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HOW TO LEARN SCIENCE LITERACY? OVERVIEW OF MOST TOPICAL AND RESEARCHED LEARNING APPROACHES

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ABSTRACT

Rising levels of disinformation and fake news have been posing risk to democracy, public health and wellbeing of a democratic society, an issue becoming even more evident during Covid-19 pandemic. Thus, in the current post-truth era, where opinions are becoming more important than facts, scientific literacy skills enhanced by education is seen as one of the solutions to help combat a threat of misleading information. In order to understand the most effective educational approaches that aims to enhance science literacy skills, systemic literature review of the research articles published between year 2018 and 2021 were performed. The goal of this systemic literature review is to gain an overview on the most researched learning techniques and approaches that has proven to successfully improve educational processes and enhance scientific literacy and understanding of science. After content analysis of 262 article abstracts containing keywords "Science literacy" or "Scientific literacy" on the *Web of Science* database, a total of 54 articles were identified that had described a learning approach or a technique that has improved learning process and results in the subjects of science, technology, engineering or mathematics while enhancing general understanding of science and improving science literacy. It was found that the following learning approaches were seen to be effective when improving scientific literacy skills – **citizen science**, **context-based learning**, **inquiry-based learning** (including discovery learning method, guided inquiry, and active learning), **problem-based learning** and **socio-scientific learning approach**. Each of the approaches were analysed and compared to find common/different aspects that can help identify and choose the right approach for specific target audience.

Keywords: *Scientific literacy, science literacy, disinformation, education, learning approaches*

Introduction

Current technology and information driven society requires necessary skills and ability to make a critically evaluated decisions, choices and opinions. To discern falsehoods and pseudoscience from science-based information, it is important to have a thorough understanding on how data-supported claims are made and how valid reasoning is different from well-presented personal opinions (Edelsztein & Vázquez, 2021). That, in turn, requires relevant competencies and skills to effectively evaluate available data and scientific facts while considering many variables and conditions that could potentially confuse or mislead (Golumbic et al., 2020). Scientific literacy can be described as all the above-mentioned skills – as an ability to recollect and apply the scientific knowledge learned in the face of real-life problems, contributing to informed decision-making society. This complex skillset offers a thorough understanding of scientific processes and methods as well has how science, technology and society are interrelated, affecting own life, health and well-being (Queiruga-Dios et al., 2020). One of the most essential skills of a scientifically literate individual is the ability to engage in the science related discussion in their everyday lives (Garrecht et al., 2021).

Science literacy is stated as one of the key competencies in the framework of *PISA*, defining it (science literacy) as an ability to comprehend, understand and use the scientific knowledge in broader concept, allowing this knowledge to be used to achieve broader goals (OECD, 2019). Scientific literacy can also contribute to higher citizen engagement in democratic and civic processes, therefore should be closely linked and addressed in combination with other educational goals and activities. To successfully implement scientific literacy competencies into the overall teaching strategy that could help enhance science literacy skills in young adults, **the goal of this systemic literature review is to gain an overview of the most often researched learning techniques and approaches that has proven to successfully improve educational processes and enhance scientific literacy and understanding of science.**

Methodolgy

To achieve the abovementioned goal of this study, a systemic literature was carried out based on the guidance and steps suggested by Xu Xiao and Maria Watson (Xiao &Watson, 2017).

Firstly, to identify all the research articles and proceeding papers published between year 2018 and 2021 on *Web of Science* database, an initial keyword search was performed. Based on the research question of this study, the relevant keywords "Science literacy" and "Scientific literacy" were used for search resulting in total of 262 articles.

Secondly, to further narrow down the most relevant material for analysis, a qualitative review of all abstracts was performed, developing inclusion and exclusion criteria outlined below.

Exclusion criteria:

- Articles containing an overall measurement of the science literacy skills or understanding in a certain region, school or population;
- Articles measuring or comparing *PISA* results on scientific literacy;
- Articles developing and testing textbooks, learning materials (games, programmes, apps etc.);
- All other articles that are not directly describing or measuring a certain approach or technique of learning strategy concerning scientific literacy;
- All the articles other than in English.

Inclusion criteria:

- All articles involving any type of learning strategy and approach that can be generalised and replicated.

Results

After qualitative analysis of all the articles containing keywords "science literacy" and "scientific literacy", based on the inclusion and exclusion criteria, 54 articles were identified that had described a learning approach that has improved learning process and results in the subjects of science, technology, engineering or mathematics while enhancing general understanding of science and scientific literacy skills.

