STEM Tools, Education Guidelines and Curricula Training Considering Society and Businesses Demands in the Transition to Post COVID

Nuno Soares Domingues

***Abstract*— It is practically beyond cliché that children are our future: if we teach them well, they will lead the way. Therefore, the mission of teach is transversal and is not only a responsibility of schools but also a responsibility of all parties, such as families, organizations, stakeholders, companies and communities. The collaboration between them benefits the education and removes the gap between the theory teached in schools and the applicability for the requirements of businesses. Bearing that in mind, a group of concerned entities from universities and enterprises developed the project PAFSE Partnerships for science education [1]. With the focus “Teaching public health science in pandemic times”, it contributes to the topic “Open schooling and collaboration in science education” under the programme “Science with and for Society (SWAFS)”.**

The present paper focus on an educational scenario developed in the PAFSE project: “Droplets & the physics of viruses transmission”, presenting specifications, considerations and guidelines to implement it. The PAFSE project is innovative in that it makes use of project-based learning, problem-based learning and digital learning packages to engage a wide and diverse range of actors.

Addressing public health challenges and indirectly backing the achievement of the sustainable development goals (SDGs), partners are developing other educational scenarios through an open schooling framework and using social media for dissemination. Engaging more than 3000 students and their families in the project activities, the outcomes will be disseminated to more than 1000 schools. It will also reach the society through activities involving communities, social organizations, parents’ associations and others.

The PAFSE project students have 12-15 years old and are in the 3rd Cycle.

The concerns and guidelines given in the present paper comes in a moment of wondering the evolution of the pandemic and the eventual shifting on measures to deal with it.

I. Introduction

The increasing concern that the curricula put heavy emphasis on memorization of facts and little stress on problem solving or self-directed study skills necessary for a practice, it 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 [2].

An European Union (EU) Special Report gives an overview of education approaches across the EU and points out the EU’s educational objectives [3]. 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 emphasis that the achievements and surplus are so important that similar programs should additionally started to be available to even more younger students [3]. 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 [4]. 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 [5]. 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 [6]. One school implemented Project CHILD (Computers Helping Instruction and Learning Development) as its instructional model and the other did not. Each classroom in

Instituto Politécnico de Lisboa/ Instituto Superior de Engenharia de Lisboa, Rua Conselheiro Emidio Navarro, 1, 1959-007 Lisbon, Portugal

https://doi.org/10.17758/URUAE17.AE09221009

the cluster has at least six learning stations to accommodate varied learning modalities. Students rotate to each classroom in the cluster throughout the day for instruction in reading, writing, and mathematics. Students spend three years working with the same teachers team. Project CHILD students who had completed a full three-year cycle of the program scored higher on all test comparisons. Significant differences were obtained in mathematics applications, reading comprehension, mathematics computation, and mathematics application.

Some studies go beyond their analysis on knowledge acquisition going until the link with the labour market. For example, Schoon and Parsons investigates 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) [7]. 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. 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 [8]. 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 [9-11]. 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 [12-14]. 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. perform 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 1 of 2 parallel courses delivered by either PBL or lecturing over one academic year [15]. The primary outcome measure was students' critical thinking disposition measured by the California Critical Thinking Disposition Inventory (CCTDI). Individual interviews were also conducted to elicit the students' perceptions of their learning experience. Data were collected at four timepoints spanning three years. Compared with lecture students, PBL students showed significantly greater improvement in overall CCTDI and there were significant differences in the development of students' critical thinking dispositions between those who undertook the PBL and lecture courses, respectively.

The integration of science, technology, engineering, and mathematics content (STEM) has become a mainstream topic within educational systems. Clark and Ernst discusse the technology integration model for education and the factors to be considered when contemplating technology education as a focal point of integrated curricula [16]. 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.

Adolescents' future expectations are a potentially important precursor of adult attainment and may illuminate how males and females vary in schooling and work. Thus, the longitudinal study performed by Mello, examined gender variation in developmental trajectories of educational and occupational expectations from adolescence to adulthood and in connection to corresponding adult attainment, including individuals aged 14 to 26 years old [17]. A hierarchical linear modelling analyses yielded several findings: males and females had similar developmental trajectories of educational expectations from adolescence to adulthood with the sample average expecting to attend college. Probability of expecting a professional occupation were lower for males than females. The predicted adolescent educational and occupational expectations corresponds to the attainment in adulthood, although the relationship varied by gender. Males who reported high occupational expectations in adolescence had higher occupational attainment in adulthood compared to males with low occupational expectations, whereas females' adult occupational attainment did not vary by their adolescent occupational expectations. Gender variation in expectations and attainment is discussed considering historical changes, and future directions of research are proposed [17].

