ISBN-978-989-9121-01-0
LISBON 18th International Conference on "Innovations in Science, Engineering & Technology" (LCISET-22)
Lisbon (Portugal) April 13-15, 2022

Energy Games Development Considering Energy, Economic and Environmental Indicators

Nuno Domingues[1], Nuno Henriques[1], J. M. F. Calado[1,2], Miguel A. Brito[3], Elina Megalou[4], Eliza Rybska[5], Paulo Martins[6,7], Carolina Santos[8,9]

[1] Instituto Politécnico de Lisboa/ Instituto Superior de Engenharia de Lisboa
Rua Conselheiro Emidio Navarro, 1, 1959-007 Lisbon, Portugal
[2]IDMEC, Instituto Superior Técnico, Universidade de Lisboa
[3] Centro Algoritmi, University of Minho
[4] Computer Technology Institute and Press "DIOPHANTUS" (CTI)"
[5] Adam Mickiewicz University, Faculty of Biology, Laboratory for Teaching Biology and Natural Sciences, Umultowska 89, 61-614 Poznań, Poland
[6] UTAD - University of Trás-os-Montes e Alto Douro, Quinta de Prados, 5001-801, Vila Real, Portugal
[7]INESC TEC, Rua Dr. Roberto Frias, 4200-465, Porto, Portugal
[8] National School of Public Health, NOVA University of Lisbon, Avenida Padre Cruz, 1600-560, Lisbon, Portugal
[9] Comprehensive Health Research Centre, NOVA University of Lisbon, Lisbon, Portugal.

***Abstract*:** *Science teachers are faced with the challenge of students' motivation for their own lectures and subjects. This is highly relevant in High Schools where students tend to perceive school as boring and not having any connection to their personal lives. Also, at these ages students' autonomy grows and they take decisions regarding attendance and attention in the classroom.*

A consortium of 9 Parties from 5 Countries decided to deal with the challenge and elaborated a proposal that was approved by the European Commission: PAFSE – Partnerships for science education. PAFSE is engaging schools, universities, research centres, libraries, enterprises, municipalities, non-governmental organisations, and parents' associations, in the efforts of designing and implementing innovative educational scenarios aiming to boost students' interest in public health science and STEM careers. This science education network will reinforce students' competencies in dealing with diseases such as zoonosis from a community perspective and in connection with the Agenda for Sustainable Development. The present paper introduces the project and an educational scenario on the topic "Energy sources, climate change, and public health impact". PAFSE started in September of 2021 and lasts for a 3-year period. The project is supported by the Portuguese Directorate for Education.

The project will strengthen pre-existing relationships and build new ones, thereby will improve the collaboration between stakeholders, schools, and their communities. PAFSE, involves public health scientists and epidemiologists, creating a supportive network for schools, universities, and other education providers for the benefit of education and well-being. PAFSE will bring students' learning experience closer to the EU development goals, recognized societal needs, and the reality of professional and research organisations. By doing so, it will develop a mechanism for aligning "school education" with "societal challenges" and "professions". Therefore the goal for the general public is extensive and key for students' motivation and learning.

Keywords: *design engineering, design research, design tools, didactical analysis, STEM education, Teaching Tools, student competencies (project management; making sense of scientific evidence), school-community interactions, public health, primary, secondary and tertiary prevention, epidemics*

1. Project description and objectives

The project acts on the dilemma of engaging students and parents in learning and motivating teachers and tutors in instruction. Working at local, national, and european level, the project involves civil organizations, parents' committees, associations, enterprises, and every stakeholder engaged in Science, Technology, Engineering, Mathematics (STEM) education. PAFSE delivers a set of open access educational scenarios supported by scripts for teachers, to assure appropriate enactment of the teaching-learning activities in the classroom and outside it, with the support of stakeholders. Even though the project aims to engage students aged 12-15, Universities, Research Centres, and Project-oriented organizations are the dynamizing agents. The digital tools and online teaching-learning environments developed by the Consortium are complemented by in-class debates and open schooling events, so PAFSE combines formal and informal learning activities. [1] [2]

The Project-Based Learning framework guides students through active, hands-on, and motivating learning experiences. Project-Based Learning (PBL) is focused on the construction of knowledge through a long and continuous work of study, whose purpose is to answer a question, address a challenge or solve/mitigate a problem. When building projects, students learn in an autonomous and protagonist way, but with the full support and guidance of their teachers. From this point, students begin a process of research, establishing hypotheses and searching for resources to conduct the project. It also involves the practical application of the information obtained until reaching a final product or a satisfactory solution to the initial question. A challenging problem is launched to a group of students, with no easy answers that can be obtained quickly. It is necessary to stimulate the imagination, encouraging students to find the answers and build solutions (outputs of the project). So, PBL connects the teaching process with societal challenges, the everyday lives of students - making them inseparable. Methodologically, PBL involves exploring the context, developing ideas from knowledge, and peer-to-peer communication. A great advantage of this methodology still lies in the fact that students can organize their findings through graphs and statistics, videos, applications, and simple programs, among other multimedia instruments. Using these tools, pupils demonstrate their expertise through presentations or products relevant for end-users and real audiences. PBL focuses on the process of developing knowledge and competences in real-world problems and challenges students to develop specific skills while working collaboratively. [3] [4] [5] [8] [9] [12] [13] [14] [15] [16] [17] [18] [20] [22] [23] [24] [25] [26] [27] [28] [29] [31] [32]

