educational scenario in the knowledge, risk perception in traffic, intentions towards safe behaviours in traffic, and self-declared risky behaviours as a pedestrian are presented in Table 1 and figures 1 to 4.

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Table 1. Scores of the domains assessed in the PAFSE and Control groups, pre- and post-scenario.

Variable	Group	N	Pre-scenario		Post-scenario		Student's t-test (pre-post) *p-value*	Interaction time * group *p-value*
			Mean	SD	**Mean**	SD		
Knowledge	PAFSE	15	36.19	12.21	57.62	12.51	***p < 0.001***	***p = 0.009***
	CONTROL	14	31.63	12.75	36.73	16.30	*p = 0.146*	
Risk perception in traffic	PAFSE	15	3.51	0.49	3.84	0.53	***p = 0.021***	***p = 0.046***
	CONTROL	14	3.66	0.40	3.62	0.45	*p = 0.740*	
Intentions towards safe behaviours in traffic	PAFSE	15	3.24	0.59	3.64	0.58	***p = 0.005***	***p = 0.032***
	CONTROL	14	2.99	1.06	2.76	0.62	*p = 0.392*	
Self-declared risky behaviours as a pedestrian	PAFSE	15	3.00	0.38	2.71	0.54	***p = 0.024***	*p = 0.169*
	CONTROL	14	3.05	0.63	3.02	0.61	*p = 0.880*	

The mean score of knowledge increased significantly in the PAFSE Group (from 36.19 to 57.62, p < 0.001) and did not change in the Control Group (from 31.63 to 36.73, p = 0.146). The interaction term was significant (p = 0.009), showing a significant improvement in the PAFSE Group, when compared to the Control Group (Table 1 and Figure 1).

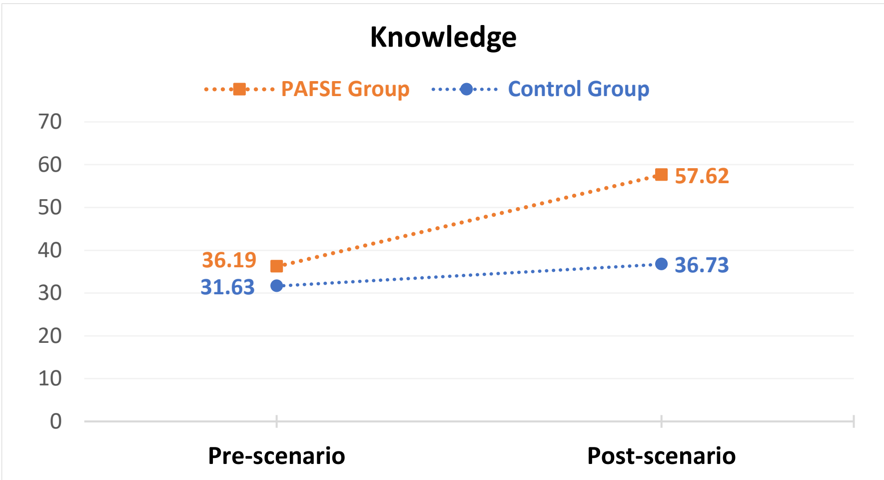

Figure 1. Mean scores of the domain "knowledge" in the PAFSE and Control groups, pre- and post-scenario.

The scenario also increased the risk perception of unsafe behaviours in traffic in the students who participated in the educational scenario, when compared to the other students (interaction: p = 0.046): the mean score increased from 3.51 to 3.84 in the PAFSE Group (p = 0.021) and did not change significantly in the Control Group (p = 0.740) (Table 1 and Figure 2).

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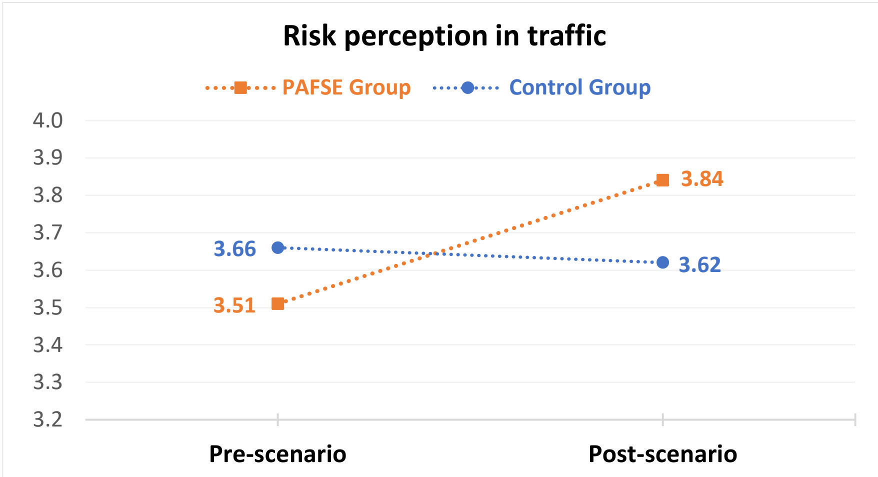

Figure 2. Mean scores of the domain “risk perception in traffic” in the PAFSE and Control groups, pre- and post-scenario.

The educational scenario also had a positive effect in the intentions towards safe behaviours in traffic (interaction: p = 0.032): the mean score increased from 3.24 to 3.64 in the PAFSE Group (p = 0.005) and did not change significantly in the Control Group (p = 0.392) (Table 1 and Figure 3).

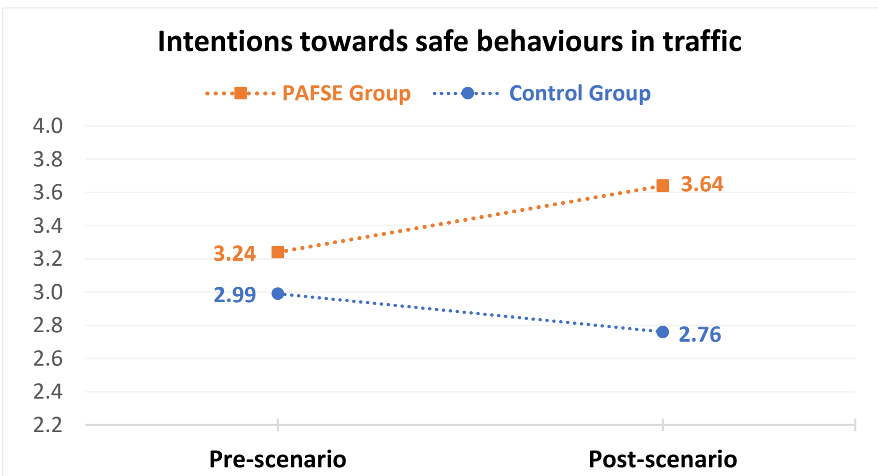

Figure 3. Mean scores of the domain “intentions towards safe behaviours in traffic” in the PAFSE and Control groups, pre- and post-scenario.

As for the self-declared risky behaviours as a pedestrian, results show a significant decrease in the prevalence of the behaviours in the students who participated in the educational scenario (from 3.00 to 2.71, p = 0.024), while there were no significant changes in the other students (p = 0.880). However, the interaction term was not statistically significant (p = 0.169), indicating that the differences pre-post scenario did not differ significantly between the two groups (Table 1 and Figure 4).

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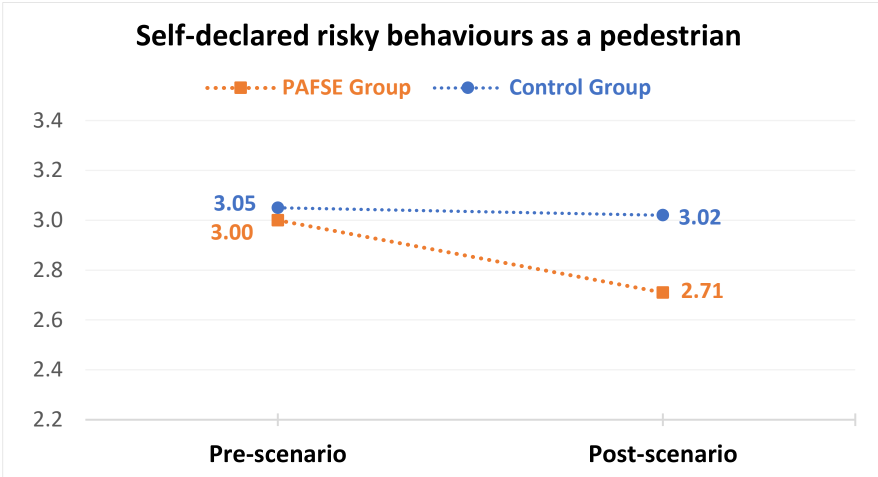

Figure 4. Mean scores of the domain "self-declared risky behaviours as a pedestrian" in the PAFSE and Control groups, pre- and post-scenario.

DISCUSSION AND CONCLUSIONS

Results have shown that the involvement in the educational scenario and in the research data-driven science project increased the knowledge related to road safety, increased the risk perception of unsafe behaviours in traffic; increased the intention of safe behaviours in traffic in the future; and decreased the frequency of unsafe self-declared behaviours in traffic as a pedestrian.

The active participation in both the educational scenario and the research data-driven science project proved to be a rich experience with extensive benefits, promoting a multi-dimensional impact on students' development. Primarily, the engagement significantly contributed to improving awareness of risky behaviours in traffic, leading students to become aware of potential dangers and challenges associated with their participation in the road environment. This increased awareness forms the basis for a safety-minded culture in traffic, emphasizing the importance of adopting responsible and safe behaviours on the road. Through these immersive experiences, students not only understood individual risks but also actively contributed to the collaborative effort of promoting safer behaviours within their community. Furthermore, the educational initiative provided a unique platform for students to apply the knowledge and skills acquired in their academic disciplines to real-world contexts, establishing a robust link to their community. This hands-on experience enhanced their understanding of theoretical concepts and empowered them to make meaningful contributions to addressing tangible challenges in their local community.

The importance of project-based learning and open schooling in this context becomes evident, as these methodologies play an important role in developing essential skills in students. Through project-based learning, students develop critical thinking abilities by actively analyzing and solving real-world problems, such as identifying and addressing risky behaviours in traffic. Project-based learning, characterized by its emphasis on real-world problem-solving, critical thinking, and collaborative endeavors, proves to be an important methodology in preparing students for the challenges of the 21st century. As students engage in real-world problem-solving scenarios, they inherently develop skills such as adaptability, creativity, collaboration, and communication – skills that are indispensable to deal with the complexities of the contemporary world. The integration of these skills goes beyond the immediate context of road safety, preparing students for a future where the ability to think critically, solve problems, and collaborate effectively is invaluable. Students were not passive recipients of information but active contributors to their own learning experience. They

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designed inquiries, collected, and analyzed data, and proposed interventions based on evidence. This active involvement transforms theoretical knowledge into practical skills, laying the foundation for a deeper understanding of the subject matter.

The incorporation of open schooling principles further enriches the educational landscape. Open schooling encourages collaborative learning, communication, and adaptability, aligning with the demands of the modern world. Students engage not only with the academic aspects of road safety but also with diverse stakeholders, including experts, local authorities, and community members during open schooling events. This dynamic interaction enhances their interpersonal and communication skills, fostering an important set of skills essential for their future. In the context of road safety, project-based learning became a vehicle for experiential learning.

In conclusion, the participation in the educational scenario and research data-driven science project contributed to a safety-minded culture in traffic. Students actively contributed to their community, applying academic knowledge to real-world contexts. This approach, emphasizing problem-solving and collaboration, develop in students' essential skills vital for the 21st century, including adaptability, creativity, and effective communication.

