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HOW HABITS OF MEDIA CONSUMPTION RELATE TO SCIENTIFIC LITERACY

A Quantitative and Qualitative Analysis

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ABSTRACT

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As humanity is facing considerable global challenges, like pandemics and the ongoing anthropogenic global warming, *scientific literacy* (SL) has become more important than ever. Yet, the level of SL around the world continues to be considerably low. This undermines both our individual and collective decision-making processes, in terms of them being able to arrive at well-reasoned and scientifically informed resolutions to the many challenges we face.

Previous research by Jon D. Miller, among others, has indicated that television consumption, on average, has a negative impact, print media consumption a positive impact, and Internet consumption the most positive impact on SL. In this thesis, I find out if these indications can be supported and expanded, for the purpose of finding out what kind of media consumption may best support SL. This is done by utilizing a mainly quantitative live paper survey (n = 138), gathered during 2014, in Finland. I look for relevant correlations between people's more detailed *media consumption habits* and their level of SL. Two included qualitative questions are also analyzed, to reveal more specific habits of media consumption that may support SL. Further, I look for contributing background information correlates with SL that have been suggested in previous research.

Analysis of the quantitative questions found several significant correlations that support and expand Miller's findings. Television consumption negatively correlated with SL, moderated by understanding of English as a second language. General print media consumption did not correlate with SL, but the more specific category of written non-fiction consumption did positively, as did giving relatively more value to non-fiction books in learning new knowledge. Though Internet consumption inversely correlated with television consumption, no significant correlation between general Internet consumption and SL was found. However, the more specific category of 'organization of life via Internet' did positively correlate with SL, moderated by education.

The qualitative questions revealed specific kind of Internet consumption to be predictive of SL. Participants with higher SL were more prone to mention learning most amount of new knowledge from *social learning-related Internet platforms, channels, and forums* (SLIPs), and especially from ones unique to the sample, while also being more prone to mention reading non-fiction books and to not mention television. A quantified analysis of the qualitative answers confirmed a significant positive correlation between SL and SLIPs mentioned.

Significant background information correlates, in line with prior research, were also found. SL positively correlated with both education and self-reported understanding of English as a second language, and negatively with religiosity (both in terms of belonging to a religious community and view of God(s)). A negative correlation was further found between the quality of Internet connection and religiosity. Moreover, view of God(s) negatively correlated with Internet consumption and mentions of SLIPs, both moderated by education.

Based on the results, it is theorized that particularly SLIPs may provide benefits for SL as, at their best, they can function as efficient epistemic communities or networks that socially support the process of learning. However, finding the best SLIPs, and effectively utilizing them, is a challenge that often requires media literacy and English proficiency, together with science curiosity as an initial motivator. The best communities, once found, can then feed them further, potentially creating a lifelong socially supported cycle of curiosity and learning, and thus support SL. Alongside SLIPs, especially non-fiction books appear to support SL.

These findings can be utilized in designing and developing educational and habitual solutions to better support SL – and thus to support both our individual and collective decision-making processes. Some practical suggestions are made for educators, policymakers, content designers, parents, journalists, and the public. Additionally, a philosophy-influenced historical overview of SL is presented, developments in the media landscape since 2014 considered, and guidelines for potential future research discussed.

Keywords: scientific literacy, media consumption, public understanding of science, science communication, social media, television, print media

TIIVISTELMÄ

Kangassalo, Mikko : Miten mediankäyttötavat liittyvät tieteelliseen lukutaitoon – Kvantitatiivinen ja kvalitatiivinen analyysi
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Ihmiskunnan kohdatessa globaaleita haasteita, kuten pandemioita ja meneillään olevan ihmislähtöisen ilmastonlämpenemisen, *tieteellisestä lukutaidosta* (TL:sta) on tullut tärkeämpää kuin koskaan. Ja silti ympäri maailman TL pysyy matalalla tasolla. Tämä heikentää sekä yksilöllisten että kollektiivisten päätöksentekoprosessiemme kyvykkyyttä tuottaa hyvin järkeiltyjä ja tieteellisesti informoituja päätöksiä, joilla vastata kohtaamiimme haasteisiin.

