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Science Literacy

2nd of May 2022

EAPC VZW · Palliative Care Unit Galilee, Holy Metropolis of Mesogaia and Lavreotiki · Universidad de Navarra · Transilvania University of Brasov, Faculty of Medicine · Hospice Casa Speranței, Making Every Moment Count

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Learning Objectives (cognitive- attitude)

1. Describes science definition
2. Describes science literacy definitions and history
3. Defines the different aspects of science literacy
4. Understands the interrelation of science and humanities and how they shape peoples' engagement with science
5. Describes the similarities and differences of individual and civic science literacy
6. Discusses appropriate methods for measuring science literacy
7. Recognizes how personal beliefs affect scientific interpretation and practice
8. Recognizes how individual science literacy can be augmented or mitigated by civic literacy

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Definition of Science

Science is a way of knowing about the world

Science is a naturalistic material exploratory system
used to account for natural phenomena
that ideally must be objectively and empirically testable

Yore 2003 Int J Sci Edu
Science Literacy: Concepts, Contexts, and Consequences (2016) http://nap.edu/23595

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Origin of Literacy

- Literacy has its origin is *letra*, Latin for letter
- Literacy once very simply referred to
  "the capacity to recognize letters and decode letter strings into recognizable words"
- along with the concomitant capacity
  " to write words and sentences"

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The changing Science 1970-2021 *(ongoing)*

- 1971 : Invention of cellular phone battery
- 1974 : Black hole theory introduced
- 1975 : Microsoft was founded
- 1978 : 1st "tube baby" with IVF was born
- 1993 : W.W.W.
- 2021 : Artificial Intelligence, Deep Machine Learning, Metaverse

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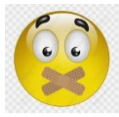
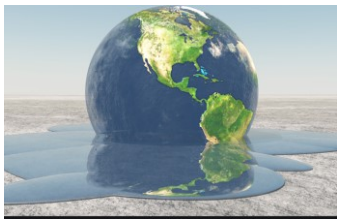
The changing Science

Science for Scientists



Science for All



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The Challenges of Modern Science
One or Multiple Sciences?

- The initial view:
  durable standards of truth, objectivity and reputable method

- The postmodern view :
  understanding science carries implicit messages of power, class, gender, race and ethnicity
  One interpretation may appear true, BUT there may be others equally true

- The predominant middle-of-the-road, view :
  integrates outcomes of the inquiry, and a critical part of **making sense of the inquiry**
  considering previous experiences and beliefs

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How would you define Science Literacy?

Knowing about the world

Knowing, understanding, evaluating and applying information about the world

Knowing, understanding, evaluating, applying and communicating information about the world

None of the above

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Evolution of Science Literacy Definitions http://nap.edu/23595

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AUTHOR/YEAR	DEFINITION
Hurd / 1958	Acquaintance with scientific forces and phenomena Learning experiences of science as an intellectual achievement & procedure for exploration & discovery
Pella /1966	(a) an understanding of the basic concepts in science (b) the nature of science (c) the ethics that control the scientist in his work (d) the interrelationships of science and society (e) the interrelationships of science & humanities (f) the differences between science & technology
Shen /1975	• practical (scientific and technical know-how) • civic (allows citizen to participate in democratic processes of an increasingly technological society) • cultural (desire to know about science as a major human achievement)
Norris /1995	(a) learning science (the facts, laws, and theories of science) (b) learning about science (the philosophical, historical, and sociological foundations of science) (c) learning to live with science.
Ryder 2001	(a) subject matter knowledge (d) collecting and evaluating data (b) interpreting data (e) modeling in science, (c) uncertainty in science (f) science communication in the public domain
Norris 2014	(a) the states of *knowing* one might obtain (b) the capacities one might refine (c) the personal traits one might develop
Koeppen (2008), OECD (2013) (draft), PISA 2015	1. **Explain phenomena scientifically**: Recognize, offer and evaluate explanations for a range of natural and technological phenomena 2. **Evaluate and design scientific enquiry**: Describe and appraise scientific investigations and propose ways of addressing questions scientifically 3. **Interpret data and evidence scientifically**: Analyze and evaluate data, claims & arguments in a variety of representations & draw appropriate scientific conclusions