As for the educational scenario, after receiving feedback from teachers, students and participants in the open school event, amendments were done in order to improve the scenario enactment and its effect in contributing to a safety-minded culture in traffic in the community. Teachers mentioned that the number of hours estimated to develop all the planned activities was insufficient, which lead to the reformulation of the activities planned for the six lessons before the project planning. Furthermore, some of the digital learning objects provided were improved based on teacher's suggestions and student's feedback. Some participants in the open school event mentioned that the results of the research project should be more strongly disseminated in the community to promote safety-minded culture in traffic. Based on this feedback, the importance of the dissemination of the results and recommendations via social and conventional media was highlighted in the educational scenario.

RECOMMENDATIONS

It is strongly recommended to include comprehensive road safety education in school curricula. Recognizing the important role of traffic safety and mobility education in shaping attitudes and motivations toward risk awareness and personal safety, integrating it into the school curriculum is vital for cultivating a safety-minded culture. This inclusion aligns with an integrated approach to traffic safety, providing students with the knowledge and skills necessary to participate safely in traffic. Education serves as a powerful tool to positively influence behaviour patterns, contributing to safer road practices. The recommendation extends beyond the immediate goal of ensuring safer traffic practices – it addresses the broader societal impact of instilling a culture of safety. Integrating road safety into the school curriculum not only gives students practical knowledge but also shapes their attitudes and intrinsic motivations toward promoting safety for themselves and fellow road users.

To enhance the educational experience and better prepare scholars for the challenges of the 21st century, it is strongly recommended to incorporate project-based learning (PBL) into academic curricula. PBL serves as a dynamic method, allowing students to apply theoretical knowledge in practical, real-world situations. This approach not only deepens their understanding of academic concepts but also develops vital skills such as problem-solving, critical thinking, and collaboration.

Simultaneously, the promotion of open schooling initiatives is paramount. Open schooling establishes a more symbiotic relationship between educational institutions and their communities. By actively involving schools in community awareness, particularly in addressing public health

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issues like road safety, a heightened sense of responsibility and community participation can be instilled in students.

Moreover, the development of 21st-century skills must be emphasized within these educational approaches. Scholars need to possess adaptability, creativity, and effective communication skills to thrive in the rapidly evolving landscape of the modern world. These skills are not only pertinent to academic success but also essential for professional and personal growth.

As a comprehensive recommendation, education authorities and institutions should advocate for the widespread incorporation of experiential learning methods. This holistic approach ensures a more impactful educational journey, where students not only acquire academic knowledge but also practical skills and a heightened sense of community awareness.

In conclusion, active participation in community-driven initiatives should be actively encouraged. This enables schools to contribute not only to the academic development of students but also to the broader well-being of the community. By implementing these recommendations, educational institutions can create a learning environment that is not only academically enriching but also socially responsible and in line with the needs of the contemporary world.

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3.9. University of Cyprus (UCY) – Theoretical Contribution

Enhancing Public Health by Advancing Health Literacy and Health Education

Abstract
The emergence of the COVID-19 pandemic and the explosion of health misinformation and disinformation have highlighted the urgent need for a stronger and more coordinated global strategy to improve public health outcomes. Although public health authorities play a pivotal role in managing public health issues, individuals should also develop health literacy to address various health inequalities and challenges. This study aims to explore the relationships between public health, health education and health literacy, as well as to identify the main components and pedagogical learning approaches, strategies, and methods for effective health education programs that contribute to enhancing health literacy and health education, empfasizing public health. The results of this exploration indicate that health literacy is a social determinant of public health and an outcome of effective health education. Health literacy increases individuals' abilities to access, evaluate and use health information and services needed to make appropriate health decisions and maintain their health. In addition, the results show a dynamic relationship between individual abilities, environmental demands, contextual challenges, health literacy, health systems and public health. The main components of health education programs to enhance health literacy and health education are participants' involvement in all stages of health education programs' development, recognizing preventable health issues within the community through community intervention, implementation of a comprehensive, long-term, and integrated programs into the settings where people live. However, the results suggest that health education programs, which employ learner-centered, socio-constructivist approaches, open schooling learning methods, and inquiry- and project-based learning strategies, are likely to be more effective in fostering health literacy. The effectiveness of these programs also depends on the variety of teaching and learning methods used, which should be tailored to the needs of the learners and the content being taught.

Keywords: health education, health literacy, pedagogical learning approaches, public health, social determinants of public health.

1. Introduction

Health constitutes a fundamental and inviolable human right, as well as a prerequisite, indicator, and outcome of a sustainable society (European Union (EU), 2007). Despite considerable progress in the field of health over the past decades, serious challenges persist globally, which both nations and citizens are called upon to address. These challenges include chronic diseases (such as cardiovascular and metabolic conditions like diabetes and obesity), cancer, autoimmune diseases, mental health disorders, health inequalities, microbial resistance to antibiotics, negative effects of environmental pollution and climate change, epidemics, and pandemics caused by infectious diseases, tobacco use, alcohol, drug-related issues, incidents of violence, injuries, vaccine shortages, vaccinations hesitancy, and more.

Research indicates that health literacy contributes significantly to public health by fostering informed choices, preventive behaviours, effective communication, and equitable access to healthcare services (Coughlin, Vernon, Hatzigeorgiou, George, 2020). On the other hand, health education is a cornerstone for improving health literacy, enabling individuals to take charge of their well-being, and contribute to healthier communities (World Health Organization (WHO), 2012).

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Research evidence indicates that high or low literacy levels have different impacts, notably on the individual's health and the efficiency of the health system. People with higher health literacy levels demonstrate healthier behaviours, are more adherent to treatment, report less chronic illness, feel healthier, and live longer. Conversely, low health literacy is associated with reduced use of preventive services and management of chronic conditions, and higher mortality. It can also lead to problems such as medication errors, misdiagnosis due to poor communication between providers and patients, low rates of treatment adherence, hospital readmissions, and other related complications or conditions. Yet, low health literacy is considered as a key source of economic inefficiency in the healthcare system. In summary, addressing health literacy is crucial for improving patient outcomes and reducing healthcare costs. Ensuring that individuals can access, understand, and use health information effectively benefits both patients and the healthcare system (WHO, 2012; Nutbeam, 2000).

2. Aim and methods of the study

This study aims to explore the relationships between public health, health education, and health literacy. Additionally, we strive to identify the main components and pedagogical learning approaches, strategies, and methods that render health education programs effective. Our focus is on programs that have the potential to enhance health literacy and health education, emphasizing public health, and drawing insights from existing health behavior theories.

To achieve this aim, we analyse and synthesize theoretical and empirical perspectives from current educational research and practice. Our goal is to contribute to the development of a theoretical framework that can enhance public health by advancing health literacy and health education.

3. Theoretical Perspectives

3.1. Public Health

The WHO defines health not simply as the absence of disease or disability, but rather as a holistic state of complete physical, mental, and social well-being (WHO, 1948). This definition underpins the mandate of modern healthcare systems, tasked with guaranteeing the highest attainable level of health and well-being across all these dimensions for every citizen. Furthermore, the WHO (2013) emphasizes that addressing population health sustainably necessitates collective action within the realm of public health.

The term public health refers to the health of the population, involves the exercise of public policy, and is the responsibility of the state and the community (WHO, 2013). In 1920, Charles-Edward Amory Winslow (1877–1957), an American bacteriologist and expert in public health matters, formulated a more detailed definition of public health that remains relevant: "*Public health is the science and art of preventing disease, prolonging life, promoting physical health, and ensuring the efficiency of individuals through organized efforts of society for environmental sanitation, control of infectious diseases, education of each individual in personal hygiene, organization of medical and nursing services for early diagnosis and preventive treatment of diseases, and the development of a 'social machinery' that ensures each person a level of life adequate for the preservation of health*" (Winslow, 1920, p.30).

Research conducted within the EU reveals a consistent citizen prioritization of health above all other life aspects. This prioritization, however, coexists with growing concerns regarding widening health inequalities within the region. The catalytic role of health in fostering citizen participation in both social and economic

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spheres is easily identified. As a key driver of individual and communal well-being, happiness, and satisfaction, health exerts a noteworthy influence on both individual and societal levels (European Commission Joint Research Centre, 2017).

Nowadays, the novel approaches to public health include three main components of health: (i) Individual determinants of health, (ii) Social determinants of health; and (iii) Environmental determinants of health. These determinants all interact as part of a complex adaptive system of health (Bircher, & Kuruvilla,2014). The Individual determinants of health – individuals' biologically given and personally acquired potentials– are influenced by social and environmental determinants of health, including inequalities of resources and power and unhealthy environments (Bircher, & Kuruvilla,2014; Haines, Alleyne, Kickbusch, & Dora, 2012; Jamison et al., 2013). According to this approach *Health is a state of wellbeing emergent from conducive interactions between individuals' potentials, life's demands, and social and environmental determinants* (Bircher, & Kuruvilla, 2014).

Research evidence indicates a strong correlation between individual and community health and the social determinants of health (Baum, 2018; Wilkinson, & Marmot, 2003). According to the WHO, social determinants are 'the non-medical factors that influence health outcomes. They are the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life. These forces and systems include economic policies and systems, development agendas, social norms, social policies, and political systems' (Senate Standing Committees on Community Affairs, 2013; WHO, 2022).

The WHO (2022) lists the following as social determinants which can influence health equity in positive and/or negative ways:

- income and social protection
- education
- unemployment and job insecurity
- working life conditions
- food insecurity
- housing, basic amenities and the environment
- early childhood development
- social inclusion and non-discrimination
- structural conflict
- access to affordable health services of decent quality.

These factors interact, intersect, overlap and cluster together in their effects. Certain factors may also change independently of one another. They vary in their salience in different societies at various stages of economic development. While certain factors are always associated with disadvantage (e.g. poverty), others depend on context (e.g. occupation, ethnicity). Standards of social justice change over time and between cultures. What is considered just, or fair can vary significantly based on cultural norms, historical context, and societal values. Understanding their interplay is crucial for addressing societal challenges and promoting fairness and equity (Kelly, Morgan, Bonnefoy, Butt, & Bergman, 2007).

Specifically, people low on the social ladder are twice as likely to get sick and die young, compared to those at the top. This gap exists across society, not just between rich and poor. Even low-ranking middle-class workers have higher disease rates and earlier deaths than higher-ranking ones. The causes of this

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disparity are multifaceted, stemming from both material and psychosocial factors. Stress, bad jobs, poor housing, and other disadvantages pile up, hurting health over time. This can include limited family resources, poor education, job insecurity, unsafe or dead-end jobs, bad housing, family struggles, and low retirement income. The longer these disadvantages last, the worse the health effects (Wilkinson, & Marmot, 2003).

Within the EU, and indeed within individual member states, significant disparities in public health persist across diverse population groups. These disparities are demonstrably influenced by a complex interplay of social, economic, and environmental factors, with a consequential impact on both life expectancy and overall population health status (EU, 2022).

At a global level, disparities in public health are more profound. The Health Equity Report by the WHO (WHO, 2023) reveals that 90% of health inequalities can be attributed to factors such as economic insecurity, residence in poor-quality housing and neighbourhoods, social exclusion, lack of decent employment, poor working conditions, and inadequate education. To improve health outcomes, targeted interventions are needed. These could involve policy changes, community programs, or healthcare services. But these efforts should align with the specific social determinants of health challenges faced by each population. It is evident that due to the dynamic and multifaceted nature of social determinants of health, a differentiated and contextualised approach to their analysis and mitigation efforts is required (Wilkinson & Marmot, 2003).

The environmental determinants of health, based on the definition of environmental health, include: "… all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviours … targeted towards preventing disease and creating health-supportive environments (including clean air and water, healthy workplaces, safe houses, community spaces and roads and managing climate change). This definition excludes behaviour not related to environment, as well as behaviour related to the social and cultural environment, and genetics" (WHO, 2014).