Ravitz describes the status of small school reforms in U.S. high schools and anticipates their future [18]. The author asks how cultural and instructional reforms, including project-based learning (PBL) and other inquiry-related practices, differ across school reform types, analyses focusing on indicators of teacher and student culture. Findings are based on data from a national survey completed by 395 high school teachers who were responsible for and had used PBL in core academic subjects.

Study participants taught in large, comprehensive high schools; in schools that had converted to small learning communities; and in newly created small school start-ups. In general, start-up teachers reported more success implementing reforms than teachers in a steady state phase in schools, and teacher culture was reformed much more often than student culture and instruction.

Kaldi et al. reported the outcomes of a study on the effectiveness of project-based learning on primary school pupils regarding their content knowledge and attitudes towards self-efficacy, task value, group work, teaching methods applied and peers from diverse ethnic backgrounds [19]. A cross-curricular project was implemented within the curriculum area of environmental studies under the title sea animals. The findings of the mentioned study support the view that pupils can gain benefits through project-based learning in obtaining content knowledge and motivation (self-efficacy and task value in terms of environmental studies).

Stohlmann et al. describe the implementation of the integrated curriculum Project Lead The Way (PLTW) in middle schools, make recommendations on how teachers can be effective at teaching integrated STEM education based on a support, teaching, efficacy, and materials (s.t.e.m.) model [20]. The study establishes that there is a need for further research and discussion on the knowledge, experiences, and background that teachers need to effectively teach integrated STEM education but consider that the s.t.e.m. model is a good starting point for teachers implementing and improving integrated STEM education.

Bédard et al. present results of a study conducted with undergraduate students involved in either problem or project-based curricula (Medicine and Engineering, respectively) at the Université de Sherbrooke, Canada, to measure the impact of these innovative curricula on students’ engagement and persistence in higher education [21]. The research question was: What determinants better predict students’ engagement and persistence in innovative curricula such as PBL? Nine variables were examined as potential predictors of both factors (engagement and persistence). Results showed a variation in variables predicting engagement and persistence, with the most significant predictor being stress related.

English and Kitsantas sustains that, in order to be successful in problem or project-based learning (PBL), students must take responsibility for the learning process by setting goals, monitoring, reflecting, and sustaining their motivation from the beginning of the project until the end [22]. However, the authors alert for the fact that these processes do not occur naturally or easily for many students. Therefore, the learning environment and teaching practices in PBL must be designed with intention to support students’ self-regulated learning (SRL) describing specific learning environment features and teaching practices to foster student responsibility for learning in each phase of PBL. To accomplish this, a theoretical model of the relationship between PBL and SRL is presented in [22], along with research-driven guidelines on how to promote student responsibility for learning in PBL.

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 [23]. Teachers in 3 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 6 weeks for 3 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.

Hughes et al. provide an overview of the evidence-base underpinning careers education and its impact upon pupils’ skills and outcomes. The literature review considered 96 different studies – 73 focused on careers education and 23 on part-time working studies. Only literature published from 1996 and concerning OECD countries were included in the analysis. All studies included had quasi-experimental or experimental methodologies. The types of interventions included in the examined studies included careers provision, career guidance, enterprise, ICT and careers, job shadowing, mentoring, transformational leadership, volunteering, work experience, and work-related learning. The interventions were considered in terms of their impact upon educational, economic and social outcomes. Findings highlight the fragmented nature of literature within the career’s education field, though the robust studies that exist are largely positive. 60% of the literature relating to educational outcomes were related to positive outcomes for young people. 67% of the literature relating to economic outcomes were related to positive outcomes, as interventions were linked to higher wages in later life and reduced likelihood of young people becoming Not in Employment, Education or Training (NEET). No studies looking at economic outcomes were linked to negative outcomes, the others found mixed results. Likewise, 62% of the literature looking at social outcomes had positive outcomes. Results show that young people from poorer backgrounds are more likely to have career aspirations that are misaligned with their educational ambitions. Misaligned ambitions increase the possibility of young people becoming NEET. [24].

II. Curricular considerations regarding the STEM educational scenario

In Portugal, Basic education is universal, compulsory and comprises three sequential cycles:

- 1st Cycle: from 1st to 4th Years
- 2nd Cycle: 5th and 6th Years
- 3rd Cycle: from 7th to 9th Years

The PAFSE project students have 12-15 years old and are in the 3rd Cycle, where the student must know how to define a concept, present a coherent argument even though it may be more informal than the explanation provided by the teacher. However, the student must know how to justify the various steps used in his explanation and justify the statement in specific cases, without being required to prove it in general but must knowing the result. The student also must present a mathematical demonstration as rigorous as possible, and simply justify the statement, evoking an already known property. Abbreviately, one can say that the steps are: (1) Identify / designate; (2) Recognize; (3) Recognize, given; (4) Know; (5) Prove / Demonstrate; (6) Extend; (7) Justify. For example, around energy sources and energy transfers there are the following:

- Identify, in concrete situations, systems that are sources or receivers of energy, indicating the direction of energy transfer and concluding that energy remains in the world
- Identify several energy transfer processes (conduction, convection and radiation) in daily life, justifying choices that promote a rational use of energy
- Distinguish renewable energy sources from non-renewable energy sources and argue about the advantages and disadvantages of their use and their consequences on the sustainability of the Earth from an interdisciplinary perspective
- Distinguish heat temperature by relating them through examples.