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A shift in Science Literacy

Science learners in the 60s were expected to be a **"warehouse" science information** and were prepared to become future scientists and engineers

Scientific literacy in 70s-90s gradually refers to the "the ability of **citizens to make decisions about science related social issues"**

Science related questions can now be answered immediately through **online searches signifying less of a need to store content information** over time in one's mind

With such a flood of information, science literacy requires the **ability to find, integrate and interpret information**, as well as the time and ability for **reflection and evaluation**

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Science Literacy Definition in Brief

An individual's understanding of:

- scientific concepts and phenomena
- scientific processes
- ability to apply this knowledge

PISA, 2018 oecd-ilibrary.org/docserver/9789264305274-en.pdf

Scientific literacy means knowledge and understanding of the scientific concepts and processes required for personal decision-making and participation in civic and cultural affairs

Lemke C. Metiri Group. 2002

https://www.researchgate.net/publication/234731444_enGauge_21st_Century_Skills_Digital_Literacies_for_a_Digital_Age

Scientific literacy goes beyond the mere acquisition of scientific knowledge

It includes the ability

- to think scientifically and critically assess information
- apply knowledge in practice
- actively engage in an informed democratic dialogue using valid scientific evidence and scientific tools for reasoning

CULT Europa

https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2019)629188)

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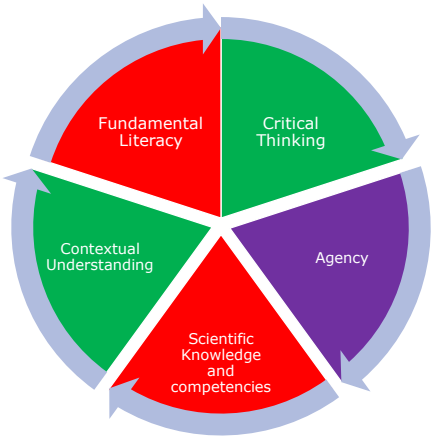
Commonly Proposed Aspects of Individual Science Literacy

- Foundational Literacy
- Content Knowledge
- Understanding of Scientific Practices (Procedural Knowledge)
- Identifying and Judging Appropriate Scientific Expertise
- Epistemic (Epistemologic) Knowledge
- Cultural Understanding of Science
- Dispositions and Habits of Mind

Science Literacy: Concepts, Contexts and Consequences (2016)

http://nap.edu/23595



Research for CULT Committee European Parliament

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Commonly Proposed Aspects of Individual Science Literacy 1,2

http://nap.edu/23595

Foundational Literacy (textual literacy, numeracy, visual literacy, and understanding of graphs and charts etc)

Content Knowledge (understanding a set of scientific terms, concepts, and facts)

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Foundational Literacy

Reading literacy :

- learning from text
- synthesizing information from multiple sources
- analyzing text to infer the writer's point of view
- critiquing claims and arguments in text

Numeracy :

understand probabilistic and mathematical concepts (graph, charts, statistics etc)

Visual literacy :

interpret, use, appreciate, and create images and videos

In order to advance thinking, decision-making, communication, and learning

Lemke C. Metiri Group. 2002
https://www.researchgate.net/publication/234731444_enGauge_21st_Century_Skills_Digital_Literacies_for_a_Digital_Age

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Commonly Proposed Aspects of Individual Science Literacy 3-5

http://nap.edu/23595

Understanding of Scientific Practices (what scientists do and how to interpret scientific findings)

Identifying and Judging Appropriate Scientific Expertise (judging the expertise of scientists and the value of their publications)

Epistemic (Epistemologic) Knowledge (how the procedures of science support the claims made by science, i.e. why scientific results can be believed, why uncertainty is an inherent aspect of science, how the evaluative process of peer review sustains objectivity etc)

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When poll is active, respond at **pollev.com/galileegalilee364**

Text **GALILEEGALILEE364** to **+44 7860 048879** once to join

Science Literacy depends on the individual's disposition and beliefs towards scientific issues

True

False

I do not know

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Commonly Proposed Aspects of Individual Science Literacy 6,7
http://nap.edu/23595