After careful analysis of **teaching/learning approaches** identified, the following categories used in the context of the enhancement of scientific/science literacy emerged:

- **Citizen science** (4 articles);
- **Context based** (11 articles, using contextual learning, integrated science, contextual approach synonyms, real-life based);
- **Inquiry based learning** (15 articles, including discovery learning method, guided inquiry and active learning);
- **Challenge based learning** (6 articles, including problem-based learning);
- **Socio-scientific approach** (6 articles).

Citizen science

Citizen science connects scientists and non-expert citizens while collaborating on scientific research, allowing ordinary citizens to take part in creating new scientific knowledge. Participation can include various activities such as data collection, data analysis or being part of the debate with experts, at the same time having an opportunity for public to access real time data that may influence their current lives (Golumbic et al., 2020).

Implementing citizen science projects in school curriculum demonstrates more positive attitudes and appreciation towards science, as well as affecting pupils' eagerness to learn and participate. Being able to work on real-life data students are more motivated and eager to take part in the debate whilst forming their own opinions, potentially encouraged to act and contribute to the change of their own environments, health and society in general (Queiruga-Dios et al., 2020).

Context based approach

As part of many different approaches for science teaching context-based approach have been tested in different countries and age groups and have shown positive results, improving scientific understanding and transferable knowledge to other scientific subjects (Edelsztein & Vázquez, 2021). For a successful implementation of context-based learning, the process should aim to involve a clearly defined context in which concepts are used, so that the knowledge gained is of relevance or interest to student as well as applicable to real-life situations (Gilbert et al., 2010). Contextual approach anticipates learning process in which students analyse and solve problems derived from real life problems, allowing to learn concepts of science and apply them to real world situation. Examples include analysing earthquakes and floods (Ulfah, 2019), nutrition and health-related choices, Covid-19 pandemic (Anderson et al., 2020), animal behaviour (Oberbauer et al., 2021) and many more, showing the transferability of those concepts to other scientific issues. Gilbert defined context as a "focal event in its cultural setting" (Gilbert, 2006).

Inquiry based learning

This student-cantered approach and active learning have been one of the keystones in science education for the last decades showing contradicting results. Motivated individuals and those evaluating learning atmosphere in a positive manner perform well, whereas some struggle with this learning approach (Kang, 2020). Instead of just memorising things, inquiry-based process involves planning, exploring, proposing, investigating, evaluating and guiding students' own learning process. Active involvement, observation, problem solving as well as testing the hypothesis and drawing own conclusions can contribute to greater independent thinking and better understanding of science concepts. Active learning as an investigation process that encloses the ability to come up with the research design, lead an experiment and/or gather and evaluate necessary data, present the results and findings show increased science literacy skills, better knowledge of the subject and higher competencies (Sutiani et al., 2021).

Challenge based learning/problem-based learning

Problem-based learning is one of the active learning methods that engages students into open-ended questions and hypothesis-driven research to develop self-directed learning skills and ability to acquire and apply scientific knowledge that can also be applied to other disciplines (Hussa, 2018). This approach is seen to not only improve science literacy and critical thinking skills but also enhance the ability to evaluate information and its sources. Challenge based learning approach a lot of times is mentioned in the same context and interchangeably with the problem-based approach, however, challenge-based approach is more interdisciplinary, collaborative and oftentimes international, aimed at sustainable and urgent result, yet focusing a lot on the process (Gallagher & Savage, 2020).

Socio-scientific approach

As part of problem-based learning approach the issues that is of concern for the whole society such as climate change, water supply, public health and generation of energy are put at the core of the solution-oriented learning. In the process of teamwork and interdisciplinary collaboration students addressing these global issues develop their problem-solving skills as well as enhancing well-informed decision making (Brown & Lawless, 2019). Connecting science to real life issues can enhance students' understanding about global complex issues that affects larger societal matters. Socio-scientific approach allows to develop scientific knowledge while considering potential social implications of a given issue thus thinking of science and its effect on society in a larger global scale (Ke et al., 2021). Putting the learning in the context of everyday life can increase motivation and eagerness to learn and acquire knowledge and promote better understanding of science methods and concepts.

In the final stage of this research, all the identified learning approaches were carefully analysed and compared to one another, resulting in finding key similarities which could point to the crucial qualities and characteristics distinguishing the five identified approaches from the rest when goal is to enhance scientific literacy skills (Table 1).