2. Educational scenario development and methodology

When following PBL, the teacher doesn't expose all the planned teaching content, so that the classroom can build the relevant questions and start research work. Then, students themselves search for the materials and knowledge to achieve the proposed learning purposes. The teacher's role, in this case, is to act as an advisor, intermediating and collaborating on time with the students. So, for the same initial question, the teams can reach different answers and results, being able to even add different and complementary knowledge to each other. [29][30][31][32]

Usually, the following steps are followed by the teacher when applying PBL:

- a problem is suggested
- students investigate possible causes and develop hypotheses
- after getting to know the challenge and its origins better, they define tactics for solving the challenge
- establish a plan
- present the plan and execute it, being able to demonstrate the results later

- are evaluated by the advisor.

The key point is that each student can interact with their reality, identify what is wrong and understand what needs to be improved or resolved. From there, the student should suggest one or more ways to prevent or solve the challenge. Due to this factor, PBL manages to involve the hybrid teaching of different resources and methods and aims to foster transdisciplinary in the development of solutions or answers. In other words, it encompasses themes, competencies, and resources from various academic subjects. [6] [7] [10] [11]

In addition, the student can also learn some essential processes for conducting projects, such as:

- elaboration of hypotheses.
- refinement of ideas.
- making forecasts.
- experimenting with hypotheses.
- data collection.
- carrying out new questions.
- development of concrete materials (applications, reports, documents, etc.).

There are some requirements to apply PBL in a class. First, having a complex question that sparks curiosity and student participation. It is from there that the program is developed. It is worth mentioning that the paths taken to answer it do not need to be defined in advance, as each student or group can find different approaches to address the challenge, but equally satisfactory. Second, the initial idea, the question, and the project must be developed, considering what is expected from the class. Students acquire skills by exercising:

- communication.
- logical reasoning.
- collaboration and group work.
- creativity-
- reflective thinking.
- the use of different technological resources.
- the measurement and control of time.
- frustration tolerance (when projects don't go as expected).
- resilience.
- persistence through trial and error, etc.

Third, students are asked to search broadly, conducting searches across multiple engines and media, and assessing the trustfulness of sources. It is recommended that they also search for information in different formats, going beyond the most common ones (videos, posts, and articles). In this case, it is desirable that they organize interviews, surveys, forums, and reports, among other inquiry-based resources, without, of course, forgetting the books. The content must be in-depth, in addition to being relevant to the professional and academic growth of students.

Problem-based learning is associated with the progressive education movement that advocated teaching centred on students' out-of-school experiences. This methodology, in addition to curricular learning, favours the development of transversal skills, such as:

- Problem-solving and decision making.
- Collaboration and teamwork.
- Communication capacity.
- Reflection on one's own learning (metacognition).
- Critical thinking.
- Lifelong learning.

To be implemented, the teaching-learning pathway goes through the following steps:

- Students are presented with a problem. The students, in groups, organize their ideas and try to solve it with the knowledge they already have about the subject in question. In this way, they assess their knowledge and define the nature of the problem.
- Through group discussion, students develop questions or learn questions about aspects of the problem under study. These questions are noted by the group. Students are continually encouraged to define what they know and, above all, what they do not know about the problem.
- Students rank the learning issues raised by the group in order of importance and decide which issues will be investigated by the whole group and which will be asked individually and later shared with the rest of the group. The students and the teacher can also discuss what resources are needed in the investigation phase, taking into account the learning issues.
- As a group, students explore learning issues, integrating new knowledge to try to answer the starting problem. At this stage, students must make a synthesis of the new knowledge, relating it to what they already knew. It is normal that, as they progress in answering the problem, they continue to define new learning questions. In this way, they realize that learning is a continuous process and that there will always be – even for the teacher – learning issues to be explored.
- After finishing the work and finding the answer to the problem, students evaluate themselves and in pairs, and they develop the ability to reflect on their learning.
- the concepts needed to solve the problem must be presented and discussed with the students.
- problems must be clearly defined.
- problem analysis involves asking, explaining, and formulating hypotheses.
- the new information collected must be summarized and presented.

Below, is an example of a provisional plan for educational scenaria on topics, competencies, knowledge, skills, and attitudes considered relevant for managing a defined public health threat. The scenario is being developed under the topic "Energy sources, climate change, and public health impact".