Cultural Understanding of Science (acknowledges the interrelationships of science and society and science and the humanities and recognizes science as a major human achievement)

Dispositions and Habits of Mind (dispositions such as inquisitiveness, open mindedness, a commitment to evidence etc, shape how people engage with science)

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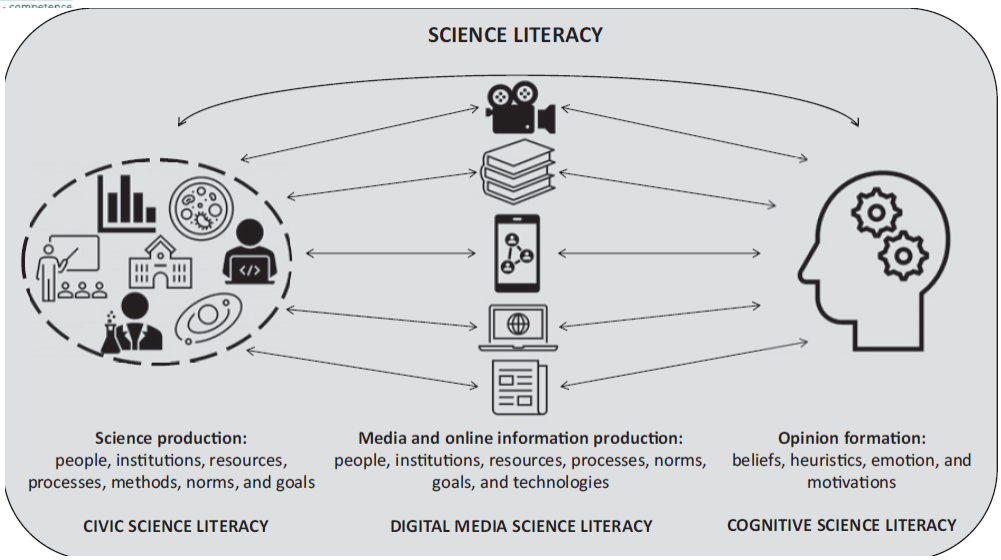
Science Literacy & Social Sciences



(Mis)informed about what? What it means to be a science-literate citizen in a digital world ***Howell EL & Brossard D,*** PNAS 2021 Vol. 118 No. 15, https://doi.org/10.1073/pnas.1912436117

Individual vs Civic Science Literacy

- Cognitive science literacy :understanding how people interpret science information when they come across it
- Civic science literacy : understanding how science is produced, and what that means for how science relates to broader society

Howell EL & Brossard D, PNAS 2021

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New **domains of** literacy

- Technological Literacy
- Information Literacy
- Media/ Digital Literacy
- Multicultural Literacy
- Financial Literacy
- Health Literacy
- Research Literacy

Lemke C. Metiri Group. 2002
https://www.researchgate.net/publication/234731444_enGauge_21st_Century_Skills_Digital_Literacies_for_a_Digital_Age

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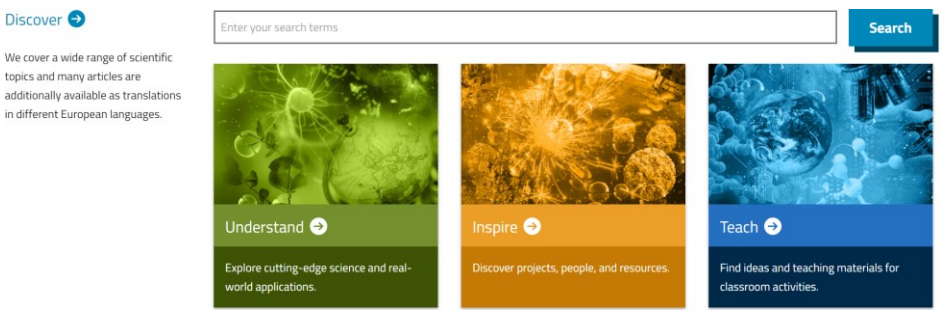
An Example of the Historical Evolution of Science Literacy

Science Learning in



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Canada Science for Junior HS
1970's
https://www.curriculumhistory.org/

1978–1993 period emphasized :
the issues of **textbooks'** content and style **students**' reading skills **and teachers**' use of textbooks as if they were independent dimensions of reading