The theme that suits the STEAM project education scenario is Fluid Mechanics of Physics, which is an area for the study of fluids in motion or at rest. The study of Fluid Mechanics is constructed with the help of physical quantities that describe or are properties of fluids such as viscosity, volume, surface tension, vector velocity, etc. Fluid mechanics is divided into the following two sub-areas:

- Hydrostatic that studies fluids that are in static or dynamic equilibrium. In static equilibrium, the fluid is free of acting forces. In other words, the fluid is at rest. In dynamic equilibrium, the fluid is under the action of one or more forces such that the resulting force is zero. This means that the fluid is in a uniform rectilinear movement (MRU). Hydrostatics got its name due to the first studies related to this subject being linked to water. Hydrostatics is based on some concepts such as fluid and some properties and quantities that describe it, such as pressure, density, among others
- Pascal's principle that says that the increase in pressure exerted anywhere within an ideal liquid in equilibrium is fully transmitted to all points contained in the liquid and to the walls of the container that contains it. Pascal's principle has as its main application the hydraulic press present in several large machines such as tractors, drill bits, excavators and so on. In addition to the hydraulic press, the Pascal principle is also present in car brakes, car steering, hydraulic machines, among others.
- Archimedes 'theorem (or Archimedes' principle) that says that every object totally or partially immersed in any liquid is subjected to a vertical force from the bottom up, equal to the weight of the portion of liquid displaced by the body. This force is called the buoyant force
- Stevin's principle that states that points at the same level within a liquid in static equilibrium withstand the same pressure. Stevin's principle has as its main application the so-called communicating vessels.
- Hydrodynamics that studies fluids in more general movements, with varying speeds and accelerations
- The flow is a physical quantity that measures the amount of fluid that flows into a certain tube with a well-defined cross-sectional area.
- The continuity equation says that, although any pipe does not have the same cross-sectional area along its length, the flow rates throughout its length are the same.
- The Bernoulli principle is analogous to the Stevin principle of Hydrostatics. However, as the fluids are in motion, an additional term containing the velocities of the fluids involved should be considered. This means that it takes the Bernoulli principle into account a potential sector, a kinetic sector and a potential gravitational sector. The Bernoulli principle is a type of energy conservation equation and has numerous applications in Fluid Mechanics.

Mathematics concepts can also be use in the proposed STEM project education scenario, namely:

- geometry and measurement
- organization and data processing
- direct, inverse proportionality functions, related and quadratic functions
- measures of location and dispersion of a data set
- odds
- geometric figures: polygonal lines, polygons and quadrilaterals
- measure, unit changes and conversions of measures
- volumes, perimeters and areas
- operations with finite domain numeric functions given by tables, arrow diagrams or cartesian graphs
- square and cubic roots
- ordered sequence of data
- properties of a data set (median, mean, etc.)
- problems involving tables, graphs and location measures
- problems involving the Pythagorean and Thales theorems and involving the determination of unknown distances by using these theorems
- function graphs
- monomials and polynomials
- trigonometry: sine, cosine and tangent of an acute angle; fundamental formula of trigonometry; relationship between the tangent of an acute angle and the sine and cosine of the same angle; relationship between sine and cosine of complementary angles; problems involving distances and trigonometric ratios
- discrete and continuous statistical variables; classes determined by numerical intervals; grouping data into classes of the same range

- histograms; properties
- problems involving the representation of data in frequency tables and histogram
- probabilities: deterministic and random experiences, events: favourable cases, elementary, compound, certain, impossible event; disjoint or incompatible and complementary events; random experiences with equiprobable elementary events; Laplace definition of probability; problems involving the notion of probability and the comparison of probabilities of different compound events, using double-entry tables and tree diagrams; comparison of probabilities with relative frequencies in random experiments in which possible cases are equiprobable.

The Portuguese curricula is similar to the mainstream around the world. [25] [26] [27] [28] [29] [30] [31] [32] [33] [34].