Nowadays, the emergence of the COVID-19 pandemic, the major environmental challenges such as climate change, and the explosion of health misinformation have significantly disrupted decades of progress in global public health. This disruption has not only exacerbated existing health inequalities but also highlighted the urgent need for a stronger and more coordinated global strategy to improve public health outcomes. Although public health authorities play a pivotal role in managing public health issues, individuals should also develop health literacy through education to address various inequalities and challenges. Health literacy has a mediating role between education and health (Nutbeam, 2000; Zimmerman & Woolf, 2014).

3.2. Health literacy

The term health *literacy* has been defined, refined, and measured in a variety of ways over the years, responding to changing demands in an increasingly complex society. During the recent period of growing interest in health literacy as an integral part of health communication, advancements have been made in defining the term. While there is no consensus on its definition, recognizing its multifaceted nature is crucial. The field is expanding, involving diverse disciplines, larger and more interdisciplinary audience, and emphasizing complexity (Sørensen, Van den Broucke, Fullam, Doyle, Pelikan, et al. 2012).

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In the past, most health literacy definitions have focused on the abilities required by individuals to access and understand health information, enabling them to take informed actions. For instance, in 1998, the WHO defined health literacy as “the cognitive and social skills that determine an individual’s motivation and ability to access, understand, and utilize information in ways that promote and maintain good health” (WHO, 1998, p. 10). Soon after, the American Medical Association (1999, p. 553) stated that patients with adequate health literacy can read, understand, and act on health care information. On the other hand, the definition of National Library of Medicine states that health literacy is “the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions” (Ratzan and Parker, 2000).

In 2004, the Institute of Medicine Committee on Health Literacy published a consensus study on health literacy, emphasizing that health literacy is a shared function of social and individual factors. Individuals' health literacy skills and abilities are mediated by their education, culture, and language. Equally important are the communication and assessment skills of the people with whom individuals interact regarding health, as well as the ability of the media, the marketplace, and government agencies to provide health information in a manner appropriate to the audience (Institute of Medicine, 2004).

Parker and Ratzan (2010) have proposed a health literacy framework that makes explicit the extent to which health literacy is mediated by the situational demands and complexities that are placed on people. This framework highlights the dynamic relationship between personal skills, environmental demands, and health literacy outcomes. The authors claim that by considering both individual capacities and contextual challenges, we can better address health literacy challenges in our communities (Parker & Ratzan, 2010).

Sørensen and colleagues (2012) conducted a content analysis of seventeen health literacy definitions. They observed that these definitions revolve around six primary concepts: (Sørensen, Van den Broucke, Fullam, Doyle, Pelikan, et al., 2012).

- Competence, skills, and abilities
- Actions
- Information and resources
- Objective—what health literacy should empower someone to do
- Context—the setting in which health literacy is relevant
- Time—the period during which health literacy is needed or developed.

Based on this analysis, the authors propose the following “comprehensive” definition for health literacy (Sørensen et al., 2012, p. 3): “Health literacy is the combination of an individual’s competencies, skills, and abilities to access, understand, appraise, and apply health information within the context of health care, disease prevention, and health promotion. It encompasses the ability to critically analyse information, make informed decisions, and actively take part in health-related activities.” The authors build upon this definition to propose a conceptual model that encompasses both the “antecedents” (such as age, education, socioeconomic status, culture, and societal systems) and the “consequences” (including risks to patient safety, poorer health outcomes, and health costs) of health literacy (National Academies of Sciences, Engineering, and Medicine. 2016).

Rudd et al. (2012, p. 26) argue that a more comprehensive definition of health literacy should “include both the abilities of individuals and the characteristics of professionals and institutions that either support or hinder individual or community action.” Unlike earlier definitions that primarily focused on personal decision-making and action, this updated definition also acknowledges individuals’ ability to engage in

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health-related civic matters. Koh and Rudd (2015, p. 1226) emphasize that the "arc of health literacy bends toward population health," highlighting the importance of considering social organizations and systems alongside individual abilities. Such definitions highlight the complexity of health literacy, describing that it is multidimensional and operates across diverse settings and mediums (Pleasant et al., 2016, p. 1). According to Pleasant et al., (2016), the components of a new, more comprehensive definition should reflect these complexities, focusing on the promotion and maintenance of good health—for individuals, communities, and societies. According to this framework, health literacy refers to the ability to make sound health decisions in the context of everyday life – at home, in the community, at the workplace, in the healthcare system, in the marketplace, and in the political arena (Pleasant et al., 2016, p. 1).

Consequently, health literacy is a social determinant of health, and it is based on the interaction of individuals' skills with health contexts, the health-care system, the education system, the environmental context, and broad social and cultural factors at home, at work, in the community and the society.

3.3. Critical health literacy

The literature review identifies three progressive levels of health literacy: Functional Health Literacy, Interactive Health Literacy, and Critical Health Literacy (Levin-Zamir & Peterburg, 2001).

Functional Health Literacy: basic skills and understanding.

Individuals have basic skills, and they can obtain relevant health information (like understanding health risks or using the health system). These skills help them follow clear instructions, like taking medications correctly or participating in preventive activities.

Interactive Health Literacy: developing skills in a supporting environment.

Individuals can extract meaning from different forms of health communication, and they apply health information to changing situations and engage with others. For example, they might use mobile apps or interactive websites for health-related decisions.

Critical Health Literacy: advanced critically thinking skills.

Individuals have most advanced skills. They can critically analyse information from various sources, and they understand social, economic, and environmental factors affecting health. Critical health literacy empowers people to take control over their health and advocate for change.

Interactive and critical health literacy align perfectly with today's focus on health promotion and consumer engagement. In this context, health literacy becomes a personal and societal asset, empowering individuals, and communities to take control of their health decisions. (Mårtensson & Hensing, 2012; Nutbeam, 2008; Pleasant & Kuruvilla, 2008; National Academies of Sciences, Engineering, and Medicine, 2016).

The term critical health literacy, as a fundamental concept for public health, points to the importance of critical thinking for health literacy (Nutbeam, 2000). It refers to the combination of high-level cognitive abilities and social skills for critically analyzing and evaluating health information. These skills can then be used to address various health challenges. Today, this term has evolved, placing particular emphasis on public health, social determinants of health, empowerment, citizen participation, and the interconnectedness between health and society (Abel & McQueen, 2020; Chinn, 2011; Mogford et al., 2011).

The development of critical health literacy is especially urgent in our current era. On one hand, the flow of information is vast and continuous. On the other hand, misinformation, misinterpretation, and rejection of

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scientific evidence due to lack of scientific expertise are particularly pronounced (Barzilai & Chinn, 2020; Herman et al., 2022; Kienhues et al., 2020). Given these characteristics, our time has been characterized as the post-truth era, where communication in the public sphere is increasingly subject to various forms of misinformation and targeted disinformation. This situation poses risks to democracy and public health (Barzilai & Chinn, 2020; European Commission, 2018; Newman et al., 2017).

Misinformation refers to partially or entirely false information that does not necessarily reflect an intention to deceive. On the other hand, disinformation consists of inaccurate information intentionally shared to manipulate or harm (Wardle & Derakhshan, 2017). People are often exposed to targeted misinformation (Allcott & Gentzkow, 2017; European Commission, 2018), particularly related to public health issues such as vaccine safety, human-induced climate change, water fluoridation, and more (Kavanagh & Rich, 2018).

Continuous exposure to misinformation and/or disinformation makes individuals unwittingly more vulnerable to manipulation and authoritarianism, without engaging in investigating and evaluating issues that concern them (Herman et al., 2022; McIntyre, 2018). This puts their own health and public health at risk. Additionally, numerous studies indicate that people tend to prioritize their personal beliefs, emotions, and experiences over facts, scientific evidence, and expert knowledge. There is also a decline in trust in institutional providers of scientific information, including science and scientists, which undermines the ability to acquire accurate knowledge and address health challenges and inequalities (Funk et al., 2019; Kavanagh & Rich, 2018).

While none of these phenomena are historically new, their current extent and intensity appear more extreme than in the past due to social, political, technological, and psychological factors. Consequently, education plays a crucial role in promoting health literacy and protecting citizens from misinformation, disinformation, pseudoscience, and hesitancy toward evidence-based practices (Kavanagh & Rich, 2018).

Ensuring that people understand health information and navigate health systems effectively, can potentially create a more fair and healthier society. (Stormacq, Van den Broucke, Wosinski, 2019). As underlined by Nutbeam (2000), critical health literacy, reflects the cognitive and skills development outcomes, that are oriented towards supporting effective social and political action rather than individual action. Within critical health education paradigm, health education may involve the communication of information and development of skills that investigate the political feasibility and organizational possibilities of various forms of action to address social, economic, and environmental determinants of health. Education programmes in this case would be directed towards improving individual and community capacity to act on these social and economic determinants of health (Nutbeam, 2000).

Based on the above definitions of health literacy, it is influenced or formed by four key areas: Culture and society, the health system, environmental context, and the education system. Culture and society include factors like beliefs, language, education levels, and access to resources, which can all influence how people understand and interact with health information. The health system refers to the way healthcare is delivered, from the communication styles to appointment scheduling, which can either support or hinder people's ability to navigate the system effectively. Environment has a huge importance because it is recognized that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are intricately linked and interdependent (WHO, 2023). The education system plays a key role as strong foundational literacy skills and health education in schools equip individuals with the

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tools they need to understand health information throughout their lives, and address challenges and inequalities in public health.

On the other hand, the impact of health literacy is multifield: it enables the individual to understand information about his/her health; it enables a person to make informed decisions and act independently based on his/her knowledge and skills; finally, it allows a person to reflect about and explore alternative health-related options. Furthermore, health literacy could serve as a variable that impacts the connection between adverse social and economic circumstances and subsequent negative health outcomes. Unlike other social and economic factors, health literacy is more readily amenable to change. Strengthening health literacy within the population and enhancing accessibility to health services for individuals with low health literacy may prove to be a practical strategy for reducing disparities, promoting greater equity in health, and improving overall access to healthcare" (Allmendinger & von den Driesch, 2014).

3.4. Health literacy and Health Education

Health education is a social science that draws from the biological, environmental, psychological, physical, and medical sciences. The WHO characterizes health education as a blend of learning encounters aimed at enhancing health for both individuals and communities. This is achieved by expanding knowledge and shaping attitudes. Recognizing that knowledge alone might not suffice to drive change, health education also focuses on strengthening skills to positively affect health behaviours at both individual and community levels (Baumann & Karel, 2013; The Coalition of National Health Education Organizations, 2009; WHO, 2011).

The main goals of health education are (The Coalition of National Health Education Organizations, 2009):
• to improve the health status of individuals, families, communities, states, and the nation
• to enhance the quality of life for all people
• to influence the health behaviour of individuals and communities as well as the living and working conditions that influence their health
• to reduce premature deaths and to prevent diseases and disabilities
• to focus on prevention and reduce the costs (both financial and human) that individuals, employers, families, insurance companies, medical facilities, communities, the state, and the nation would spend on medical treatment.

Health education has physical, psychological, and social dimensions and involves: (I) Motivating, building skills, and boosting confidence (self-efficacy) to act for better health. (II) Communicating information about the social, economic, and environmental factors affecting health. (III) Addressing individual risk factors and behaviours, as well as understanding how to use the healthcare system. Health education aims not only to increase knowledge about personal health behaviours but also to develop values and skills to tackle social, economic, and environmental determinants of health (O'Byrne, 2011).