Muun muassa Jon D. Millerin aiemmat tutkimukset ovat indikoineet, että television käytöllä on keskimäärin negatiivinen vaikutus, printtimedian käytöllä positiivinen ja Internetin käytöllä kaikista positiivisin vaikutus TL:oon. Tässä tutkielmassa selvitän, voiko näitä löydöksiä tukea ja laajentaa, jotta selviäisi, millainen mediankäyttö saattaa parhaiten tukea TL:a. Tämä tapahtuu pääosin kvantitatiivisen, Suomessa 2014 livenä kerätyn paperikyselyn kautta (n = 138). Etsin aineistosta relevantteja korrelaatioita ihmisten yksityiskohtaisempien *mediankäyttötapojen* ja heidän TL:n tason väliltä. Analysoin myös kaksi kyselyyn sisällytettyä kvalitatiivista kysymystä, tuodakseni esiin tarkempia mediankäyttötapoja, jotka saattaisivat tukea TL:a. Lisäksi etsin aiemmissa tutkimuksissa esille nousseita korrelaatteja taustatietojen ja TL:n väliltä.

Kvantitatiivisten kysymysten analyysi löysi useita merkitseviä korrelaatioita, jotka tukevat ja laajentavat Millerin löydöksiä. Television käyttö korreloi negatiivisesti TL:n kanssa, jota löydöstä sääteli englannin kielen ymmärtäminen toisena kielenä. Printtimedian käyttö ei yleisesti korreloinut TL:n kanssa, mutta tarkempi kategoria 'kirjoitettu non-fiktio' korreloi positiivisesti, kuin myös tietokirjallisuuden suhteellisesti korkeampi arvostaminen uuden tiedon oppimisessa. Vaikkakin Internetin ja television käytön välillä oli käänteinen korrelaatio, Internetin käyttö ei yleisesti korreloinut TL:n kanssa. Tarkempi kategoria 'elämän organisointi Internetin kautta' kuitenkin korreloi positiivisesti, koulutuksen säätelemänä.

Kvalitatiiviset kysymykset paljastivat tietynlaisen Internetin käytön ennustavan TL:a. Osallistujat, joilla oli korkeampi TL, olivat taipuvaisempia mainitsemaan oppivansa eniten uutta tietoa *sosiaalisilta oppimiseen liittyviltä Internet-alustoilta, -kanavilta ja -foorumeilta* (SOLI:lta), varsinkin otoksessa uniikisti mainituilta. He myös mainitsivat useammin tietokirjallisuutta sekä välttivät mainitsemasta televisiota. Kvantifioitu analyysi vastausten sisällöstä vahvisti, että TL:n ja mainittujen SOLI:en välillä on merkitsevä positiivinen korrelaatio.

Kyselyssä paljastui myös aiempien tutkimusten kanssa yhteensopivia, merkitseviä taustatietokorrelaatteja. TL korreloi positiivisesti sekä koulutuksen että itseraportoidun englannin kielen ymmärtämisen kanssa ja negatiivisesti uskonnollisuuden kanssa (sekä yhteisöön kuulumisen että Jumala-näkemyksen osalta). Uskonnollisuuden kanssa korreloi negatiivisesti myös Internet-yhteyden laatu. Lisäksi näkemys Jumalasta korreloi negatiivisesti sekä Internetin käytön että SOLI:en mainitsemisen kanssa, koulutuksen säätelemänä.

Tulosten pohjalta teoretisoidaan, että erityisesti SOLI:t saattavat tarjota hyötyä TL:lle, sillä ne voivat parhaimmillaan toimia tehokkaina episteemisinä yhteisöinä tai verkostoina, jotka sosiaalisesti tukevat oppimisen prosessia. Parhaiden SOLI:en löytäminen ja tehokas hyödyntäminen on kuitenkin haaste, jossa usein vaaditaan medialukutaitoa ja englannin kielen taitoa, yhdessä motivaatiota tuovan tiedeuteliaisuuden (tai tieteellisen uteliaisuuden) kanssa. Kun parhaat yhteisöt löytää, ne voivat edelleen ruokkia näitä, potentiaalisesti luoden elinikäisen sosiaalisesti tuetun uteliaisuuden ja oppimisen kehän, ja näin tukea TL:a. SOLI:en rinnalla erityisesti tietokirjallisuus vaikuttaa tukevan TL:a.

Näitä löydöksiä voi hyödyntää TL:a tukevien opetuksellisten ja habituaalisten ratkaisuiden suunnittelussa ja kehityksessä – ja näin tukea yksilöllisiä ja kollektiivisia päätöksentekoprosessejamme. Joitain käytännöllisiä ehdotuksia esitetään kouluttajille, päättäjille, sisällönsuunnittelijoille, vanhemmille, toimittajille ja laajemmalle yleisölle. Lisäksi filosofiavaikutteinen historiallinen katsaus TL:sta esitetään, mediakentän kehityksiä 2014 jälkeen punnitaan sekä suuntaviivoja potentiaalisille tuleville tutkimuksille esitetään.