III. Educational scenarios development

A. Specifications for an educational scenario on the topic of “Droplets & the physics of viruses transmission”

1. Context and relevance of the scenario for public health education

The scenario prepares students and school community to reduce the risk of airborne diseases and epidemics in a phase of the COVID-19 pandemic that remains uncertain how Sars-Cov-2 virus mutates and spreads in high vaccinated populations. Nevertheless, there is strong scientific evidence that the virus is transmitted essentially by air. So is important to engage students in discourse on the measures that limit the spread of the virus droplets to prevent the fast growing of airborne diseases within the school community. The strategy to combat Sars-Cov-2 pandemic worldwide had a strong focus on the confinement of populations at home, on restricting contacts between people, on promoting the rule of “2m-social distance” and on the recommended or mandatory use of masks. With the technological advances achieved today, it is possible and relevant to explore with students a Computational Fluid Dynamics (CFD) tool that simulates and predicts the propagation of respiratory particles when changing the configuration of spaces and other conditions (e.g., area, furniture, number of inhabitants, distance between them, use/no use of mask) and so estimate the risk of disease transmission between individuals. The learning scenario increases students understanding on how airborne transmission works and how STEM may contribute to anticipate, mitigate and solve public health threats, by exploring simulations from a CFD tool.

2. Content Glossary

- Air flow – It refers to the amount of moving air around a given space or area. It is created by the natural means of wind and circulation, or it can be created artificially by the mechanical means of a fan or blower unit.

- Airborne disease - any disease that is caused by a microorganism that is transmitted through the air. There are many airborne diseases that are of clinical importance and include bacteria, viruses, and fungi. These organisms may be spread through sneezing, coughing, spraying of liquids, the spread of dust, or any activity that results in the generation of aerosolized particles. The microorganisms transmitted airborne may be spread via a fine mist, dust, aerosols, or liquids.

- Airborne Transmission - The droplet nuclei remain airborne for long periods, may disseminate widely in an environment such as a hospital ward or an operating room, and can be acquired by (and infect) patients directly, or indirectly through contaminated medical devices. Housekeeping activity such as sweeping, using dry dust mops or cloths, or shaking out linen, can aerosolize particles that may contain microorganisms.

- Computational Fluid Dynamics (CFD) – It is the process of mathematically modelling a physical phenomenon involving fluid flow and solving it numerically using the computational power. Computational fluid dynamics is based on the Navier-Stokes equations. These equations describe how the velocity, pressure, temperature, and density of a moving fluid are related.

- Droplet Nuclei - A type of particle implicated in the spread of airborne infection. Droplet nuclei are tiny particles (1–10 µm diameter) that represent the dried residue of droplets. They may be formed by evaporation of droplets coughed or sneezed into the air or aerosolization of infective materials.

- Droplets Transmission – The disease-causing bacteria and viruses are carried in the mouth, nose, throat, and respiratory tree. They can spread by coming into direct contact with droplets when an infected person coughs or sneezes, or through saliva or mucus on unwashed hands.

- Fluid Dynamics - Fluid dynamics refers to a sub-discipline of fluid mechanics that revolves around fluid flow in motion. Furthermore, fluid dynamics comprises of some branches like aerodynamics and hydrodynamics. Fluid dynamics involves the calculation of various fluid properties, such as flow velocity, pressure, density, and temperature, as functions of space and time.

- Incompressible Fluids - A fluid in which the density remains constant for isothermal pressure changes.

- Natural Air Ventilation – It is a method of supplying fresh air to a building or room by means of

- passive forces, typically by wind speed or differences in pressure internally and externally.

- Navier-Stokes Equations - In fluid mechanics, it is a partial differential equation that describes the flow of incompressible fluids.

- Respiratory Droplets – It is a small aqueous droplet produced by exhalation, consisting of saliva or mucus and other matter derived from respiratory tract surfaces. Respiratory droplets are produced naturally because of breathing, speaking, sneezing, coughing, or vomiting.

- Respiratory Disease – It´s a type of disease that affects the lungs and other parts of the respiratory system. Respiratory diseases may be caused by infection, by smoking tobacco, or by breathing in second-hand tobacco smoke, radon, asbestos, or other forms of air pollution. Respiratory diseases include asthma, chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, pneumonia, and lung cancer. Also called lung disorder and pulmonary disease.

- Thermodynamics – It´s the science of the relationship between heat, work, temperature, and energy. In broad terms, thermodynamics deals with the transfer of energy from one place to another and from one form to another. The key concept is that heat is a form of energy corresponding to a definite amount of mechanical work.

- Ventilation System - It´s a mechanical system in a building that provides fresh air.

- Viscosity – It is the resistance of a fluid (liquid or gas) to a change in shape, or movement of neighbouring portions relative to one another. Viscosity denotes opposition to flow.