Context

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 (heat stress, chronic respiratory and cardiovascular diseases, cancers) are supported by considerable evidence. Energy consumption highly contributes 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 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 scenario is supported on a game in which the forms of energy production used depend on the decision of the students. After choosing the energies, the environmental impact and economic outcomes are evaluated. With this scenario, we will be promoting, in an interactive and fun way, awareness on implications of energy choices on air pollution, on the planet and for community health.

Competences / Learning Goals

Key Competences

STEM/ personal, social

Learning goals and outcomes

- Uses online tools to plot tables, graphs, and maps, using updated data.
- Analyses how the consequences of unconscious behaviour can contribute to the increase of climate change.
- Obtains, evaluates, and communicates data and scientific information about energy sources, energy production, and energy transfer.
- Gives examples on how climate change is already affecting the planet and humans' life and well-being.
- Describes different approaches to protect, develop and influence community health.
- Uses evidence to propose measures and methods to fight climate change and communicates them to the community leadership.

STEM content

- Energy conservation principle.
- Energy transfer processes (conduction, convection, and radiation).
- Combustion.
- Chemical reactions.
- Sustainable Energy Management.
- Renewable Energies.
- Process of Transformation of Primary Energies (Oil, Coal, etc..), into Useful and Sustainable Energy (Electric Energy)
- Sources of indoor and outdoor air pollution.
- Air pollution as an environmental determinant of health and associated medical conditions.
- Burden of disease attributable to ambient air pollution.

Non-STEM content

- Lifestyles, Urbanisation, and Climate Change.
- Strategies to maintain quality of life and sustain basic needs with low energy consumption.
- Strategies to have access to clean and affordable energy and avoid waste.

Digital learning objects

New (*developed by PAFSE team*):

- Evidence about Climate Change (*infographic)*
- Consequences of Climate Change *(images)*
- Evidence about Primary Energy and Their Sources (*infographic)*
- Management and Energy Production (*infographic)*
- Renewable Energy Sources and the advantages of their use (*infographic)*
- Sources of Air Pollution (*infographic)*
- Consequences of Air pollution (*images)*
- Strategies to decrease energy waste (*infographic)*
- Repository of resume and exercises (solved or with solution) (*infographic)*
- Communication Brochures, banners, posters and others (*images)*

Complementary/from other sources:

- https://www.edfenergy.com/for-home/energywise/renewable-energy-sources
- https://www.empower-solar.com/blog/the-advantages-disadvantages-of-switching-to-solar-energy/
- https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy
- https://vittana.org/12-pros-and-cons-of-oil-energy
- https://www.energy.gov/ne/articles/advantages-and-challenges-nuclear-energy
- https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Measuring-the-Economics_2016.pdf
- https://www.renewableenergymagazine.com/emily-folk/the-many-economic-benefits-of-renewable-energy-20190312

Teaching -learning activities (topics)

- Lesson 1: Identify and compare primary energy sources
- Lesson 2: Search, understand, and debate how energy consumption varies over the year, the month, and the day
- Lesson 3: Explore combinations of primary energies to satisfy energy consumption needs
- Lesson 4: Quantify the energy share of each primary energy
- Lesson 5: identify measures and behaviours to reduce energy consumption without loss of comfort and basic needs

- Lesson 6: analyse the influence of energy consumption reduction on the economic, energetic, social, environmental, and health parameters

School Research Project

- **Challenge:** build an infographic about Energy Rationalization!
- **Method (summary):** students are organized in groups; each group addresses several ways to conduct energy rationalization in their school. The project challenges each group of students to create and present an infographic that synthetizes a) What they have learned throughout the teaching-learning sequence; b) Actions to reduce energy consumption at the school level; c) Relevant outcomes due to the application of such measures. By following this process, at the end of the project students will have understood the importance of rationale use of energy.

The game is based on s set of cards that represent each available primary energy source, describing the characteristics that dynamize the debate and are suitable for the learning aims. Table 2 illustrates the layout of a general game card of the game development learning scenaria.

Table II. Layout of the game card the game development learning scenaria

English	**Português**	**Other Languages**	**Photo**
– Name: – Chemical symbol: – Units: – Calorific power: – CO_2 emissions – state at room temperature – producing countries – forms of storage – Ways of transport: – Conversions: – Efficiency of power plants – Starting time – Out of service time	– Nome: – Símbolo químico: – Unidades: – Poder calorifico: – Emissões CO_2 – Estado à temperatura ambiente – Países produtores – Formas de armazenamento – Formas de transporte: – Conversões: – Rendimento das centrais – Tempo de entrada em serviço – Tempo de não funcionamento		Photo

3. Conclusion

PAFSE project is engaging schools, universities, laboratories, enterprises, public health authorities, research centres, libraries, and associations, with the mission of developing educational clusters that foster improved science education. The innovative character of PAFSE is that it explores science education as a vehicle to provide citizens with the knowledge, tools, and skills to make informed decisions on public health challenges. A positive impact on students' knowledge, skills, and behaviour is anticipated using project-based learning, problem-based learning, and interdisciplinary classroom learning activities.