Avainsanat: tieteellinen lukutaito, mediankäyttö, tieteen julkinen ymmärtäminen, tiedeviestintä, sosiaalinen media, televisio, printtimedia

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1 INTRODUCTION

Scientific literacy can generally be defined as the measure of sufficient scientific knowledge, and of sufficient understanding of how the process of science works and influences our lives, for us to function as an informed citizen in a scientifically developed, technological society (Bybee, 2015; J. D. Miller, 1983; Siarova et al., 2019). The construct has been discussed for over 60 years (Hurd, 1958; McCurdy, 1958), and it has been regularly surveyed for several decades, in various ways in many countries (DeBoer, 2000; Laugksch, 2000; D. A. Roberts, 2007; see also, e.g., Bauer, 2008; Impey et al., 2017; Kawamoto et al., 2013; J. D. Miller, 2004, 2006, 2016; OECD, 2016a, pp. 17–29; 2016b, pp. 50–55; Wu et al., 2018; see also sect. 2.1.3–2.1.4, 2.2.3–2.2.4).

The average level of people's scientific literacy continues to be considerably low, on a global scale. For example, in a study from 2006, the political scientist Jon D. Miller analyzed civic scientific literacy in adult samples gathered from 33 countries in 2005, comprised of the United States and European countries, and found that the population with the highest rank – Sweden – had only 35 % civic scientific literacy rate. The US was ranked second (28 %), the Netherlands third (24 %), and Finland was at a tied fourth place with Denmark and Norway (22 %). Only these six countries had a rate above 20 %, while twelve had a rate below 10 %. The rate was conceptualized to be indicative of the percentage of adult population able to readily read and understand popular scientific articles, like the ones found on the science section of *The New York Times*. Though it seems international data have not been similarly gathered and analyzed since 2006, the rate in the US had remained at the same level in Miller's 2016 sample, at around 28 %, and China was at around 8 % level in a 2013 sample (Wu et al., 2018). In the US, there have also been reported wide gaps between the public and scientists on a host of science-related issues (Pew Research Center, 2015b). Even people who graduate from university seem likely to be scientifically illiterate on many areas outside their narrow expertise, also including the general processes and philosophical principles of science itself (Impey et al., 2017; see also Besley & Hill, 2020; J. D. Miller, 2004). Moreover, epistemically unwarranted beliefs – like paranormal, pseudoscience, and conspiracy beliefs – continue to be prevalent (see, e.g., Dyer & Hall, 2019; Fasce & Picó, 2019; Gallup, 2005; Impey et al., 2017; Lindeman et al., 2011).

These observations raise significant concerns about our ability to understand our individual situation and the world we inhabit, and to engage in personal and political decision-making processes that would lead to well-informed and -justified resolutions. Insofar as our poor understanding of, for example, climate change (Guy et al., 2014; Ranney & Clark, 2016; Shi et al., 2016), contagious diseases and vaccines (Motoki et al., 2021; Motta et al., 2018), or emerging technologies (Fernbach et al., 2019) compromises the quality of our evaluations of relevant competing arguments, and the quality of our consequent democratic or otherwise collective decisions, the future of humanity around the globe is built upon some considerable amount of uncertainty.

Though appropriate development of formal education is to be encouraged, it seems that most of our learning – especially in adulthood – happens either informally or incidentally(/implicitly): that is, from the perspective of the learner, either as an intended or unintended side effect of everyday life outside of formal learning contexts (Cerasoli et al., 2018; Falk & Dierking, 2010; LIFE Center, 2005; Stevens & Bransford, 2007). Nowadays, a large part of our informal and incidental learning – and some part of our formal learning – happens on the Internet or via other forms of media such as television and books (Falk & Needham, 2013; P. G. Lange, 2018; J. D. Miller et al., 2006; Pew Research Center, 2018; see also Greenhow & Lewin, 2016; Lucas, 1983).[1] As different forms of media have different affordances and different user environments – for example, Internet use tending to be much more social than that of television – it may be that consumption of specific forms differ in their average effects to scientific literacy. Or, depending on the direction of the effect, it might be that specific level of scientific literacy, or curiosity about (or interest in) science, moves people towards certain forms of media. Or there may be mutual third variables at play that simultaneously support scientific literacy and specific habits of media consumption.