Numerous studies indicate that individuals with lower educational levels face a higher risk of developing specific diseases compared to those with higher educational attainment. Despite education seems the most straightforward of the socioeconomic variables, it is highly interactive with other variables like income, occupation, gender, age and place of residence. A higher income family will assure its children a higher level of education, which in turn will affect the child's income once he/she becomes an adult (Campbell, 2001; Green & Kreuter, 1991; Rimer, Glanz & Rasband, 2011; Tones, 1997).

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Health education and health literacy are intricately linked, with health education aiming to improve health literacy as a key outcome of health policies and interventions (Levin-Zamir & Peterburg 2001; Nutbeam, 2000). However, despite the growing body of research on health literacy, there is insufficient attention given to educational interventions aimed at enhancing it. More effective strategies to close this gap and foster improved health outcomes for all are required (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011; Ha, Bonner, Clark, Ramsbotham, & Hines, 2016; Nutbeam, McGill, & Premkumar, 2018; Visscher, Steunenberg, Heijmans, Hofstede, Devillé, et al., 2018).

3.4. Main components of effective health education programs

While various educational interventions which aiming to enhance critical health literacy and public health are successful, there are also many which fall short of their goals. Research indicates that educational interventions most likely to achieve desired outcomes are grounded in a thorough comprehension of specific health behaviours and the environmental context in which they take place. Health education practitioners seeking assistance in designing, implementing, and assessing these interventions can refer to various planning models rooted in health behaviour theories. There are many health behaviour theories that have been developed. The best theory to use for a particular intervention will depend on the specific behaviour being targeted and the population being studied (WHO, 2012).

The health behaviour theory should be logical, consistent with everyday observations, like those used in previous successful programmes, supported by past research in the same area or related ideas (Glanz, Rimer, & Lewis, 2002; Institute of Medicine, National Academies Press, 2002; Rimer, & Glanz, 2005). Health behaviour theories consider numerous factors that influence behaviour determinants. These factors encompass individual aspects (such as thoughts, feelings, and beliefs), group dynamics, and organizational and community elements (including structures, regulations, policies, and laws) (Siepmann, 2008). Each theory provides a unique lens for understanding health behaviour, and their application depends on the specific context and population being addressed (Prochaska, Redding, & Evers, 2008).

Researchers and practitioners use theories to investigate answers to the questions of “why,” “what,” and “how” health issues should be addressed (Rimer, & Glanz, 2005). Some prominent health behaviour theories that are often used in public health interventions are the following (Prochaska, Redding, & Evers, 2008):

Health Belief Model (HBM): This theory focuses on individuals’ perceptions of health threats, benefits of acting, and barriers to change. It assumes that people are more likely to engage in health-promoting behaviours if they believe they are susceptible to a health problem, perceive the benefits of preventive actions, and perceive minimal barriers.

Transtheoretical Model (TTM) (Stages of Change): The TTM proposes that behaviour change occurs in stages—precontemplation, contemplation, preparation, action, and maintenance. It emphasizes tailoring interventions based on an individual’s readiness to change.

Social Cognitive Theory (SCT): The SCT emphasizes the role of social influences, self-efficacy, and observational learning. It posits that behaviour change is influenced by personal factors, environmental factors, and behavioural outcomes.

Social Ecological Model: This model recognizes that health behaviours are shaped by multiple levels of influence, including individual, interpersonal, community, and societal factors. It emphasizes the interconnectedness of these levels and their impact on behaviour.

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Other relevant theories include the *Theory of Reasoned Action/Theory of Planned Behaviour* (TRA/TPB), which considers attitudes, subjective norms, and perceived behavioural control; and theories related to social support and social networks.

Consequently, the recommended educational programs to improve health literacy should be Community-Based Health Education Programs, which are based on specific health behaviour theories. In the literature, reference is made to various components for effective community-based health education programs such as the following:
1. *Community Assessment and Engagement*: underlines that understanding the specific needs, resources, and cultural context of the target community is crucial. This component is based on a Social Ecological Model which acknowledges the influence of multiple levels (individual, interpersonal, community, societal) on behaviour (Israel, Schulz, Parker, & Becker, 2015).
2. *Culturally Tailored Interventions*: involve crafting messages and approaches that resonate deeply with the target community's unique cultural values, beliefs, and preferred communication styles. This component is based on a Health Belief Model which highlights the role of perceived susceptibility, severity, and barriers in behaviour change. Transtheoretical Model emphasizes stages of change and tailoring interventions accordingly (Glanz, Rimer, & Viswanath, 2008).
3. *Collaboration and Partnerships:* involve community members, local organizations, and healthcare providers and increase sustainability, and resource mobilization. Community members should be involved in all phases of a programme's development: identifying community needs, enlisting the aid of community organizations, planning, and implementing programme activities and evaluating results. This component is based on a Diffusion of Innovations Theory which suggests influential individuals and channels that increase the uptake of health literacy initiatives (Green, & Kreuter, 2009).
4. *Interactive and Empowering Activities:* Programs should go beyond lectures and encourage active participation, skill development, and problem-solving. This component is based on a Social Cognitive Theory which emphasizes self-efficacy and outcome expectations in behaviour change. Empowerment Theory focuses on building communities' capacity to act (Bandura, 2004).
5. *Evaluation and Dissemination:* focusing in regularly assessing program effectiveness and impact which allows for adaptation and sharing successes with others (Glasgow, Vogt, & Boles, 1999).

3.4.2. Teaching and learning approaches, methods, and strategies for health education programs:
Health literacy can be greatly promoted in science courses through targeted strategies and pedagogical approaches and methods such as (https://pafse.eu/):
Learner-centred approaches to learning, focusing on the needs and interests of the learner and emphasizing the importance of active learning, collaboration, and critical thinking.

Socio-constructivist approaches to learning: socio-constructivist approaches to learning emphasizing the importance of social interaction and collaboration in learning, viewing learning as a process of social construction, in which learners actively construct their own knowledge in collaboration with other community members.

Pedagogical model of Open Education or Open Schooling: within the framework of this pedagogical approach, students are active in the wider community beyond the physical boundaries of the school unit, seeking cooperation with various stakeholders (e.g. family, local community/organizations, universities, and industries). Open Schooling emphasizes the importance of collaboration between schools and the wider community. This can take many forms, such as students working on projects with local businesses

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or organizations, or schools hosting community events. Open Schooling is a student-centred approach to learning. This means that students are encouraged to take ownership of their own learning and to pursue their own interests. Open Schooling provides students with opportunities to learn in real-world contexts. This can involve students working on projects that address real-world problems, or students taking part in internships or apprenticeships. (The Open Schooling Navigator: https://openschoolingnavigator.eu/; The National Institute of Open Schooling (NIOS): https://nios.ac.in/). Furthermore, open schooling projects and initiatives promote the knowledge, practices, visions, attitudes, resources, and values of all stakeholders. It emphasizes critical thinking, sustainability, fairness, and making sure everyone feels included. It's a team effort, and students and parents become active participants in the learning process (European Commission, 2017; 2022; Li et al, 2020).

One Health approach: According to the WHO (2023), the One Health approach is of huge importance because it recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. By linking humans, animals and the environment, One Health can help to address the full spectrum of disease control – from prevention to detection, preparedness, response, and management – and contribute to global health security. The approach can be applied at the community, subnational, national, regional, and global levels, and relies on shared and effective governance, communication, collaboration, and coordination. The COVID-19 pandemic put a spotlight on the need for a global framework for improved surveillance and a more holistic, integrated system. Gaps in One Health knowledge, prevention and integrated approaches were seen as key drivers of the pandemic. By addressing the linkages between human, animal and environmental health, One Health is seen as a transformative approach to improved global health. Having the One Health approach in place makes it easier for people to better understand the co-benefits, risks, trade-offs, and opportunities to advance equitable and holistic solutions. Using One Health approach by negotiating several factors that determine human health and the inherent relationship between human health and other living organisms on our planet, as well as their environment.

Concerning strategies and teaching methods, a variety of strategies and teaching and learning methods can be used. The most effective teaching and learning methods and strategies will vary depending on the needs of the learners and the content being taught. Examples of teaching and learning methods and strategies are:

- Using controversial *socio-scientific issues* (SSIs) and phenomena related to human health (Baytelman et al., 2018; 2020; 2022; Zeidler, 2016; Zeidler et al., 2019).
- Using *inquiry-and project-based teaching and learning* (Pedaste et al., 2015; Sandoval, 2005)
- Promoting the nature of science, the possibilities, and limitations of science in addressing public health problems, and the role of consensus in science. Activities like Modelling, Argumentation about controversial socio-scientific issues, can help students to develop an appreciation for the scientific process and to understand the role of science in society (Baytelman, 2015; Baytelman & Constantinou, 2017; Baytelman et al., 2020; 2022).
- Negotiating the relationship between health and society.
- Using strategies for evaluating the reliability of information on public health issues, as well as for addressing misinformation and denial of established scientific claims.
- Using actions and collaborations between school and community.
- Using of multiple intervention channels (e.g., workshops, media campaigns, social support groups) to reach diverse populations.

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- Addressing social determinants of health (e.g., poverty, access to healthcare) for more equitable outcomes.
- Fostering long-term sustainability through capacity building and community ownership.
- Understanding all Health Dimensions: physical, emotional, and social health dimensions.

The above pedagogical approaches, methods and strategies are part of the pedagogical framework of the European Research Programme *Partnerships for Science Education* (PAFSE), which aims to raise awareness and prepare the public to address future epidemics and other public health risks and challenges, as well as to support efforts to achieve the sustainable development goals.

Three prerequisites for effective health education and the promotion of health literacy are:
1. *Strengthening the professional development of educators*
Providing resources and training to educators for the effective implementation of learner-centred and socio-constructivist approaches. This could include workshops, online courses, and mentoring programs focused on public health education strategies.
Fostering teacher leadership: Encouraging teachers to actively participate in the design and adaptation of health education materials and programs to fit the needs of their students and communities.
2. *Developing engaging resources*
Creating culturally relevant materials: Designing lesson plans, activities, and multimedia resources that resonate with students' diverse backgrounds and experiences.
Strategically integrating technology: Utilizing digital tools and interactive platforms to promote active learning, collaboration, and critical thinking in health education.
Focusing on accessibility: Designing materials that are inclusive and accessible to all students, regardless of learning style or ability.
3. *Planning, needs and resources assessment*
Planning involves identifying the health problems in the community that are preventable through community intervention, formulating goals, identifying target behaviour and environmental characteristics that will be the focus of the intervention efforts, deciding how stakeholders will be involved and building a cohesive planning group.

Prior to implementing a health education initiative, attention needs to be given to identifying the health needs and capacities of the community and the resources that are available.

4. Conclusions

In this paper, we explored the relationships between public health, health education, and health literacy, aiming to enhance public health by advancing health literacy and health education. To achieve this aim, we analyzed and synthesized theoretical and empirical perspectives from existing educational research and practice.

Our exploration indicates health education, health literacy and public health are closely linked, with health education aiming to improve health literacy and public health outcomes. Individuals' health literacy knowledge, skills and abilities are influenced by the nested contexts of communities and societies. Social and environmental determinants play a crucial role in shaping an individual's health literacy development and promotion of public health. Additional, research evidence shows a link between health literacy and prevention of diseases (Simmons et al., 2017), following treatment plans and actively participating in health care decisions (Fleary & Ettienne, 2018). Furthermore, research shows that improving health literacy can

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lead to positive behaviour changes, ultimately reducing the burden of disease (Miller, 2016). Even greater progress is possible by connecting health literacy efforts with established theories about how people change their behaviour (Walters et al., 2020).