In traditional **teacher-directed classrooms**, teacher-directed verbal patterns of initiation, response and follow up and **questions were used** to evaluate students

Speaking, listening, reading, and writing were ignored or portrayed as **unidirectional processes**:
speaker to listener, text to reader, or memory to text

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Junior Cycle Science - Assessment Task

NCCA

Group Discussion

Nitrates in drinking water

Instruction: **The Modern "Textbook"**

This booklet presents information about water polluted by nitrates. Follow your teacher's directions to work as a group. Read and discuss the information presented in a variety of ways;

Newspaper Article | Text | Diagram | Map | Table

Use the prompt questions on page 9 to help shape your discussion.

FROM text-driven models

TO reader-driven models

TO interactive reader and text models

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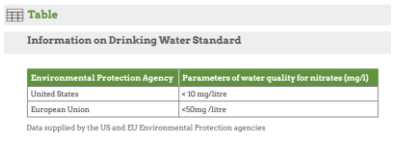


Table

Information on Drinking Water Standard

Environmental Protection Agency	Parameters of water quality for nitrates (mg/l)
United States	< 10 mg/litre
European Union	<50mg /litre

Data supplied by the US and EU Environmental Protection agencies


Newspaper article

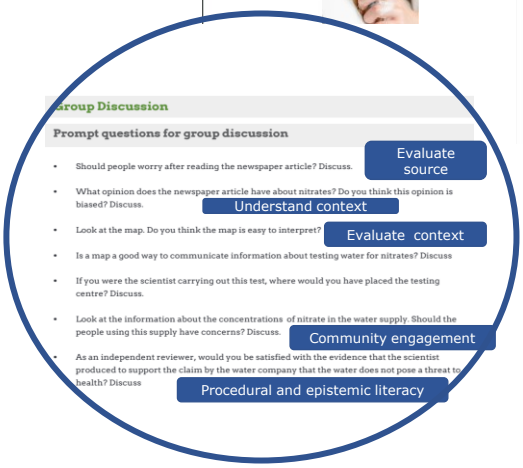
DO YOU KNOW WHAT YOU'RE DRINKING?


Text

Information about water polluted by nitrates

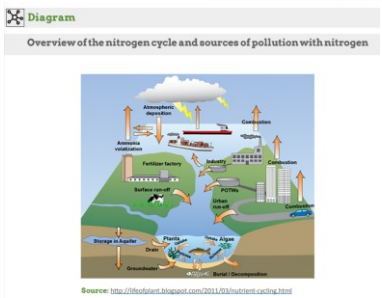
"Overall, the quality of water in Ireland is still quite good compared to other countries. Over the past thirty years, however, water quality has decreased and many incidences of pollution have cropped up. The pollutants of most concern to groundwater in Ireland are Nitrates from fertiliser used on land. The diagram above gives an overview of the nitrogen cycle and sources of water pollution with nitrogen in Ireland."

From *Water Quality in 2016 An Indicators Report* European Environment Agency


Group Discussion

Prompt questions for group discussion

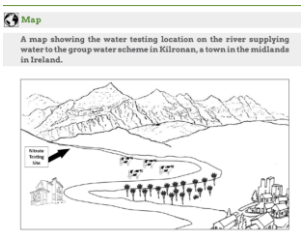
- Should people worry after reading the newspaper article? Discuss. — Evaluate source
- What opinion does the newspaper article have about nitrates? Do you think this opinion is biased? Discuss. — Understand context
- Look at the map. Do you think the map is easy to interpret? — Evaluate context
- Is a map a good way to communicate information about testing water for nitrates? Discuss
- If you were the scientist carrying out this test, where would you have placed the testing centre? Discuss.
- Look at the information about the concentrations of nitrate in the water supply. Should the people using this supply have concerns? Discuss. — Community engagement
- As an independent reviewer, would you be satisfied with the evidence that the scientist produced to support the claim by the water company that the water does not pose a threat to health? Discuss — Procedural and epistemic literacy



Diagram

Overview of the nitrogen cycle and sources of pollution with nitrogen

Source: http://lifeofplant.blogspot.com/2011/03/nutrient-cycling.html


Map

A map showing the water testing location on the river supplying water to the group water scheme in Kilronan, a town in the midlands in Ireland.