Table 1

	Citizen Science oriented learning	**Context based learning**	**Inquiry based learning**	**Challenge based (problem-based learning)**	**Socio-scientific approach learning**
Active learning (process)	Yes, definitely	Yes, definitely	Yes, definitely	Yes, definitely	Some, but not emphasising
Self-directed learning (process)	Mostly stems from the research problem or question set by the leading researcher or team	Could be self-directed, could be initiated by the teacher.	Focused on self-directed learning and allows many possible scenarios/solutions to solve the problem (not just one right answer)	Focused on self-directed learning, Various solutions and ways of looking at the same problem	Many sides and angles, which can give a very different perspective on the same issue
Individual responsibility (process and learning outcome)	A lot of the process is externally determined (what and how certain things need to be done)	Individual responsibility is achieved via relevance to students' life and context	Very individual-oriented learning, requiring student to take responsibility for identifying the problem and guide their own learning	Learning process is oriented on the individual work, but the problem/challenge can be presented by the teacher or found by the learner itself	Individual responsibility is achieved via relevance to real life challenges and context
Social & ethical relevance (learning outcome)	Most of the cases are very relevant to broader public, society or environment	Very much oriented for the benefit of the common good while improving individual's cognitive skills	Could be oriented on the common good, could be anything very small and relevant to individual or smaller group	Most of the time is oriented in solving an issue relevant to the broader society	In essence is always oriented towards solving a problem concerning society or environment, very ethically concerned method

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	Citizen Science oriented learning	**Context based learning**	**Inquiry based learning**	**Challenge based (problem-based learning)**	**Socio-scientific approach learning**
Learning as social experience, as communal task	The success of citizen science lies in the crowdsourcing and community engagement, so only functioning in communal process	Can be individual, can be both	Depends on the inquiry and nature of it, but could be individual or communal	Working in groups contributes to testing own hypothesis and knowledge, leading to discussions and collaborations, thus fostering understanding diverse information and knowledge (Jenkins, 2006), also contributing to greater tolerance towards different learning styles	Usually, focused group work to give the opportunity to approach highly complex and controversial issues, leading to more tolerant society
Interrelation with other learning approaches	Citizen science is unique as it's always part of larger research	Context based learning is very much related to real-life based learning, motivating the learner to approach the subject as part of their life, emphasising the relevance	IBL is a broader term, in which problem-based learning is one of the techniques. IBL can also be merged in a project-based learning approach. At the heart of the approach is the method of inquiry, self-directed learning. Unlike challenge/problem-based learning, a problem could already be solved	Problem-based learning is seen as sub-category of Context Based Learning (Overton, 2016), identifying an issue or problem that could be of relevance to both – the individual and the public. At the core of the approach is a problem that needs to be solved (and sometimes there isn't just one way)	Similarly, to challenge/problem-based learning, this approach does not restrict itself to one answer. Socio-scientific approach is considered context based learning, but adds a dimension of social context to the problem

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	Citizen Science oriented learning	**Context based learning**	**Inquiry based learning**	**Challenge based (problem-based learning)**	**Socio-scientific approach learning**
Student-cantered approach	No. Very much solution and result oriented approach	Focusing on student and his active learning process in acquisition of knowledge	Student's ability to lead his own learning process and discovery is seen as major part of this approach	Very much focused on the individual learning and student's own approach, at the same time aiming for a solution for the common good	Focused on developing students reasoning and negotiation skills, considering diverse and controversial issues
Real, concrete context	Citizen-science is real-life oriented, working on scientific project (lots of times environmental) with real-time data	One of the most important factors of the success of this approach is its relevance to the social context. Firstly, the problem is identified, then the necessary theory and knowledge is learned to solve the problem (not the other way round, as per classic education) (Sevian et al., 2018)	Most of the times the approach is using the real-life issues and problems but could also be theoretical	Real-life context and existing problem concerning broader society contributes to deeper understanding of the subject	Real, socially relevant issues are being discussed as part of socioscientific approach, such as climate change, abortion, stem cell use, energy consumption etc. (Betul Cebesoy & Chang Rundgren. 2021)
Any preparation or specific setting needed	No previous knowledge or required skills are needed, anyone can take part as long as they have interest in the topic	Usually some pre-knowledge required, at least an understanding of the topic gained from the real-life	Experienced learners usually perform better, others might struggle with management and time planning (Ellis & Gabriel, 2010)	Experienced learners usually perform better, others might struggle with management and time planning (Ellis & Gabriel, 2010)	Some interest and knowledge about the topic could help in creating engagement

Discussion

After careful analysis of the learning approaches covered in the recent research, it is evident that those above-mentioned are not strictly defined or separated, moreover – a lot of them are used, mixed and integrated, making it harder to discern and draw the borders between them. Comparison outlined in the *Table 1* shows that there are many similarities that can be identified between those approaches, which could point out the key elements to successful learning thus contributing to enhancing critical thinking skills – presence of **1) the real-life based context, 2) active, engaging learning process and 3) social, ethical relevance** to the learner's society.