To empower students' health literacy, it is essential to recognize that students living in unequal social and environmental conditions require tailored and diverse health literacy opportunities. These opportunities should ensure that health education is accessible to all students, empowering them to interact effectively with health-related information within the complex societal and environmental framework, and participate in informed and quality decision making. To address this issue, it is crucial to examine the social structures and environmental determinants of public health within each community. Additionally, considering the unique potential of each student, we should create tailored health literacy opportunities. This involves implementing effective pedagogical learning approaches, strategies, and methods in health education programs, that promote student-centred learning, inquiry- and project-based learning and an open schooling learning approach. By doing so, we can promote individual and community health while enhancing the efficiency of the health system. Figure 1 below shows the relationships between the variables related to public health outcomes as derived from this study.

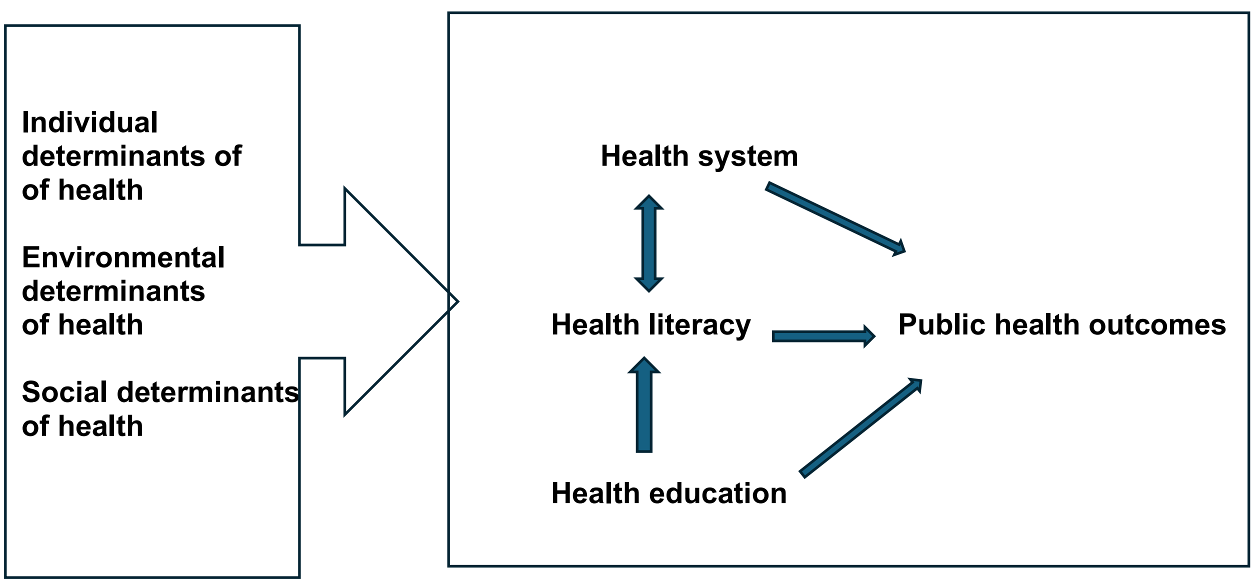

Figure 1: Relationships between the variables related to public health outcomes.

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3.10. University of Cyprus (UCY) – Theoretical Contribution

Using Controversial Public Health Socio-scientific Issues in Health Education in a Post-Truth Era: Theory, Research and Practice

Abstract

Socio-scientific issues (SSIs) are complex socially relevant, real-world problems that are informed by science and often are controversial. Research evidence indicates that learning science in the context of socio-scientific issues can promote scientific literacy that links science to everyday life and society. In this paper, we explore the use of controversial public health socio-scientific issues in health education. Specifically, this paper attempts to answer the following research question: *In what ways the use of controversial public health socio-scientific issues in educational settings can promote critical health literacy and health education in a post-Truth Era?* To address this question, we analyse and synthesize the theoretical and empirical perspectives emerging from the existing educational research and practice. We emphasize on public health education, which uses science education as a vehicle to provide citizens the knowledge, skills, attitudes, behaviours, and values necessary to make informed decisions about public health challenges in the context of controversial socio-scientific issues, particularly in our post-Truth Era.

Keywords: Controversial public health Socio-scientific issues, critical health literacy, health literacy, health education, post-Truth Era.

1. Introduction

Research indicates that schools play a crucial role in promoting health literacy (St. Leger, 2000; St Leger & Nutbeam, 1999; St Leger & Nutbeam, 2000), which is particularly important for health education, health, and well-being (WHO-EURO, 2021) for individuals, communities, and societies.

Health literacy refers to the capability to obtain, comprehend, and apply information to enhance personal and community health through lifestyle modifications and improved living conditions. Recent interpretations include the critical evaluation of health information and critical thinking about health assertions as fundamental elements of the health literacy framework. This is also mirrored in the concept of critical health literacy (Nutbeam, 2000; Paakkari & Paakkari, 2012; WHO-EURO, 2021).

Specifically, the literature review identifies three progressive levels of health literacy: Functional Health Literacy, Interactive Health Literacy, and Critical Health Literacy (Levin-Zamir & Peterburg, 2001; Nutbeam, 2000).

Functional Health Literacy refers to an individual's ability to understand and apply health-related information in practical situations. It encompasses skills such as following medication instructions accurately, participating in preventive health activities, and effectively using the local health system.

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Interactive Health Literacy means that individuals can engage with health information and can extract meaning and apply health information to changing situations and engage with others.

Critical Health Literacy means that individuals have most advanced thinking skills. They can critically analyse information from various sources, and they understand social, economic, and environmental factors affecting health. Critical health literacy empowers people to take control over their health and advocate for change. Critical health literacy is an important dimension of health literacy beyond fundamental literacy and comprehension skills in health contexts. It includes quite useful notions and skills for a health literate citizen in modern society. Critical health literacy consists mainly of the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular, the notion of social determinants of health), and the participation in civic collective actions for the promotion of health (Nutbeam, 2000; WHO-EURO, 2021).

Higher health literacy levels empower individuals by enabling greater autonomy and control over their health. Progression depends on cognitive development, exposure to diverse health information, critical evaluation of health information and critical thinking, as well as individual responses mediated by personal skills and self-efficacy (Nutbeam, 2000).

On the other hand, WHO defines health literacy "as the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health. Furthermore, Organisation for Economic Co-operation and Development report (OECD report, 2018) *The Future of Education and Skills 2030* named health literacy as a core competence for the 21st century and a critical target for education in order to empower citizens increasing their control over their own health and their community.

Yet, research findings indicate that enhancing critical health literacy in schools can boost students' learning, health, and lifelong learning abilities. It equips them to tackle health issues effectively (Okan, Kirchhoff, & Bauer, 2020). For instance, critical health literacy promotes students' understanding of the risks of viruses like coronavirus, how to protect themselves and others from epidemics and pandemics and cope with public health measures.

In general, strengthening health literacy and providing systemic support at all levels will improve health and foster educational, social, and sustainable development. According to WHO-EURO (2021) "*Investment in the health and well-being of children and adolescents through improved health literacy is a core public health issue and should be embedded in health promotion and prevention strategies. Addressing the health literacy of children and adolescents from an early age onwards will benefit their present health, their later adult health, and the health of the next generation."*

The role of schools in promoting critical health literacy is crucial because they are essential beneficiaries and implementers of health literacy initiatives. Students in educational settings benefit from health literacy education by gaining essential knowledge, skills, attitudes, behaviours, and values related to health, well-being, and diseases prevention. Schools have a unique opportunity to integrate critical health literacy into their curricula and create health-promoting environments (WHO-EURO, 2021).

By recognizing the role of schools and incorporating critical health literacy education, schools contribute to building a healthier society (Coughlin, Vernon, Hatzigeorgiou, George, 2020). In today's interconnected

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world, this is indispensable because there is growing concern over the widespread acceptance of misinformation and disinformation. Even, when robust evidence contradicts these beliefs, individuals often cling to them. This trend is worrying and has been called the "post-Truth Era" (Kavanagh & Rich, 2018; McIntyre, 2018; Osborn & Pimentel, 2023). According to Oxford English Dictionary (2016), post-Truth Era is a social moment "in which objective facts are less influential in shaping public opinion than appeals to emotion and personal belief.

Studies suggest that critical health literacy is influenced by both educational factors such as academic performance, literacy skills, and motivation to learn, as well as socioeconomic factors like family wealth, parental education, and profession. It has been observed that students from wealthier families tend to have higher health literacy levels (Okan, Kirchhoff, & Bauer, 2020). Therefore, it is imperative to explore how schools can empower young individuals with knowledge, skills, attitudes, behaviours, and values concerning health at the highest level in the current era, which is often associated with the rise of social media and the ease of sharing information, regardless of its accuracy.

In this paper, we explore that use of controversial public health socio-scientific issues related to public health (The term public health refers to the health of the population, involves the exercise of public policy, and is the responsibility of the state and the community. WHO, 2013) in educational settings, because they could potentially promote students' conceptual and epistemological understanding, enhance higher-order thinking skills and critical health literacy, develop moral sensitivity and both individual and societal responsibility concerning public health issues (Barzilai, & Chinn, 2020; Baytelman et al., 2020; 2022; Baytelman & Constantinou, 2017; 2018; Chinn et al., 2021; Herman et al., 2021; 2022; Sadler, 2004; Zeidler et al., 2013; 2019). The use of controversial public health socio-scientific issues which are characterized by non-obvious and uniquely accepted solutions and are susceptible to alternative approaches and proposals for resolution (Herman et al., 2022; Herman et al., 2024; Sadler, 2004) are essential because in the current era, around the world, people are increasingly willing to accept false information or disinformation/ misinformation, even when there's a lot of proof against it, and there are various uncertainties and risks, as well as public's lack of trust in science (Ha et al., 2024).

Specifically, this paper attempts to answer the following research question*: In what ways the use of controversial public health socio-scientific issues in educational settings can promote critical health literacy and health education in a post-Truth Era?* By doing so, we advocate for strengthening critical health literacy and health education in schools, giving emphasis on public health education.

2. Aim and methods of the study

The study aims to explore effective ways to use controversial health socio-scientific issues in educational settings emphasizing on public health education. The goal is to promote health education and critical health literacy. By emphasizing critical health literacy, it is indented to navigate the challenges posed by misinformation/ disinformation, risks and scientific uncertainties of our post-Truth Era.

To address the research question, we analyse and synthesize theoretical and empirical perspectives from existing educational research and practice. For this aim, an in-depth scientific literature analysis was conducted.

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Overall, this study seeks to contribute to professional development and community's understanding of effective pedagogical strategies and methods related to controversial health socio-scientific issues, in order to promote health education and critical health literacy and support students navigate this complex world by teaching them how to use science to understand the socio-scientific issues they face in their everyday lives and make appropriate use of science in social context. Additionally, the study can enrich the relevant literature and the comprehensive framework for the optimal integration of controversial socio-scientific issues in health education.

3. Theoretical Perspectives

3.1. Socio-scientific issues

Socio-scientific issues (SSIs) are defined as issues in which scientific, socio-economic-political, and ethical aspects coexist (Baytelman & Constantinou, 2017; Baytelman et al., 2020; 2022; Herman et al., 2022; Kolstø, 2001; Sadler, 2004), and for which conflicting scientific approaches and views are often articulated (Braten et al., 2011; Carliste et al., 2010; Herman et al., 2021; Hivon, et al., 2010; Kienhues et al., 2011; Sadler, 2004). Their potential to enhance formal science education and specifically scientific literacy is broadly acknowledged in both educational research and practice (Zeidler, Herman, & Sadler, 2019).

Various socio-scientific issues concern health issues and are controversial issues. They are typically characterized by non-obvious and uniquely accepted solutions and are susceptible to alternative approaches and proposals for resolution (Baytelman et al., 2018; 2020; 2022; Herman et al., 2022; Sadler, 2004). Examples of controversial public health socio-scientific issues are anthropogenic climate change, genetically modified products, vaccinations, water fluoridation, artificial tanning, euthanasia, stem cells, microbial antibiotic resistance, etc. (Baytelman et al., 2018; Herman et al., 2022; Sadler, 2004).