3. Knowledge

Physics concepts:

- air flow
- ventilation system
- fluid dynamics

Epidemiology concepts:

- transmissibility
- sociability
- infectiousness
- epidemic spreading

Medical science concepts:

- droplets
- social distancing
- EPIs (individual protective equipment)
- Airborne disease

Knowledge - outcome assessment:

- Explains how airborne transmission works.
- Identifies factors that influence the propagation of droplets.
- Identifies sources of risk in the environment.
- Identifies measures and proposes general action to fight diseases that spread by air.
- Understands how ventilation systems inhibit airborne transmission.

B. Specifications for an educational scenario on the topic of "Energy sources, and public health impact"

1. Context and relevance of the scenario for public health education

Air pollution is a global issue with well-documented public health effects. While some of the consequences of pollution are unpredictable in terms of climate change, others such as heat stress, chronic respiratory and cardiovascular diseases, cancers, are supported by considerable evidence. Energy supply chains highly contribute to air pollution, which now causes over 7 million deaths every year, with over 4 million deaths from household air pollution, and over 3.5 million from outdoor air pollution. Given the nature of the Earth as an energy-dependent system, the educational scenario supports physics teachers in organising classroom debate on energy transition towards more carbon-neutral environments. The learning experience prepares youths to become aware of energy sources and the importance of renewable sources in the sustainability of the Earth as a viable ecosystem. The impact of different sources of energy is discussed, with a focus on rationalization, economic and environmental impacts. With this scenario, teachers will be promoting awareness on implications of energy choices on air pollution, on the planet and for community health.

2. Content Glossary

- Air Pollution - It is the release into the atmosphere of various gases, finely divided solids, or which could be dispersed as liquid aerosols at rates that exceed the natural capacity of the environment to dissipate and dilute or absorb them. These substances may reach concentrations in the air that cause undesirable health, economic, or aesthetic effects.

- Chemical Reactions - A process in which one or more substances, the reactants, are converted into one or more different substances, the products. Substances are either chemical elements or compounds. A chemical reaction rearranges the constituent atoms of the reactants to create different substances as products.

- Climate Change - Refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle. The consequences of climate changes, nowadays includes, among others, intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms and biodiversity declining.

- Combustion – A chemical reaction between substances, usually including oxygen and usually accompanied by the generation of heat and light in the form of flame.

- Primary Energy - Is an energy form found in nature that has not been subjected to any human engineered conversion process. It can be energy contained in raw fuels, or it can be other forms of energy, including waste, received as input to a system. Primary energy can be non-renewable or renewable.

- Energy Conservation Principle - Principle of physics according to which the energy of interacting bodies or particles in a closed system remains constant.

- Energy Transfer process – Energy transfer is the process by which energy is relocated from one system to another, for example, through the transfer of heat, work or mass transfer. Thermal energy transfers only occur in three ways: through conduction, convection, and/or radiation. When thermal energy is transferred between neighbouring molecules that are in contact with one another, this is called conduction. Convection is the transfer of heat energy in a fluid. Radiation is the transfer of heat energy through space by electromagnetic radiation.

- Energy Transformation Process - Energy transformations are processes that convert energy from one type (e.g., kinetic, gravitational potential, chemical energy) into another. Any type of energy use must involve some sort of energy transformation. For example, the transformation of oil, gas, or hydraulic power into electric power.

- Indoor Air Pollution - Refers to chemical, biological, and physical contamination of indoor air. It may result in adverse health effects. In developing countries, the main source of

https://doi.org/10.17758/URUAE17.AE09221009

indoor air pollution is biomass smoke which contains suspended particulate matter (5PM), nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (Ca), formaldehyde and polycyclic aromatic hydrocarbons (PAHs).

- Outdoor Air Pollution - It´s often referred to as ambient air. The common sources of outdoor air pollution are emissions caused by combustion processes from motor vehicles, solid fuel burning and industry. Other pollution sources include smoke from bushfires, windblown dust, and biogenic emissions from vegetation (pollen and mould spores).
- Renewable Energies - Are ways to generate energy from (theoretically) unlimited natural resources. These resources are either available with no time limit or replenish more quickly than the rate at which they are consumed. Renewable energies are also often referred to as “green energies” or “clean energies”. Still, this doesn’t mean that these energies aren’t harmful to the environment and have zero impact. Nonetheless, they have a low environmental impact compared to fossil fuels.
- Sustainable Energy Management - Combines management skills with an understanding of responsible energy resources use and the development of sustainable sources of energy (e.g., wind, solar, biomass, hydro, geothermal, etc.)

3. Knowledge

Physics concepts:

- Energy production.
- Energy transfer.
- Energy conservation.
- Primary energy and fuels.
- Renewable energy sources.
- Non-renewable energy sources.

Environmental health concepts:

- Environmental determinants of health.
- Pollution, climate change.
- Indoor air pollution, sources.
- Outdoor air pollution, sources.
- Air pollution as a risk factor for non-communicable diseases (e.g.: chronic pulmonary disease).