Evidence suggests that PBL stimulates the development of relevant skills in the 21st century, such as autonomy, proactivity, and curiosity for problem-solving. It also encourages interpersonal communication and teamwork, both among students and between students and teachers. Thus, the educator becomes a guiding collaborator and not just the person in charge of passing content vertically. In addition to encouraging students to solve problems alone, and as a team through trial and error, PBL focuses knowledge development on everyday dilemmas, that are real-life issues. For this, projects are developed, just as companies do, but on a smaller scale.

Due to this way of operating, PBL works as an active training method, proposing the inclusion of practical activity as a teaching tool. Therefore, PBL is based on practice combined with academic teaching.

Problem-Based Learning is a teaching methodology that promotes active student-centred learning by confronting them with complex real-world problems. Students are led to problematize, reflect, assign meaning to their learnings, and find the answers to the problems presented to them. In this sense, this methodology, in addition to favouring essential skills for lifelong learning, stimulates critical thinking, collaboration, creativity, and open communication.

PAFSE involves students aged 12-15 on a blend of formal and informal learning activities, using digital tools and online teaching-learning environments to develop their competencies in project management and processing of scientific evidence, on relevant public health topics in a society and community perspective.

Collaborative projects involving community stakeholders are designed based on a problem recognized by all as relevant and students develop significant outputs that are presented and discussed in open schooling events. Thereby, we also anticipate a positive impact of PAFSE on teachers' literacy, and in the way they transfer knowledge.

The project is organized in each country in connection with STEM curricula so that members of the consortium can have feedback on the appropriateness of the learning objects and educational scripts to activate the scenarios in an inclusive and meaningful manner.

Acknowledgements

Authors wish to thank all the partners of the PAFSE consortium.

Funding

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

References

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

[2] 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

[3] 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

[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] 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.

[9] 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.

[10] 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

[11] 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

[12] 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/10.1080/03004270903179538

[13] H. Lattimer and R. Riordan, "Project-based learning engages students in meaningful work," Middle School Journal, vol. 43, no. 2, pp. 18-23, 2011.

https://doi.org/10.1080/00940771.2011.11461797

[14] Benbow, C. P. (2012). Identifying and nurturing future innovators in science, technology, engineering, and mathematics: A review of findings from the study of mathematically precocious youth. Peabody Journal of Education, 87(1), 16–25.

https://doi.org/10.1080/0161956X.2012.642236

[15] 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

[16] C. Zhou, A. Kolmos, J. Nielsen, and D. Frederik, "A problem and project-based learning (PBL) approach to motivate group creativity in engineering education," International Journal of Engineering Education, vol. 28, no. 1, pp. 3-16, 2012.

[17] 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

[18] 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

[19] Vuolo, M., J. T. 2Mortimer and J. Staff (2014), "Adolescent precursors of pathways from school to work", Journal of Adolescent Research, Vol. 24/1, Sage Publications, California, pp. 145–162.

https://doi.org/10.1111/jora.12038

[20] L. Mataka and P. Madalitso, “Problem-based learning (PBL) in the college chemistry laboratory: Students' perceptions of PBL and its relationship with attitude and self-efficacy beliefs,” Western Michigan University, ProQuest, UMI Dissertations Publishing, 2014.

[21] 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

[22] The Effect of Project-Based Learning on Learning Motivation and Problem-Solving Ability of Vocational High School Students, C. L. Chiang and H. Lee, International Journal of Information and Education Technology, Vol. 6, No. 9, September 2016

https://doi.org/10.7763/IJIET.2016.V6.779

[23] 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

[24] Musset, P. and L. Mytna Kurekova (2018), "Working it out: Career guidance and employer engagement", OECD Education Working Papers, No. 175, OECD Publishing, Paris https://doi.org/10.1787/51c9d18d-en

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

[26] 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

[27] 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

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

[29] Barrows, H. S.; Tamblyn, R. M (2003). Problem-based learning: an approach to medical education. Springer series on medical education (vol. 1). Springer Publishing company: New York.

[30] Dewey, J. (1916). Democracy and education: An introduction to the philosophy of education. New York, NY: The Free Press.

[31] Duch, B., Groh, S. E., and Allen, D. E. (2001). The Power of Problem-Based Learning: A Practical “How-to” for Teaching Undergraduate Courses in Any Discipline. Sterling, Va.: Stylus.

[32] Barrows, H. S. (2000). Problem-based learning Applied to medical education. Springfield: Southern Illinois University Press.