The idea of specific forms of media providing specific influences on scientific literacy comes from Jon D. Miller's path model to predict civic scientific literacy. Miller's analysis – based on a US sample – has indicated that, on average, television consumption has a negative, print media consumption a positive, and Internet consumption the most positive effect on civic scientific literacy (see Appendix 1; J. D. Miller, 2010b). These findings are consistent with research both preceding and succeeding Miller's (see Huber et al., 2019; Nisbet et al., 2002; Takahashi & Tandoc, 2016). Prior research has also indicated that interest in science is positively related to using the Internet, and negatively related to using television, as source for science information (Takahashi & Tandoc, 2016).

To try and find out if Miller's analysis can be further supported and expanded, the present thesis performs a closer examination of the relationship between people's *media consumption habits* and

[1] The OECD (Organisation for Economic Co-operation and Development) has further encouraged recognition of *non-formal learning* as an intermediate concept between what may be considered as the continuum of formal and informal learning (OECD, n.d.-c; Werquin, 2007). Thus, more generally, this continuum can be noted. However, definitions of these terms are contested: for example, instead of a continuum, some researchers try to maintain clearly defined boundaries between the terms (for a review, see Greenhow & Lewin, 2016). Also, whereas OECD defines "informal learning" as unintentional learning in everyday life, some view it to be behaviorally intentional while characterizing the further concept of "incidental learning" as its unintentional counterpart (e.g., Cerasoli et al., 2018).

In any case, consciously cultivated educational habits of online media consumption, where the habit may be intendedly cultivated (e.g., when deciding who or what to "follow" for educational purposes), but the contents of learning may or may not be incidental (e.g., them being serendipitously decided by the followed content producers and made hierarchically salient by algorithms), could be considered non-formal learning. Informal learning could then be understood as intendedly seeking contents that are more strictly planned (contra incidental), and incidental learning as unintended happenstance.

level of *civic scientific literacy*. This is done by utilizing a mainly quantitative live paper survey (*n* = 138), gathered during 2014, in Finland. Two included qualitative questions are also analyzed, to gather more in-depth information about specific media contents people with different levels of scientific literacy like to use and learn new knowledge from. Additionally, some background information correlates with scientific literacy, that are in line with prior research, are reported.

Generally, there are three main paradigms in public understanding of science (PUS): scientific literacy (focusing on knowledge), public understanding (focusing on attitudes), and science and society (focusing on trust) (Bauer et al., 2007; Bauer, 2008). Past research indicates that people tend to have a generally interested attitude towards science, and relatively high trust in scientists or the scientific institution, albeit there are differences between groups and topics (*in Finland*: Tieteen tiedotus, 2019; *in the EU*: Eurobarometer, 2014; *in the US*: Besley & Hill, 2020; Pew Research Center, 2015a, 2020a, 2020b; *and elsewhere*: Pew Research Center, 2020c; for recent confusions about this point, see also Krause et al., 2021). However, these do not straightforwardly translate into scientific literacy (see Takahashi & Tandoc, 2016; see also, e.g., Impey et al., 2017; J. D. Miller, 2006, 2016; Pew Research Center, 2015b). In the present study, focus is put on civic scientific literacy and how different media consumption habits relate to it. As a result, the study contributes to the important research on how scientific literacy and the value of science could best be supported in public, and in this case specifically by means of encouraging and cultivating more fruitful habits of media consumption and production.

In the following chapter 2, a theoretical background for the study is presented, along with a broad historical and partly philosophical overview of the importance of scientific literacy. Chapter 3 then presents the methodology of the study, and the results are presented in chapter 4. In chapter 5, the study is discussed in terms of its findings, and in terms of its limitations and their implications for potential future research. And, finally, summary of key findings along with corresponding practical recommendations take place in the concluding chapter 6, also including considerations on the limits of scientific literacy and what other factors should additionally be noted in public communication concerning science.

2 THEORETICAL BACKGROUND

In this chapter, I lay out the theoretical background of scientific literacy relevant for the present study. In section 2.1, I define the key concepts of the study. Section 2.2 further elaborates on the importance of scientific literacy by placing the concept and research tradition in a deep historical context, going from prehistory to present day.