Epidemiology and health economics concepts:

- Indicators of disease burden related with air quality loss (e.g.: deaths caused by indoor and outdoor air pollution).

Social and global health concepts:

- Sustainable Development Goals (SDG 3 in relationship with 7, 11, 12, 13)
- Growing urbanization and environmental health challenges.
- Public policy on air pollution and energy-related issues.

Knowledge - outcome assessment:

- Recognizes that the production of carbon dioxide is the primary factor driving anthropogenic climate change.
- Defines the concept of primary energy and its sources.
- Identifies several ways of energy production and energy transfer.
- Recognizes the difference between renewable and non-renewable energy sources.
- Identifies the advantages of using renewable energies and challenges associated with the use of these type of energy.
- Identifies measures and proposes general action to fight climate change.

C. Specifications for an educational scenario on the topic of “noise pollution and quality of life”

1. Context and relevance of the scenario for public health education

Noise pollution is a societal problem, particularly prevalent in city environment, with well-documented public health impacts. Exposure to noise can negatively affect a whole day of work, or even a night's sleep, reduce day-to-day productivity and harm people health and quality of life. According to the World Health Organization, noise pollution is one of the most important determinants of health. 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 protection of wildlife and humans’ health and well-being, public discussions under the topic should be taken frequently, and assessments of noise intensity in specific situations/contexts/environments are recommended, to compare with the recommended limits. The scenario makes available for students a tool that supports upload of audio files and displays histograms, spectrograms, frequency, and amplitude values. A table with identified and expected risks is developed for each frequency, amplitude, and duration time, based on scientific studies. 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 have an effect on the health and quality of life of the community.

2. Content Glossary

- Amplitude – In physics, it is the maximum displacement or distance moved by a point on a vibrating body or wave measured from its equilibrium position. It is equal to one-half the length of the vibration path.
- Decibels - It is used as a unit for expressing the ratio between two physical quantities, usually amounts
- Of acoustic or electric power, or for measuring the relative loudness of sounds. One decibel (0.1 bel) equals 10 times the common logarithm of the power ratio.
- Frequency – In physics, it is the number of waves that pass a fixed point in unit time; also, the number of cycles or vibrations undergone during one unit of time by a body in periodic motion. A body in periodic motion is said to have undergone one cycle or one vibration after passing through a series of events or positions and returning to its original state.
- Loudness – It is the attribute of a sound that determines the magnitude of an auditory sensation and that primarily depends on the amplitude of the sound wave involved.
- Noise - Noise is defined as unwanted sound. In engineering, noise has the additional connotation of signals varying over time without meaning, whereas sound connotes meaningful signals. From a physics standpoint, there is no distinction between noise and desired sound, as both are

vibrations through a medium, such as air or water.

- Noise pollution – It is an unwanted or excessive sound that can have deleterious effects on human health, wildlife, and environmental quality. Noise pollution is commonly generated inside many industrial facilities and some other workplaces, but it also comes from highway, railway, and airplane traffic and from outdoor construction activities.
- Period – Period refers to the time that takes to do something. Frequency and period are distinctly different, yet related, quantities. Frequency refers to how often something happens. Period refers to the time it takes something to happen. Frequency is a rate quantity. Period is a time quantity. Frequency is the cycles/second. Period is the seconds/cycle. In Physics period is the time required for one complete cycle of vibration to pass a given point.
- Sound – It´s a pressure wave which is created by a vibrating object. These vibrations set particles in the surrounding medium (typical air) in vibrational motion, thus transporting energy through the medium. Since the particles are moving in parallel direction to the wave movement, the sound wave is referred to as a longitudinal wave.
- Timbre – It is a parameter used to distinguish between two sounds when they are of the same frequency. Every sound we hear depends on its source. Sound timbre is known as the characteristic waveform of sound that depends on the material from which it produces.
- Vibration – It´s the oscillating, reciprocating, or other periodic motion of a rigid or elastic body or medium forced from a position or state of equilibrium. It can also be defined as the analogous motion of the particles of a mass of air or the like, whose state of equilibrium has been disturbed, as in transmitting sound.
- Wave - A wave can be described as a disturbance that travels through a medium from one location to another location. Consider a slinky wave as an example of a wave. When the slinky is stretched from end to end and is held at rest, it assumes a natural position known as the equilibrium or rest position.
- Wave-length – It´s the distance between corresponding points of two consecutive waves.

3. Knowledge

Physics concepts:

- Noise.
- Pitch.
- Timbre.
- Decibels.
- Wave Sound.

Environmental health concepts:

- Environmental determinants of health.
- Noise pollution, health impacts.
- Noise pollution, sources.
- Noise pollution as a risk factor for the quality of life.

Epidemiology and health economics concepts:

- Indicators of loss of quality of life due to noise pollution (e.g.: decrease of productivity in work, school, etc…).