Yet, the controversial public health socio-scientific issues usually are value-laden issues and have moral dimensions. Fowler, Zeidler, and Sadler (2009) highlight the Four Component Model (Rest et al., 1974) as a valuable framework for examining value-laden issues and socio-scientific issues morality. In general, the Four Component Model can guide individuals in navigating moral dilemmas in their everyday lives. It helps them recognize moral issues, reason about them, commit to a course of action, and have the courage to carry it out. This model can be applied to value-laden public health socio-scientific issues in educational settings (Baytelman & Constantinou, 2017; Fowler, Zeidler & Sadler, 2009).

This model was developed by Rest and his team at the Centre for the Study of Ethical Development, who conducted comprehensive research on moral development. Their creation and validation of the Defining Issues Test (DIT) (Rest et al., 1974) significantly advanced the study of moral reasoning. Rest's Four Component Model, which was developed based on findings suggesting that moral reasoning does not necessarily determine moral behaviour, proposes four psychological processes that contribute to moral behaviour. The four components of Rest's model are (Baytelman & Constantinou, 2017; Fowler, Zeidler & Sadler, 2009):

- Moral Sensitivity refers to the ability to recognize moral aspects of a situation and anticipate the consequences of actions.

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- Moral Reasoning refers to the process of analysing a situation to determine the most morally desirable action and justifying it.
- Moral Commitment involves the recognition that personal interests may not always align with the moral course of action, and the willingness to prioritize moral concerns.
- Moral Courage is related to the strength to follow through with a moral course of action, even when faced with pressure to act otherwise. This is closely related to moral commitment.

Even though Fowler and Amiri (2004) concluded that science content knowledge alone did not increase moral sensitivity, Baytelman and Constantinou (2017) found that such content knowledge could promote the ability of students to recognize when a situation, such as a socio-scientific issue, contains a moral aspect and involves harm to another individual. In addition to science content knowledge, a series of other factors emerge as important dimensions of socio-scientific decision-making. These factors include emotions, misconceptions, personal experiences, family biases, the impact of popular culture (Fowler, Zeidler & Sadler, 2009; Sadler & Zeidler, 2004; 2005; Sadler, 2004), epistemic beliefs, which refer to individuals' beliefs about the nature of knowledge and the process of knowing (Baytelman & Constantinou, 2016a, 2016b; 2017), etc.

However, the use of controversial socio-scientific issues as a pedagogical framework (SSI framework) must be differentiated from simply discussing science concepts from a contentious perspective (Kinskey & Newton, 2024). The SSI framework goes beyond mere context for scientific content. It fosters the development of scientific literacy through a sociocultural approach, drawing upon the interplay of science, culture, and ethical considerations (Zeidler, 2014; Zeidler et al., 2014; Zeidler & Sadler, 2023; Zeidler et al., 2005). It addresses the normative factors which often neglected in traditional science education. These factors include moral motivations, personal values, epistemic beliefs, an ethic of care, and the broader social context that influences scientific understanding. Traditional approaches often prioritize scientific reasoning in isolation from these crucial influences (Baytelman, Iordanou, & Constantinou, 2018; 2020; 2022; Baytelman & Constantinou, 2017).

Furthermore, negotiating controversial socio-scientific issues is very complex because their socio-economic-political, ethical, and other aspects are just as important as their scientific evidence for decision-making, even when the scientific part of them is very well scientifically documented (Baytelman et al., 2020; 2022; Gilbert et al., 2011; Herman, 2015, 2018; Hodson, 2009; Sadler & Zeidler, 2005; Zeidler et al., 2005, 2013). Intense misinformation and disinformation, as well as denial of scientific evidence due to rejection or ignorance of scientific expertise, further complicate these discussions (Herman et al., 2015, 2018, 2022; 2024; Zeidler et al., 2013). Since these issues involve both science and society, social and ethical factors significantly influence how people view scientific information and, consequently, decision-making. Additionally, understanding probability and risk may be necessary (Sadler & Zeidler, 2005).

3.2. Negotiating controversial socio-scientific issues and Informal Reasoning

Given that the negotiation of controversial socio-scientific issues is often considered challenging due to their multidimensional nature, complexity, and uncertainty, various researchers highlight their association with thought processes tied to informal reasoning (IR), which is suggested as a framework for their negotiation (Baytelman, 2015; Baytelman & Constantinou, 2018; Sadler, 2004; Sadler & Zeidler, 2005a).

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Sadler and Zeidler (2005a) define IR as encompassing both cognitive and emotional processes used to address complex issues. IR guides the construction and evaluation of arguments, drawing not only on formal logic but also on factors like personal beliefs, values, intuition, and emotions.

Mainly, IR becomes crucial when information access is limited or problems are open-ended, complex, uncertain, or poorly defined – characteristics typical of controversial socio-scientific issues. Dual process theories (Evans, 2003, 2008) offer a cognitive explanation for IR. These theories posit two distinct thinking systems: System I (fast, intuitive) and System II (slow, analytical). System I operates based on existing knowledge, beliefs, and biases, while System II uses critical reflection and analytical thinking (Evans, 2003, 2008; Evans & Holmes, 2005). Both systems can independently or jointly influence informal reasoning (Evans, 2003, 2008).

System I relies on pre-existing cognitive structures, science understanding, personal beliefs, biases and emotional responses. System II depends on an individual's intelligence, working memory, focus, and ability to inhibit System I's influence (Evans, 2008; Berrouillet, 2011). Researchers (Evans & Stanovich, 2013; Kahneman, 2011) highlight the interaction between the two systems. System II does nott necessarily override System I's initial intuitions, but rather, may analyse them more deeply. Notably, even quick intuitive responses are often followed by attempts to justify them, revealing the interplay between encountered stimuli and existing cognitive structures (Kahneman, 2011).

The IR framework is useful to explore how to teach students to avoid judgment biases, and how to make policies that consider the judgment limitations of students and other individuals. For instance, judgment heuristics are used, often, when self-interest, existing beliefs, or uncertainty come into play. In these situations, students and others are more likely to rely on heuristics, which can sometimes lead to risky or poor decisions. Moreover, teachers can promote students' metacognitive competencies that allow students to inhibit reliance on heuristics or only experiential processing and use analytical thinking (Jacobs & Klaczynski, 2002).

Researchers like Kuhn (1992, 1993), Sadler & Zeidler (2005a, 2005b), Wu & Tsai (2011), and Zeidler (2004) propose that IR is expressed through constructing arguments and arguing. They believe that the ability to argue (argumentation skills) reflects and reveals the IR abilities. Sadler and Zeidler (2004) clarify this distinction. They point out that while arguments express IR (as noted by Driver et al., 2000), they are not the same thing. IR is the mental and emotional process we use to grapple with complex issues and form or adopt a position. Argumentation, on the other hand, is the act of expressing that reasoning.

Research suggests correlations among conceptual understanding, epistemological beliefs, and IR (Baytelman, 2015; Baytelman & Constantinou, 2018; Wu & Tsai, 2011). For instance, Weinstock & Cronin's (2003) findings demonstrated that epistemological beliefs form the foundation for specific juror-reasoning abilities and the comprehensive generation of arguments. Wu & Tsai (2011) examined the interplay among 68 high school students' Epistemological beliefs, their conceptual comprehension of nuclear power utilization, and their IR on this topic, as articulated through argumentation. The results revealed a significant correlation between students' beliefs regarding the justification of scientific knowledge and the quality of their arguments.

Additional, studies of Bell & Linn (2000), Baytelman (2015) indicated that students who perceived science as a dynamic, complex, and constantly changing were inclined to construct more sophisticated and

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cohesive arguments during their IR. Yet, the results of Baytelman, Iordanou and Constantinou (2020; 2022) indicated that the research participants who exhibited relatively sophisticated beliefs about the structure of knowledge - simplicity beliefs - constructed greater quantity and quality of supportive arguments, counterarguments and rebuttals on controversial public health-SSIs during their IR, than participants who held less sophisticated beliefs about the structure of knowledge. On the other hand, Nussbaum and Bendixen (2003) illustrated that students who held the belief that knowledge is straightforward, absolute, and static found argumentation to induce anxiety, leading them to typically evade such discussions.

Using the theoretical framework of IR can foster the effectiveness of negotiating controversial public health socio-scientific issues, especially considering their contentious nature. In general, the theoretical framework of IR can provide a structured approach to facilitate an effective discourse and decision-making in these controversial, complex, multi-dimensional and value-laden issues.

3.3. Controversial public health Socio-scientific issues and public health education

Even though numerous studies suggest that in many areas of life, public trust in science and technology is high (National Science Board, 2016; Pew Research Center, 2015), when it comes to controversial public health socio-scientific issues, this trust is not a given. In these cases, factors such as people's beliefs about the Nature of Science (NOS), how science operates, how scientists work, the relationship between science and society, as well as socio-cultural-economic factors, religion, emotions, gender, identity, political ideology, etc., significantly influence people's opinions, feelings, thoughts and choices about these issues (Baytelman, et al., 2018; Baytelman & Constantinou, 2017; Herman, 2013; 2015; 2021; Herman et al., 2020; Hodson, 2009; Zeidler, et al., 2013).

Furthermore, if there is misinformation or disinformation about the scientific content of controversial public health socio-scientific issues and about the way science works, then trust is further undermined. Misinformation or disinformation exacerbates the complexity of controversial public health socio-scientific issues, putting entire societies and public health at risk and making educational efforts to understand the nature of science and public health exceedingly difficult (Herman et al., 2024). Based on Dual process theories (Evans, 2003, 2008) that provide a cognitive explanation for IR, it is understood that epistemological beliefs, biases, stereotypes, social prejudices, political orientation, and emotions predetermine individuals’ decisions on how to handle such issues (Harker, 2015; Herman et al., 2022, Baytelman, 2015; Baytelman, et al., 2018). Yet, the public's perception of science is further complicated by "motivated reasoning" and selective information processing (Herman et al., 2024). People tend to prioritize information that aligns with their existing beliefs, regardless of its scientific merit. This is especially true for complex, value-laden issues like controversial socio-scientific issues (Hansson, 2017). The spread of misinformation and conspiracy theories further fuels controversy and distrust in science. One such example is the COVID-19 pandemic and vaccinations, which highlight the need for more targeted education to promote public health.

Additionally, research suggests that socio-cultural factors and personal biases can influence how scientists approach their work, public communication, and even contribute to mis/disinformation (Hoffman et al., 2016; NIH, 2023). This raises a concern: are science students adequately equipped to navigate these

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influences, particularly regarding controversial socio-scientific issues? Traditional science curricula might not sufficiently address the impact of these biases on personal decision-making and public communication.

This highlights the need for science education to go beyond technical knowledge. Equipping future STEM professionals with the critical thinking skills to recognize and manage biases, stereotypes, social prejudices and emotions, combat mis/disinformation, promote the NOS and epistemological understanding, and effectively communicate about socio-scientific issues is crucial for fostering public trust in science.

3.3.1. Enhancing Health Education: Epistemology, Nature of Science, scientific uncertainties, and controversial health socio-scientific issues

According to Kitchener (2002), "epistemology" is a theory of knowledge and how it develops, while "personal epistemology" is a personal theory about how individuals develop knowledge. (Baytelman et al., 2020). Epistemological beliefs refer to individuals' beliefs about the nature of knowledge and the process through which knowledge develops (Greene, Sandoval, & Bråten, 2016; Hofer & Pintrich, 1997; Muis et al., 2015). On the other hand, Nature of Science (NOS) describes how science functions, and explains the strengths and limitations of science, as well as the value of diverse types of scientific knowledge (MaComas, 1998).