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Modern Science Learning

Yore LD et al, Int. J. Sci. Educ., 2003

- Is holistic in nature of teaching and learning
- Multi directional
- Introduces:
  "interactive–constructive" models of discourse, "project–to–learn" and "writing-to-learn" science education

❑ Reading has expanded to consider :

- sources other than textbooks (internet, media etc)
- comprehension strategies
- metacognition
- and the design of inquiry environments

Metacognition is an awareness of one's own thought processes and an understanding of the patterns behind them (Wikipedia)

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"**To comprehend** what we are taught verbally, or what we read, or what we find out by watching a demonstration or doing an experiment

we must invent a model or explanation for it

that **organizes the information** selected from the experience in a way **that makes sense to us**, that fits our logic or real-world experiences, or both*" (Osborne RJ and Wittrock MC 1983)*

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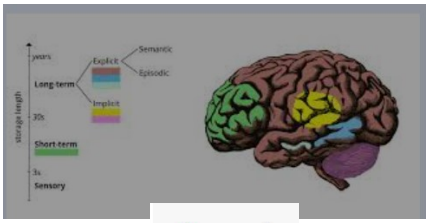
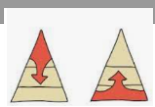
Metacognition. The global meaning Process

Bottom-up Processing : Science **readers construct understanding in short-term memory** by extracting information from the text-based on situation and concurrent experience

Top-down Processing : by **retrieving information from their long-term memory** and **deciding what should be considered** in a specific context

while monitoring, strategically planning, and regulating in order to "create knowledge"





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Can you name factors that may affect behavior towards Science?

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Factors that affect behavior

Knowledge and skills
Self-efficacy
Self-concept and self-esteem

Political ideology
Religiosity
Occupational stress
Recreation and leisure

Intentions
Perceived risk
Attitudes and beliefs
Perceived consequences

Demographics
Social norms
Social support networks
Media habits

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Factors Other Than Knowledge That Influence Attitudes Toward Science (examples)

- **Media Use :** public attitudes toward embryonic stem cell research can be shaped by cues from the news media
- **Value predispositions :**Christian conservatism and social ideology influenced citizen evaluations regarding embryonic stem cell research
- **Trust :** Trust in scientists and scientific institutions affects attitudes toward science

http://nap.edu/23595

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"Motivated reasoning"

Individuals tend to **select information that is consistent with their views** or beliefs

and alternatively

Avoid information that is inconsistent with their views or beliefs

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Interrelation of Individual and Civic Science Literacy

- Science literacy is desirable not only for individuals, but also for the well-being of communities and society
- Although science literacy has traditionally been seen as the responsibility of individuals, individuals are nested within communities that are nested within societies
- As a result, individual science literacy is limited or enhanced by the circumstances of that nesting

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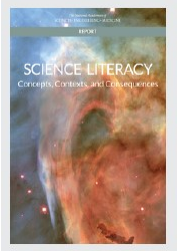
Science Literacy: Concepts, Contexts, and Consequences The National Academies Press (2016)



- **CONCLUSION 8** Communities can develop and use science literacy to achieve their goals
- Science literacy can be expressed in a collective manner when the knowledge and skills possessed by individuals are leveraged alongside the knowledge and skills of others in a community
- **CONCLUSION 9** Communities can meaningfully contribute to science knowledge through engagement in community action, often in collaboration with scientists