Social and global health concepts:

- Sustainable Development Goals (SDG 3 in relationship with other SGDs).
- Growing urbanization and environmental health challenges.
- Public policy on noise pollution and its determinants.
- Relationship between lifestyle and noise pollution (determinants of health).

Knowledge - outcome assessment:

- 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 measure, reduce or mitigate exposition to noise.
- Identifies relevant action to address challenges related with harmful noise exposition at the community and societal level.

IV. Conclusion

Students as the centre of project-based learning is the big change given by this project. From the time being, few opportunities are offered to students to solve complex and large global problems. Problem solving involves, on the part of students, the reading and interpretation of statements, the mobilization of knowledge of facts, concepts and relationships, the selection and proper application of rules and procedures, previously studied and trained, the review whenever necessary, the recommended strategy and the interpretation of results. More than that, having a problem that is not solved in a single classroom but are brought outside the 50 minutes scheduled class gives more involvement of students. Problem solving should in this context not be confused with vague activities of exploration and discovery which, being able to constitute motivation strategies, do not prove to be adequate for the effective realization of such a demanding purpose. In Project Based Learning, students are protagonists and have an active voice. That means they need to develop autonomy. To do so, students must decide the paths to follow in their projects, recounting the guidance of the teacher.

The time to present the completed project is critical for students but periodically presentations are promoted. This encourages communication and leadership, while encouraging them to evolve into next projects. There is also preparation for the professional market, since presentations of projects, results, plans, among other topics are common in the business world. Although students may begin by presenting more informal resolution strategies, using schemes, diagrams, tables or other representations, they should be encouraged to progressively resort to more systematic and formalized methods. Presentation of the report of simulations by students in a community setting and dissemination of evidence recommendations via social, community and conventional media.

REFERENCES

[1] Partnerships for science education Project description, available online: https://cordis.europa.eu/project/id/101006468

[2] H. S. Barrows, “Problem-based, self-directed learning,” Journal of the American Medical Association, vol. 250, no. 22, pp. 3077-3080, 1983. https://doi.org/10.1001/jama.250.22.3077

[3] Special report no 16/2016: EU education objectives: programmes aligned but shortcomings in performance measurement, EUROPEAN COURT OF AUDITORS, ISBN 978-92-872-5187-9, ISSN 1831-0834, https://doi.org/10.2865/573605

[4] S. Wolk, “Project-based learning: Pursuit with a purpose,” Education Leadership, vol. 52, no. 3, pp. 42-45, 1994.

[5] D. K. Meyer, J. C. Turner, and C. A. Spencer, “Challenge in a mathematics classroom: Students' motivation and strategies in project-based learning,” The Elementary School Journal, vol. 97, no. 5, pp. 501-521, 1997. https://doi.org/10.1086/461878

[6] Butzin, S. M. (2001). Using instructional technology in transformed learning environments: An evaluation of project CHILD. Journal of Research on Computing in Education, 33(4), 367–373. https://doi.org/10.1080/08886504.2001.10782321

[7] Schoon, I. and S. Parsons (2002), “Teenage aspirations for future careers and occupational outcomes”, Journal of Vocational Behavior, Vol 60/2, Elsevier, Amsterdam, pp. 262–288. https://doi.org/10.1006/jvbe.2001.1867

[8] Yetkiner, Z. E., Anderoglu, H., & Capraro, R. M. (2008). Research summary: Project-based learning in middle grades mathematics, Retrieved from http://www.nmsa.org/Research/ResearchSummaries/ProjectBasedLearninginMath/tabid/1570/Default.aspx

[9] Edutopia (2008), Project-Based Learning Research Review: Evidence-Based Components of Success, https://www.edutopia.org/pbl-research-evidence-based-components

[10] Thomas, J. W. (2000). A review of research on project-based learning. San Rafael, CA: Autodesk Foundation.

[11] Markham, T., Larmer, J., & Ravitz, J. (2003). Project-Based Learning Handbook: A Guide to Standards Focused Project-Based Learning for Middle and High School Teachers. Novato, CA: Buck Institute for Education.

[12] Boaler, J. (2002). Learning from teaching: Exploring the relationship between reform curriculum and equity. Journal for Research in Mathematics Education, 33(4), 239-258. Retrieved from http://tnl.esd113.org/cms/lib3/WA01001093/Centricity/ModuleInstance/276/BoalerReformCurriculumandequity.pdf https://doi.org/10.2307/749740

[13] Strobel, J. & van Barneveld, A. (2008). When is PBL more effective? A Meta-synthesis of metaanalyses comparing PBL to conventional classrooms, Interdisciplinary Journal of Problem-based Learning, 3(1), Article 4. Retrieved from http://docs.lib.purdue.edu/ijpbl/vol3/iss1/4 https://doi.org/10.7771/1541-5015.1046

[14] Wasley, P. & Lear, R. (2001). Small schools, real gains. Educational Leadership, 58(6). Retrieved from http://www.txechs.com/downloads/19_smallschoolsrealgains.pdf

[15] Tiwari A, Lai P, So M, Yuen K. A comparison of the effects of problem-based learning and lecturing on the development of students' critical thinking. Med Educ. 2006 Jun;40(6):547-54. doi: 10.1111/j.1365-2929.2006.02481.x. PMID: 16700770.