Several studies indicate significant relationships between students' personal epistemology, epistemological beliefs, and understanding of the NOS, and their learning achievements (e.g. Baytelman et al., 2020; Barzilai & Eshet-Alkalai, 2015; Chan et al., 2011; Herman et al., 2019; Mason et al., 2013; Schomer, 1990; Trevors, et al., 2017a; 2017b; Wu & Tsai, 2011). For instance, Schommer (1990) had investigated the influence of epistemological beliefs on learning. Since then, research has shown a connection between these beliefs and various academic outcomes. This includes academic performance, comprehension, conceptual change and understanding, views of science, and career choices in science (Chen, 2012; Cheng et al., 2009; Mason et al., 2013; Trevors et al., 2017a; Trevors et al., 2017b). Additionally, studies suggest that epistemological beliefs directly impact how students approach learning (Chan et al., 2011). This includes selecting learning strategies, shaping their understanding of concepts, and problem-solving (Chan et al., 2011). Furthermore, these beliefs influence a student's ability to generate different arguments and counterarguments (Baytelman et al., 2020).

Additionally, some scholars have identified deep understanding of scientific concepts and the NOS, as well as sophisticated scientific epistemological beliefs, as significant factors influencing people's engagement with socio-scientific issues. For instance, Schalk (2012) found that a curriculum focused on core scientific concepts like evolution and the tentative nature of scientific knowledge encouraged students to see science as constantly evolving. Research by Herman (2018) and Herman et al. (2019) suggests that learning about the NOS, including how scientific methods can vary and theories can change, gained through a socio-scientific issues intervention, leads to both deeper understanding of content and decisions – making that have a less negative impact on the environment (Herman, 2018; Herman et al., 2019). Furthermore, Baytelman et al. (2020) showed that students with a deep scientific knowledge and sophisticated epistemological beliefs were better at constructing diverse and high-quality arguments when presented with real-world health socio-scientific dilemmas.

On the other hand, scholars investigating the relationship between trust in science and understanding of the NOS caution that individuals may misinterpret the subjective and tentative aspects of NOS to justify

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rejecting valid scientific findings (Abd-El-Khalick & Lederman, 2023; Clough, 2007, 2020; Good & Shymansky, 2001; Kohut, 2019). This misinterpretation could stem from the expectation that science must always offer definitive answers and absolute certainty, particularly when addressing complex socio-scientific issues (Herman et al., 2023). Furthermore, Osborne and colleagues (2022) propose that trust in scientists' recommendations—whether related to human health, the environment, the economy, or social well-being—requires substantial confidence in their expertise, the accuracy of their claims, and the effectiveness of their methods for managing uncertainty (Osborne et al., 2022). Consequently, understanding the NOS is necessary for the public to gain trust in the work of scientists and scientific achievements.

Furthermore, there is a global concern regarding the widespread acceptance of false or misinformation, even when confronted with robust evidence to the contrary (Kavanagh & Rich, 2018; McIntyre, 2018; Osborne & Pimentel, 2023). The propagation of unsupported positions or misconceptions—such as the unfounded link between vaccines and autism or climate change denial— has created a lack of trust in science and raises significant concerns. Some of these beliefs, particularly the perception that vaccines pose a danger, can have harmful consequences. Not only do they jeopardize the well-being of the individuals who hold them, but they also imperil the health of the entire community (public health) (Osborne & Pimentel, 2023).

In addressing the public's lack of trust in science, the literature describes two relevant approaches (Osborne & Pimentel, (2023). The first approach is *Protectionism*: Students are equipped with specific teaching-learning material to identify false claims. Programs like Finland's and Wineburg's teach skills like checking source credibility and evaluating evidence. Research shows these methods are effective (Wineburg & McGrew, 2019). The second approach is *Media Education*: This approach assumes students already have the necessary skills due to the information-rich environment (Reid & Norris, 2016). However, research suggests existing tools like the CRAAP test (Currency, Relevance, Authority, Accuracy and Purpose) are ineffective because it has limitations in detecting flawed sources (Breakstone et al., 2018, 2019). Research by Breakstone et al. (2018) suggests it does not prioritize source credibility, a crucial element in identifying misinformation.

Schools can rebuild trust in science by including controversial socio-scientific issues in curricula to promote students' epistemological beliefs and understanding of nature of science, including the scientific uncertainties involved, rather than focusing solely on scientific facts. Previous research has identified two main categories of scientific uncertainties that students experience: conceptual and epistemic (Ha et al., 2024).

(i) Conceptual uncertainty arises when students struggle to apply their existing understanding of scientific concepts to new situations (Chakravartty, 2017; Chen & Qiao, 2020; Kampourakis & McCain, 2020).

(ii) Epistemological uncertainty, on the other hand, emerges when students are unsure about how to use their scientific reasoning skills to investigate and explain phenomena. This can happen at various stages, including formulating questions, collecting data, analysing data for patterns, interpreting data as evidence, and reasoning to identify gaps in their understanding (Ha et al., 2024; Kampourakis, 2018; Kirch, 2010; Urbanek et al., 2023).

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4. Bridging Theory and Research with Educational Praxis

4.1 Socio-scientific Issues-Based Learning

According to Alcaraz-Dominguez, Shwartz and Barajasa (2024) Socio-scientific-based learning (SSI-BL) distinguishes itself from other educational applications of socio-scientific issues by using them as a tool to facilitate science curriculum learning. This approach, known as a context-based science education (Bencze et al., 2020), is similar to models like Socio-scientific Teaching and Learning (SSI-TL) and Socio-scientific Inquiry-Based Learning (SSI-BL) by Sadler et al. (2017) and Amos, Knippels, and Levinson (2020) respectively, with some differences.

In SSI-BL, students begin a lesson by exploring a socio-scientific issue and develop a well-reasoned position by the end. This process helps them acquire essential scientific literacy skills. Research shows this method is effective for teaching scientific knowledge on SSI-topics (Feucht et al., 2021), promoting epistemological beliefs and the NOS (Baytelman, 2015; Khishfe, 2014; Sadler). SSI-BL has also been shown to be useful in teaching skills like argumentation, decision-making (Wu & Tsai, 2007; 2011) and communication (Chung et al., 2016), as well as fostering qualities like moral awareness, according to some research (Fowler et al., 2009).

The SSI-BL framework outlines three scientific competences that are essential for understanding and actively participating in debates related to socio-scientific issues. These competences are: (i) Scientific Explanation: The ability to elucidate phenomena in a scientific manner. (ii) Scientific Inquiry: The skill to assess and construct scientific investigations. (iii) Scientific Data Interpretation: The competence to analyse data and scientific evidence (Alcaraz-Dominguez, Shwartz & Barajasa, 2024). Additionally, using controversial socio-scientific Issues-Based Learning, students acquire skills in navigating dynamically evolving scientific uncertainties during sensemaking and communicate their results (www.pafse.eu/).

4.2 Engaging with an open schooling model for Inquiry-based learning in the context of controversial public health socio-scientific issues

The theoretical framework of an open schooling model emphasizes partnerships between teachers, students, researchers, businesses, and the public. This collaborative approach tackles real-world challenges and fosters innovation, all while promoting critical thinking, sustainability, equity, and inclusion (European Commission, 2017; Li et al, 2020). The open schooling model breaks away from traditional textbooks and lectures and it fosters critical thinking and a sense of fairness as students grapple with complex issues.

Open schooling offers a more inclusive learning environment compared to traditional models. It values the knowledge and perspectives of everyone involved (students, parents, teachers, businesses, and the community). This collaborative approach creates a team environment where everyone plays an active role in shaping the learning journey (European Commission, 2017; Li et al, 2020).

An open schooling model for inquiry-based learning in the context of controversial public health socio-scientific issues aims to promote public health literacy and public health itself. This is achieved by fostering school-community interactions and encouraging active student participation in community discourse (https://pafse.eu/). The key pillars of the framework of an open schooling model according to PAFSE project are the following:

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Controversial public health socio-scientific issues

(i). Using of controversial public health socio-scientific issues. The selected controversial socio-scientific issues should align with the learning objectives as per the curriculum and should be used as contexts for exploration. The appropriate socio-scientific issues should be chosen based on the concepts, phenomena, NOS, and principles that will be explored, as well as skills, attitudes, behaviours, and values that will be promoted. Furthermore, controversial SSIs should encompass opposing and conflicting information, approaches, and perspectives from multiple sources, and should not have a single solution.

(ii). Linking controversial socio-scientific issues to curriculum goals and students' daily lives. Implementing targeted activities that address misconceptions, stereotypes, social prejudices, and scientific uncertainties with the goal of promoting conceptual and epistemological change. This change aims to enhance understanding in these areas. Inquiry-based Learning is used as the primary framework for teaching and learning (NRC, 1996, p. 23).

(iii). Focusing on the complex and multidimensional nature of each socio-scientific issue, the associated uncertainties and social risks, and the necessity to analyse such issues and potential solutions from the perspectives of different stakeholders. Recognizing that various health issues have social dimensions that cannot be addressed solely by science and are thus considered socio-scientific issues. Explaining that various socio-scientific issues typically are characterized by non-obvious and uniquely accepted solutions, are susceptible to alternative approaches and proposals for resolution, and are therefore deemed controversial.

(iv). Employing targeted activities that promote conceptual and epistemological understanding, to achieve the curriculum's learning objectives. These activities should provide students with the opportunity to reflect on the uncertainty, variability, complexity, and need for continual evaluation of scientific knowledge related to controversial socio-scientific issues. Emphasis should be placed on the concept of conflicting information and approaches, which can arise from numerous factors, including differing worldviews, value systems, political and social contexts of experts, and the inherent limitations of science itself.

(v). Encouraging students to examine the conflicting information in socio-scientific issues, evaluate them for validity and reliability, construct arguments, and subsequently make decisions. In this manner, socio-scientific issues can serve as tools for developing skills in interpreting, analysing, and evaluating information, as well as skills in inferring, arguing, and decision-making.

(vi). Employing strategies to promote reflection, formative assessment, dialogue, as well as the attitudes, values, and behaviours that constitute democratic citizenship.

(vii). Evaluating the anticipated outcomes through formative and summative assessment, employing a variety of tools.

Inquiry-based learning in the context of controversial public health socio-scientific issues

Inquiry-based learning is an efficient instructional model in science education research and practice. It refers to the active engagement of students in learning processes (Pedaste et al.; Schröder et al., 2007), promoting higher order thinking skills such as critical and creative thinking (Sandoval, 2005), modelling and argumentation skills, communication, and cooperation skills (Minner et al., 2010). In the framework of

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Inquiry-based learning in the context of controversial public health socio-scientific issues all activities of the proposed approach should aim to engage students in authentic knowledge-building processes, foster student autonomy for exploration and decision-making, and promote the development of positive attitudes, behaviours, and values for democratic citizenship. Yet, the integration of controversial socio-scientific issues into the learning process encourages inter-disciplinarity and trans-disciplinarity. This bridges the gap between natural sciences and humanities, promoting a more holistic understanding of knowledge and avoiding its fragmentation.

Open schooling event in the context of controversial public health socio-scientific issues

At an open schooling event, students actively engage the audience by presenting their school project. They present their research questions, methodology, results, and conclusions, further disseminating knowledge by distributing brochures on relevant public health topics. The event culminates in a thought-provoking discussion focused on key public health concepts, including the social determinants of health and the crucial role of schools and communities in promoting health and well-being, the need to address misinformation/ disinformation, uncertainties, risks, and the public's lack of trust in science. The open schooling format significantly encourages interaction among students, parents, teachers, scientists, community members, and policymakers. This collaborative space fosters dialogue, debate, and reflection on the students' research and public health challenges. As a result, the event has the potential to spark future collaborations and initiatives aimed at addressing public health challenges and enhancing community health and well-being.