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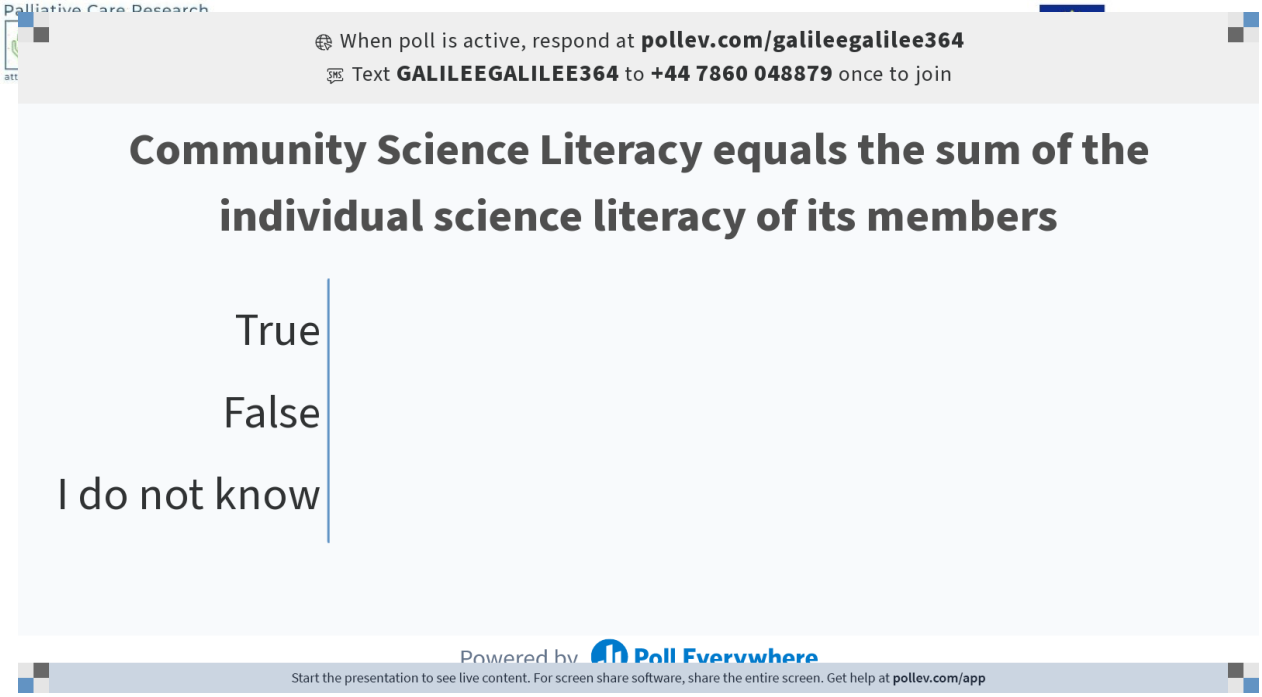

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Interesting comparisons between communities and PC teams!

- *There are examples of communities that accomplish various goals*

✓by virtue of their collective literacy

✓that cannot be easily attributed to the actions of any particular individual (environmental issues, HIV and medications)

- *Science literacy in a community does not require each individual to attain a particular threshold of knowledge, skills, and abilities*
  - ✓rather, it is a matter of a community having sufficient shared resources
  - ✓that are distributed and organized in such a way
  - ✓that the varying abilities of community members work in concert to contribute to the community's overall well-being

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One Topic – Different Approaches Individual, Community and Global Science Literacy

OECD 2018: ***https://www.oecd-ilibrary.org/docserver/9789264305274-en.pdf***

Figure 4.3 ▪ **Contexts in the PISA 2015 and PISA-D scientific literacy assessment**

	Personal	Local/National	Global
Health and disease	Maintenance of health, accidents, nutrition	Control of disease, social transmission, food choices, community health	Epidemics, spread of infectious diseases
Natural resources	Personal consumption of materials and energy	Maintenance of human populations, quality of life, security, production and distribution of food, energy supply	Renewable and non-renewable natural systems, population growth, sustainable use of species
Environmental quality	Environmentally friendly actions, use and disposal of materials and devices	Population distribution, disposal of waste, environmental impact	Biodiversity, ecological sustainability, control of pollution, production and loss of soil/biomass
Hazards	Risk assessments of lifestyle choices	Rapid changes (e.g. earthquakes, severe weather), slow and progressive changes (e.g. coastal erosion, sedimentation), risk assessment	Climate change, impact of modern communication
Frontiers of science and technology	Scientific aspects of hobbies, personal technology, music and sporting activities	New materials, devices and processes, genetic modifications, health technology, transport	Extinction of species, exploration of space, origin and structure of the universe

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What aspects of Science Literacy do we usually measure

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Science Literacy: Concepts, Contexts, and Consequences The National Academies Press (2016)