[16] Clark, A. C. & Ernst, J. V. (2007). A model for the integration of science, technology, engineering and mathematics. The Technology Teacher, 66(4), 24–26.

[17] Mello, Z., (2008), “Gender variation in developmental trajectories of educational and occupational expectations and attainment from adolescence to adulthood”, Developmental Psychology, Vol. 44/4, APA Publishing, Washington DC, pp. 1069–1080. https://doi.org/10.1037/0012-1649.44.4.1069

[18] J. Ravitz, “Beyond changing culture in small high schools: Reform models and changing instruction with project-based learning,” Peabody Journal of Education, vol. 85, no. 1, pp. 290-312, 2010. https://doi.org/10.1080/0161956X.2010.491432

[19] Kaldi, S., Filippatou, D. & Govaris, C. (2011). Project-based learning in primary schools: Effects on pupils’ learning and attitudes. Education 3–13, 39(1), 35–47. https://doi.org/10.1080/0161956X.2010.491432

[20] Stohlmann, Micah; Moore, Tamara J.; and Roehrig, Gillian H. (2012) "Considerations for Teaching Integrated STEM Education," Journal of Pre-College Engineering Education Research (J-PEER): Vol. 2: Iss. 1, Article 4. https://doi.org/10.5703/1288284314653

[21] D. Bédard, C. Lison, D. Dalle, D. Côté, and N. Boutin, “Problem-based and project-based learning in engineering and medicine: Determinants of students‟ engagement and persistence,” Interdisciplinary Journal of Problem-Based Learning, vol. 6, no. 2, pp. 7-30, 2012. https://doi.org/10.7771/1541-5015.1355

[22] M. C. English and A. Kitsantas, “Supporting student self-regulated learning in problem and project-based learning,” Interdisciplinary Journal of Problem-Based Learning, vol. 7, no. 2, pp. 128-150, 2013. https://doi.org/10.7771/1541-5015.1339

[23] Sunyoung Han, Robert Capraro, Mary Margaret Capraro (2015), How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: the impact of student factors on achievement, International Journal of Science and Mathematics Education 13: 1089Y1113 https://doi.org/10.1007/s10763-014-9526-0

[24] Hughes, D. et al., (2016), Careers Education: International Literature Review, Education Endowment Foundation, London. Kashefpakdel, E. and C. Percy (2017), “Career education that works: An economic analysis using the British Cohort Study”, Journal of Education and Work, Vol. 30/3, Taylor and Francis, London, pp. 217-234. https://doi.org/10.1080/13639080.2016.1177636

[25] Alberta Education (1990). STS science education - unifying the goals of science education. Alberta: Curriculum Support Branch.

[26] Bárrios, A., Sá. E.M., Cunha, I.M., Castro, J., Dias de Deus, J., Adragão, J.V., Feytor Pinto, P. & Pena, T. (1999). Inovação nos planos curriculares dos ensinos básico e secundário – Reflexões sobre programas de Língua Materna, Matemática e Ciências

[27] Conselho Nacional da Educação (2000). Parecer 2/2000 – Proposta de reorganização curricular do ensino

[28] Galvão, C., Freire, A.M., Neves, I. & Pereira, M. (2000). Competências Essenciais em Ciências no Ensino Básico. http://www.deb.min-edu.pt/NewForum/ciencias.pdf

[29] Gräber, W & Nentwig, P. (1999). Scientific literacy: bridging the gap between theory and practice.

[30] Ministério da Educação, Departamento da Educação Básica. (1999). Reflexão Participada sobre os Currículos do Ensino Básico. Lisboa

[31] Ministério da Educação, Departamento da Educação Básica. (1999). Ensino Básico Competências gerais e transversais. Lisboa

[32] Ministério de Educação, Departamento da Educação Básica (2201). Reorganização curricular do Ensino Básico – Princípios, medidas e implicações. Lisboa: Autor.

[33] Wenham, M. (1995). Understanding primary science: ideas, concepts and explanations. London

[34] Sweller, J., Clark, R. & Kirschener, P., Teaching general problem-solving skills is not a substitute for, or a viable addition to, teaching mathematics (pp. 1303-1304), Doceamus 57(10), 2010.