The real-life based context

Evidence suggests that understanding of the science and ability to apply acquired information will not reach its full potential if gained knowledge fails to be relevant and connected to real life issues (Feinstein, 2010), which is why context-based learning, socio-scientific approach and problem-based learning has proven to be amongst successful approaches when it comes to boosting scientific literacy skills. Choosing research topic that is highly relevant to students' daily lives not only boosted engagement in the learning process, but also facilitated discussion amongst peers and demonstrated how science literacy can be developed via citizen science (Oberbauer et al., 2021).

Active, engaging learning process

Even though inquiry-based and challenge/problem-based approaches can have different learning goals and issues at heart, active and self-directed learning is a key to deeper and more thorough understanding of the problems presented, thus contributing to respectful and reasoned discussion while developing critical thinking from an early age. Research results show that ability to evaluate and form an opinion on controversial issues does not come naturally to pupils, so integrating socio-scientific issues as part of problem or inquiry in the learning process contributes to higher understanding of complex issues, allowing to enhance their decision-making and reasoning skills (Oberbauer et al., 2021). Teamwork that can and mostly is implemented in all the learning approaches identified in this systemic literature review contributes to more understanding un united society even when approaching the most controversial problems.

Social, ethical relevance

When problem presented to the learner is a challenge to the whole of the society or environment and solutions to those problems can contribute to the better society, socio-scientific approach can really benefit as being most inviting approach to open discussion for even the most diverse opinions on such as climate change, abortion, stem cell use, energy consumption etc.

Conclusions

Even though there are still challenges to be solved when integrating science literacy in the science curriculum, such as identifying which components of science literacy contributes to better understanding of science and enables students to spot misleading facts and pseudoscience as well as how to help learners to transfer skills and knowledge acquired to the real-life issues and problems (Sharon & Baram-Tsabari, 2020), it's become evident that improving scientific literacy skills is not only crucial cognitive skill for young students and learners of all age and social groups, but is also a step towards more engaging, open-minded and critically thinking society contributing to better decision making and stronger democracy (Solomon, 2021).

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References

Anderson, A. E., Justement, L. B., & Bruns, H. A. (2020). Using real-world examples of the COVID -19 pandemic to increase student confidence in their scientific literacy skills. *Biochemistry and Molecular Biology Education, 48*(6), 678–684. https://doi.org/10.1002/bmb.21474

Betul Cebesoy, U., & Chang Rundgren, S. N. (2021). Embracing socioscientific issues-based teaching and decision-making in teacher professional development. *Educational Review*, 1–28. https://doi.org/10.1080/00131911.2021.1931037

Brown, S.W., Lawless, K.A. (2019). The GlobalEd 2 Project: Interdisciplinary Simulations Promoting Students' Socio-scientific Literacy. In Díaz P., Ioannou A., Bhagat K., Spector J. (Eds.), Learning in a Digital World. Smart Computing and Intelligence. Springer, Singapore. https://doi.org/10.1007/978-981-13-8265-9_

Edelsztein, V., & Vázquez, C. (2021). Checkable nutrition: a scientific literacy experience for students. *International Journal of Science Education*, 1–16. https://doi.org/10.1080/09500693.2021.1884315

Ellis, R., & Gabriel, T. (2010). Context-based learning for beginners: CBL and non-traditional students. *Research in Post-Compulsory Education*, *15*(2), 129–140. https://doi.org/10.1080/13596741003790658

Feinstein, N. (2010). Salvaging science literacy. *Science Education*, *95*(1), 168–185. https://doi.org/10.1002/sce.20414

Gallagher, S. E., & Savage, T. (2020). Challenge-based learning in higher education: an exploratory literature review. *Teaching in Higher Education*, 1–23. https://doi.org/10.1080/13562517.2020.1863354