- **CONCLUSION 12**

  Measures of science literacy in adult populations have focused on a very limited set of

  content and procedural knowledge questions which have been shown to be reasonable indicators of science knowledge

- **CONCLUSION 13**

  The commonly used measures of science and health literacy, along with other measures of scientific knowledge, are only ***weakly correlated with action and behavior*** across a variety of contexts

http://nap.edu/23595

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Evaluation of Science Literacy

OECD 2018: ***https://www.oecd-ilibrary.org/docserver/9789264305274-en.pdf***

Figure 4.8 ■ **PISA 2015 and PISA-D Framework for Cognitive Demand**

		Competencies			Depth of Knowledge		
		Explain phenomena scientifically	Evaluate and design scientific enquiry	Interpret data and evidence scientifically	Low	Medium	High
Knowledge	Content knowledge						
	Procedural knowledge						
	Epistemic knowledge						

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NCCA Guidelines for Classroom Based assessments

https://www.curriculumonline.ie/Assessment_Guidelines_Science.pdf

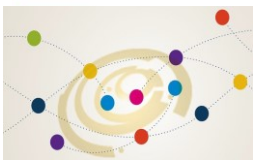

Table 1: Classroom-Based Assessments: Science

Classroom-Based Assessments	Format	Student preparation
Extended Experimental Investigation (EEI)	A report may be presented in a wide range of formats	A student will, over a three-week period[1], formulate a scientific hypothesis, plan and conduct an experimental investigation to test their hypothesis, generate and analyse primary data, and reflect on the process, with support/guidance from the teacher.
Science in Society Investigation (SSI)	A report may be presented in a wide range of formats	A student will, over a three-week period[2], research a socio-scientific issue, analyse the information/secondary data collected, evaluate the claims and opinions studied, and draw evidence-based conclusions about the issues involved, with support/guidance from the teacher.

Knowledge and Understanding
Communicating
Investigating

Features of Quality for the Extended Experimental Investigation

	Exceptional
Investigating	▪ Forms a testable hypothesis or prediction with justification ▪ Describes considerations related to reliability and fairness ▪ Outlines appropriate safety considerations, and describes the method used to accurately collect and record good quality, reliable data in a manner that could be easily repeated ▪ Uses an innovative approach that truly enhances the work ▪ Records a sufficient amount of good quality data
Communicating	▪ Presents data in the most appropriate way using relevant scientific terminology and informative representations; calculations, if any, are performed to a high degree of accuracy ▪ Describes the relationships between the variables
Knowledge and understanding	▪ Provides a justified conclusion supported by the data; identifies and explains any anomalous data ▪ Uses relevant science knowledge to assess and describe whether the hypothesis has/has not been supported ▪ Describes in detail the strengths and weaknesses of their own investigations, including appropriate improvements and or refinements, or explains fully why no further improvements could reasonably be achieved

Exceptional
Above Expectations
In line with Expectations
Yet to Meet Expectations

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Writing Type:
Items to be considered when measuring science literacy skills

- **Narrative:** involves the temporal, sequenced discourse found in diaries, journals, learning logs, and conversations
- **Description:** involves personal, common-sense and technical descriptions, informational and scientific reports, and definitions
- **Explanation:** involves sequencing events in cause–effect relationships
- **Instruction:** involves ordering a sequence of procedures to specify directions, such as a manual, experiment or recipe, and can effectively utilize a series of steps in which the sequence is established by tested science and safety
- **Argumentation:** involves logical ordering of propositions to persuade someone in an essay, discussion, debate, report, or revieW