4.3 Pedagogical Strategies and Methods for Navigating Public Health Controversial Socio-Scientific Issues

Learning science research has investigated strategies for educators to support professional development and students in navigating controversial socio-scientific issues and uncertainty throughout the learning process. Drawing on the *Partnerships for Science Education* (PAFSE) project (https://pafse.eu/), potential teaching strategies to negotiate public health controversial Socio-Scientific Issues:

(i). Brainstorming

Brainstorming is an instructional technique with several variations that might take place within small group or with the entire class. During brainstorming all students shortly express their ideas, biases, emotions or concepts which are relevant to a given guiding controversial socio-scientific issue or central terms. The teacher can identify misconceptions, stereotypes, prejudices, different other biases to promote conceptual change and conceptual understanding using adequated activities.

(ii). Collaborative learning

Collaborative learning is a pedagogical method, using group (3-5 students) teaching - learning activities (except those activities which require an individual reflection on one's own learning or those that require whole-class discussions). Collaborative learning can boost the learning outcomes, students' interests and participation and their collaboration and communication skills.

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The role of the teacher is to support students, stating explicitly the aims of each task or reformulating and adapting new key questions to help them to find their own learning path. This teacher's role as a facilitator is necessary to promote a gradual development of students' learning autonomy when questioning, thinking, planning, reflecting, interacting, discussing, and gradually developing conceptual frameworks through the active participation in tasks.

Additionally, during collaborative learning, the role of teacher is to promote metacognitive reflection: Encourage students to reflect on their thinking processes. Ask questions like, "What uncertainties did you encounter?" or "How did you revise your understanding?" This metacognition promotes awareness of evolving uncertainties. Collaborative sensemaking allows students to learn from each other, challenge assumptions, and collectively address uncertainties.

One type of cooperative learning method is the jigsaw technique. The jigsaw technique is a method of organizing classroom activity that makes students dependent on each other to succeed. It breaks classes into groups that each assemble a piece of an assignment and synthesize their work when finished. The process derives its name from the jigsaw puzzle because it involves putting the parts of the assignment together to form a whole picture. This type of cooperative learning helps in better time managemen.t

(iii). Socio-scientific Inquiry-Based Learning

Using Scaffolded Inquiry which provides structured inquiry experiences, where students gradually explore scientific concepts. Start with guided questions and gradually shift toward open-ended investigations. This helps students build confidence and navigate uncertainties step by step. Socio-scientific inquiry-based teaching and learning approach has three main stages:

- Using of socio-scientific issues for raising inquiry-based authentic questions.
- Using of socio-scientific inquiry-based learning (e.g. formulating research questions, planning, searching, and evaluating sources and information, using a variety of evidence sources such as research, expert knowledge, practice experience and data to capture the complexity of a problem, analysing, negotiating the social, ethical, scientific and emotional dimensions of the socio-scientific issues, making inferences, synthesising and drawing conclusions, constructing arguments, etc.).
- Acknowledging the epistemological limitations of science and the relationship between science and society.
- Stimulating students to form opinions and formulate solutions related to the SSI - questions.
- Identifying the specific NOS ideas, and conceptual - epistemological issues most relevant to both: 1) making informed decisions regarding complex controversial socio-scientific issues, and 2) fostering a deep conceptual understanding of fundamental scientific ideas.
- Providing feedback and revision: Provide timely feedback on students' work. Encourage them to revise hypotheses, experimental designs, and interpretations based on evidence. Emphasize that revisions are essential for refining understanding.
- Providing flexible assessment: Assess students' ability to navigate uncertainties, not just their final answers. Consider rubrics that evaluate their reasoning, adaptability, and willingness to revise based on evidence.

(iv). Learning Science by Using Models

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Modelling-based Learning approach is an approach for teaching and learning in science whereby learning takes place via student construction and/or use of models as representations of physical phenomena that include representations of physical objects and their characteristics, physical entities and physical processes involved in the physical phenomena. This leads to an externalized representation of the underlying mechanism of a physical phenomenon and helps students build an understanding of that mechanism.

Particularly, models help us to visualize a system and specify its structure or behaviour. Moreover, the modelling process usually simplifies a phenomenon thereby revealing its more fundamental concepts and downgrading any secondary information that is not directly relevant to those aspects of the system that are of interest for investigation purposes. Models have a representative, interpretive and predictive power.

Using Explicit Modelling, teacher can demonstrate how to handle uncertainties. Show students how scientists approach unknowns, revise hypotheses, and adapt methods. Modelling this process helps students understand that uncertainty is a natural part of scientific inquiry.

(v). Learning Science by Constructing Concept maps

Concept maps are a kind of graphic organizers like mind maps. They include concepts in frames interconnected with arrows. A verb is written above each arrow which determines the kind of the semantic connection, in a way that the two interconnected concepts and the arrow (mainly verb) form a semantically independent sentence. In addition, concept maps are a direct method of looking at the organization and structure of an individual's knowledge within a particular domain and at the fluency and efficiency with which the knowledge can be used.

(vi). Learning Science by Using Infographic

An infographic (information graphic) is a kind of multimodal representation of facts and information. It usually forms a broad graphic composition combining short texts, numerical data, graphs, diagrams, sketches, colours, and shapes. The aim of the infographic is to present a big load of information on a topic in a visual way, making it comprehensible immediately.

(vii) Using History of science and Case Studies. Explore real-world scientific cases or historical examples where uncertainties played a crucial role. Discuss how scientists addressed uncertainties in those contexts.

(viii). Constructing arguments and counterarguments and using Socio-scientific Argumentation

The ability to construct arguments is a core feature of scientific reasoning (Duschl, 2008; Erduran & Jimenez-Aleixandre, 2007; Kuhn et al., 2008). Skilled argumentation goes beyond simply advocating one's position; it demands critical consideration and evaluation of alternative viewpoints (Mason & Scirica, 2006). This skill becomes particularly crucial when grappling with complex and often controversial socio-scientific issues.

Argumentation-based science teaching stresses the evidence-based justification of knowledge claims, and it underpins reasoning across STEM domains. It helps students use cognitive/metacognitive strategies and processes, develops their collaboration and communication skills, supports their critical thinking skills, promotes scientific literacy, and makes it easier for them to understand scientific culture and practice.

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For Argumentation-based science teaching approach the focus is on how the teachers:

- structure the Task: designing activities and assignments that encourage argumentation.
- facilitate group discussions: Encouraging students to engage in dialogue, share ideas, and debate scientific concepts.
- question for evidence and justifications: prompting students to provide evidence and reasoning to support their arguments.
- model argumentation: demonstrating effective argumentation techniques and critical thinking.
- use Presentations and Peer Review: allowing students to present their arguments and receive feedback from peers.
- establish norms of argumentation: setting guidelines for respectful and constructive discourse.
- provide feedback during group discussions: offering guidance and corrections during collaborative argumentation.

(viiii). Access and navigate health information environments. Some key strategies for accessing and navigating health information environments are:

- search engines and reliable websites for scientific articles health information,
- think critically about health claims and make informed decisions about health information,
- acquire health knowledge and use it in new situations, communicate about health topics and concerns,
- use health information to promote their own health, that of others, and environmental health,
- develop healthy attitudes and behaviours,
- engage in healthy activities and avoid unnecessary health risks,
- become aware of their own thinking and behaving,
- identify and assess bodily signals (e.g. feelings, symptoms),
- act ethically and socially responsible,
- be a self-directed and life-long learner,
- develop a sense of citizenship and be capable of pursuing equity goals,
- address social, commercial, cultural, and political determinants of health.

(x). Promoting Critical Health Literacy

For the promotion of critical health literacy is fundamental the critical evaluation of health information, the comprehension of the interconnection between health and society (in particular, the notion of social determinants of health), and the participation in civic collective actions for the promotion of health (https://pafse.eu/).

(xi). Promoting One Health Approach

To promote the One Health Approach, it is essential to consider the following: The One Health approach is a transdisciplinary perspective that examines human health within a broad context, emphasizing the direct interconnections with animal health and the environment. Common issues addressed by the One Health approach include zoonoses, vector-transmitted diseases, and antibiotic-resistant bacterial strains (https://pafse.eu/).

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5. Conclusions

In this paper, we explored effective pedagogical strategies and methods to use controversial health socio-scientific issues in educational settings to promote critical health literacy and health education in a post-Truth Era. For this aim, we analysed and synthesized theoretical and empirical perspectives from existing educational research and practice, and we bridged theory and research with educational praxis.

Our results indicate that equipping students with self-regulation skills and the ability to negotiate controversial socio-scientific issues and identify misinformation/disinformation requires educators' recognition of two critical factors. First, recognizing that learning in the context of controversial socio-scientific issues is both emotional and rational, and students' backgrounds and feelings influence how they interpret information. Second, recognizing that in the context of controversial socio-scientific issues, sociocultural biases and emotions exist, which can shape how students approach scientific concepts (Baytelman, 2015; Baytelman et al., 2018; Herman et al.,2024).

Effective science teaching methods, combining high expectations, strong emotional support, and a safe learning environment, are crucial to promote critical health literacy and public health education in a post-Truth Era (Clough et al., 2009; Herman et al., 2024). Based on current research, effective teaching methods and approaches by using controversial socio-scientific issues include socio-scientific inquiry-based learning, project-based learning, socio-scientific argumentation, collaborative learning, modelling-based learning, constructing concept maps and infographics, using history of science and case studies, using one health approach and open schooling approach (www.pafse.eu/).

Teaching strategies which could be highly effective include identification of students' initial ideas, misconceptions, biases, emotions and both conceptual and epistemological uncertainties. This initial assessment helps tailor instruction to address students' specific needs. Incorporate teaching strategies that equip students to recognize and navigate the influence of personal and sociocultural biases. These biases can intensify behaviours, attitudes, and loyalties, and lead to quick, emotionally charged judgments about information, even among professionals. By helping students become aware of these biases, we empower them to make more informed and reasoned decisions (Baytelman et al., 2018; Herman et al., 2024). Encouraging open discussions about how cultural background and identity affect views on science (Bolsen et al., 2019; Dixon et al., 2017; Herman et al., 2021; Hornsey & Fielding, 2017). Designing activities and questions that highlight compatibility between students' identities and science, while also addressing inaccurate scientific reasoning and conceptual and epistemological uncertainties (Bolsen et al., 2019; Dixon et al., 2017; Ha et al., 2024; Herman et al., 2021; Hornsey & Fielding, 2017). Furthermore, activities that promote students' conceptual and epistemological understanding may involve activities that encourage critical thinking, sources and evidence evaluation and exploration of alternative viewpoints, data analysis and synthesis.

In summary, existing theory and research suggest that educational strategies and methods related to controversial socio-scientific issues can be successful in reducing students' identity-based conflicts with science topics and biases (Barnes & Brownell, 2017; Janney et al., 2024; Lindsay et al., 2019; Tolman et al., 2020). These approaches can foster constructive dialogue, allowing students to engage with diverse perspectives and develop critical thinking skills. Additionally, they can help students recognize their

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emotional responses and identify misinformation and disinformation when dealing with such issues (Herman et al., 2024).

Furthermore, promoting students' understanding of the NOS, practicing scientific processes, experiencing the tentative and evolving nature of science, fostering conceptual and epistemological understanding, and building trust in and acceptance of science—all of which are often perceived as socially controversial—are ways to promote critical health literacy in this context (Herman, 2015; Reiss, 2022). In general, we need to support educators and students to confront the social and epistemological complexity of the post-Truth Era rather than retreat from it.

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