Garrecht, C., Reiss, M. J., & Harms, U. (2021). 'I wouldn't want to be the animal in use nor the patient in need' – the role of issue familiarity in students' socioscientific argumentation. *International Journal of Science Education*, *43*(12), 2065–2086. https://doi.org/10.1080/09500693.2021.1950944

Gilbert, J. K. (2006). On the Nature of "Context" in Chemical Education. *International Journal of Science Education*, *28*(9), 957–976. https://doi.org/10.1080/09500690600702470

Gilbert, J. K., Bulte, A. M., & Pilot, A. (2010). Concept Development and Transfer in Context-Based Science Education. *International Journal of Science Education*, *33*(6), 817–837. https://doi.org/10.1080/09500693.2010.493185

Golumbic, Y. N., Fishbain, B., & Baram-Tsabari, A. (2020). Science literacy in action: understanding scientific data presented in a citizen science platform by non-expert adults. *International Journal of Science Education, Part B*, *10*(3), 232–247. https://doi.org/10.1080/21548455.2020.1769877

Hussa, E. A. (2018). Can I still eat it? Using problem-based learning to test the 5-second rule and promote scientific literacy. *FEMS Microbiology Letters*, *365*(21). https://doi.org/10.1093/femsle/fny246

Jenkins, J. O. (2006). Problem based learning in practice: understanding human water needs. *Planet*, *16*(1), 32–35. https://doi.org/10.11120/plan.2006.00160032

Kang, J. (2020). Interrelationship Between Inquiry-Based Learning and Instructional Quality in Predicting Science Literacy. *Research in Science Education*, *52*(1), 339–355. https://doi.org/10.1007/s11165-020-09946-6

Ke, L., Sadler, T. D., Zangori, L., & Friedrichsen, P. J. (2021). Developing and Using Multiple Models to Promote Scientific Literacy in the Context of Socio-Scientific Issues. *Science & Education*, *30*(3), 589–607. https://doi.org/10.1007/s11191-021-00206-1

Oberbauer, A. M., Lai, E., Kinsey, N. A., & Famula, T. R. (2021). Enhancing student scientific literacy through participation in citizen science focused on companion animal behavior. *Translational Animal Science*, *5*(3). https://doi.org/10.1093/tas/txab131

OECD (2019). PISA 2018 Assessment and Analytical Framework, PISA, OECD Publishing, Paris. https://doi.org/10.1787/b25efab8-en.

Overton, T. (2016). Context and problem-based learning. *New Directions in the Teaching of Physical Sciences*, *3*, 7–12. https://doi.org/10.29311/ndtps.v0i3.409

Queiruga-Dios, M. N., López-Iñesta, E., Diez-Ojeda, M., Sáiz-Manzanares, M. C., & Vázquez Dorrío, J. B. (2020b). Citizen Science for Scientific Literacy and the Attainment of Sustainable Development Goals in Formal Education. *Sustainability*, *12*(10), 4283. https://doi.org/10.3390/su12104283

Sevian, H., Dori, Y. J., & Parchmann, I. (2018). How does STEM context-based learning work: what we know and what we still do not know. *International Journal of Science Education*, *40*(10), 1095–1107. https://doi.org/10.1080/09500693.2018.1470346

Sharon, A. J., & Baram-Tsabari, A. (2020). Can science literacy help individuals identify misinformation in everyday life? *Science Education*, *104*(5), 873–894. https://doi.org/10.1002/sce.21581

Siarova, H., Sternadel, D. & Szőnyi, E. 2019, Research for CULT Committee – Science and Scientific Literacy as an Educational Challenge, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels

Solomon, M. (2021). Trust: *The Need for Public Understanding of How Science Works*. *Hastings Center Report*, *51*(S1). https://doi.org/10.1002/hast.1227

Sutiani, A., Situmorang, M., & Silalahi, A. (2021). Implementation of an Inquiry Learning Model with Science Literacy to Improve Student Critical Thinking Skills. *International Journal of Instruction*, *14*(2), 117–138. https://doi.org/10.29333/iji.2021.1428a

Ulfah, A. F. (2019). Implementing Context-Based Learning in Science Instruction: A Study on Science Literacy Improvement within Topics of Earthquake and Flood. doi:10.31237/osf.io/r4n95

Xiao, Y., & Watson, M. (2017). Guidance on Conducting a Systematic Literature Review. *Journal of Planning Education and Research*, *39*(1), 93–112. https://doi.org/10.1177/0739456x17723971