Yore LD et al Int J Sci Edu 2003

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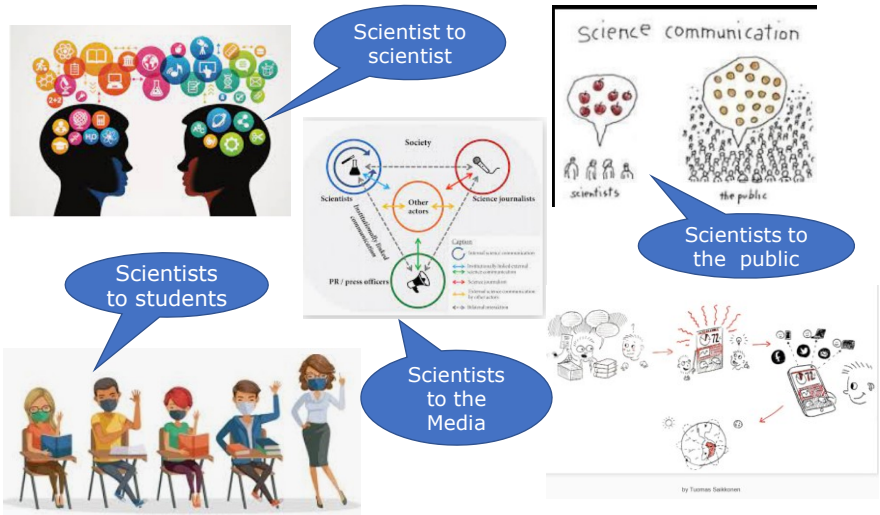
Audience: Communication of Science



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Communication of Science

These unidirectional and interactive communications require :

- scientists to establish purpose
- consider the audience
- mentally compose understandable messages
- deliver the message in an effective and persuasive manner
- listen to the responses

Yore LD et al Int J Sci Edu 2003

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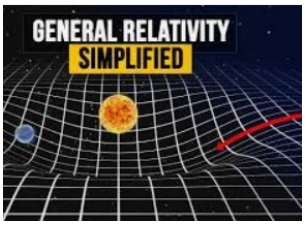

Purpose of Reading and Writing
Scientists as readers of the Literature

Scientists are pragmatic readers

Their purpose for reading, prior knowledge, and evaluation criteria influence their reading strategies

- *In their fields of their expertise* : Results and Discussion sections first
- *Outside their field* : begin with the Introduction
- *When serving as reviewers* : attending to all sections of the paper

- When they encounter comprehension difficulties, they make cost/benefit judgments, such as :
  the trustworthiness of the author
  how reasonable the approach was
  the validity of the knowledge claims determined

Yore LD et al Int J Sci Edu 2003

Recommendations on EU Actions - Measuring Scientific Literacy

EUROPA CULT *https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2019)629188*

- "The Commission should support the *integration of an assessment of students' critical thinking and civic engagement skills* into the OECD's PISA scientific literacy framework"

- "The Commission should use Eurobarometer surveys and qualitative studies to

  investigate the in-depth motivations and reactions of various groups on social and policy issues requiring scientific literacy

  and analyze more in-depth the *factors that shape the nature of scientific thinking* among various social groups"

Recommendations on EU Actions - Measuring Scientific Literacy

CULT EUROPA *https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2019)629188*

The Commission should use its existing research funding programs (such as Horizon 2020/Horizon Europe) to **fund projects exploring appropriate assessment instruments to better measure scientific literacy**

Such projects should be **multi-dimensional** (covering different types of assessment) and involve the collaboration of various stakeholders including researchers, scientists, educators and businesses engaged in the design of digital assessment tools.

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Example Science Literacy

1. Considering the different aspects of Science Literacy describe the context and other science literacy aspects of the use of opioids in pain management

and

2. Comment on how it shapes personal, community and national practice.

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Need to elaborate on:

1. Context Knowledge (Types of opioids, WHO ladder, types of pain etc),

2. Procedural Knowledge (how it is done: indications, routes, titration, side effects etc, by whom and how : laws, regulations, guidelines etc)

3. Epistemic Knowledge (understanding the pathophysiology of pain and the mechanism of action of drugs used, rotation of opioids etc)

4. How it interrelates with social norms, practices, beliefs, regulatory issues, etc (i.e myths, laws and regulations, availability of drugs, etc)

5. How it is expressed on a personal, community and national level, e.g.

	Personal	Community/National
Opioids in Pain Management	Pain tolerance, knowledge, beliefs, social myths and dispositions, etc	Opioid laws and regulations, availability of opioids (industry and distribution), norms of practice- guidelines, raising public awareness, etc

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Science Literacy Self Assessment Quiz

https://www.surveymonkey.com/r/6ZQFF96

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This project has been funded with support from the European Commission.

This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Research for all palliative care clinicians 2020-1-RO01-KA202-080128

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