2.1 Definitions

Scientific literacy has a lot to do with both science and literacy, as it pertains to the skill of being *literate* in things relating to *science* or of being literate in a manner that can be characterized as *scientific*. Therefore, before outlining the primary concept itself, it is helpful to first examine what is meant by each of the constituent concepts: science and literacy. After that, it is easier to approach the key definitions of scientific literacy, and civic scientific literacy.

2.1.1 Science

As philosophy of science is a whole sub-field of philosophy, dedicated to studying, characterizing, defining, and justifying various aspects of science, no short characterization of science can be exhaustive. Relatedly, it is noteworthy that there is no one agreed upon unified answer to the *demarcation problem*: the problem of how to distinguish between science and pseudoscience (and other non-sciences) (Hansson, 2021; Pigliucci & Boudry, 2013b). Nevertheless, there is a wide consensus among philosophers and other academics – utilizing various criteria in particular cases – that specific fields are pseudoscience disguised as science (e.g., astrology, creationism or “intelligent design”, homeopathy), while others are science (e.g., astronomy, evolutionary biology, biochemistry) (Hansson, 2021; see also Kaufman & Kaufman, 2018; Novella, 2018).

Some suggested criteria to make these distinctions include science (contra pseudoscience) being characterized by critical method, intersubjective testability, progress, and autonomy (Niiniluoto, 2002, p. 7; see also Boudry, 2021; Hansson, 2013, 2017, 2021; Novella, 2018, pp. 161–180; Shermer, 2013). More generally, what the demarcation aims to describe are the conditions implied in a more trivial description: “if a theory strays from the epistemic desiderata of science by a sufficiently wide margin while being touted as scientific by its advocates, it is justifiably branded as pseudoscience” (Pigliucci & Boudry, 2013a, p. 2; see also, e.g., Boudry & Pigliucci, 2017; Fasce & Picó, 2019; Hansson, 2013; Hietanen & al., 2020; Schmaltz & Lilienfeld, 2014). The more specific nuances of these characterizations of the demarcation cannot be solved here, but it is useful to keep in mind that there are such nuances – at least on a case-by-case basis – even if no one unified description of those nuances is currently found or agreed upon. That said, below are some approximate characteristics that have been given for what it is we are talking about when we are talking about proper 'science' (that is derived from the Latin word *scientia*, meaning 'knowledge; a (state of) knowing; expertness').

When talking about *science*, we can generally mean at least four related but distinct things: (1) science as an institution, or the organization of the research conducted by scientists; (2) scientific research activity, or the research process; (3) results generally accepted in the scientific community at a particular moment, i.e., scientific knowledge; and (4) the scientific method as a critical, self-corrective, intersubjective method for provisionally accepting beliefs (Niiniluoto, 2002, pp. 4–5; Raatikainen, 2006, p. 3; see also Niiniluoto, 1984, Ch. 1). Relating to all these aspects of science, it may more concisely be described as a human enterprise that is a source of cognitive attitudes about the world, characterized by its reliance on the scientific method (Niiniluoto, 2002, p. 4).

The *scientific method*, or methods, may further be described as the tool(s) that lays behind the enormous success of science in describing, explaining, and predicting phenomena in the natural world (i.e., in 'nature'; in the broad sense including the whole universe, i.e., the external world, ourselves as human beings, our societies, our physical constructions, and our thought constructions[2]). Broadly speaking, it consists of the community of scientists proposing hypotheses and constructing theories about their areas of interest, testing them by statistically analyzing measurements and data gathered via empirical observation and experimentation, and subjecting the results to constant process of peer evaluation and critical discussion. In these processes, both inductive and deductive reasoning are utilized (sometimes specified to also include abductive and Bayesian reasoning), and description and categorization of the studied phenomena is performed. Based on the prevailing theories, scientist often further build, test, compare, and revise models (as tools for reasoning by analogy and abstraction), and nowadays often use accompanying computer simulations to represent, predict, understand, explore, explain, and/or illustrate the systems they are studying. All this scientific inquiry results in gradual accumulation of scientific evidence and eventual scientific discoveries, including

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[2] I generally use and understand "science" in the broad sense: comprised of both the natural and psychological/social sciences whose *aim* it is to systematically make discoveries and compile a *testable* and *descriptively* accurate body of knowledge about how nature works and what it is comprised of (see also Hietanen & al., 2020; Shermer, 2013). This target of *nature* – or the natural world, or cosmos – consists of not only the physical reality external and internal to conscious creatures, including the human brain/mind and behavior, but simultaneously the psychological and social phenomena manifested within the system. Of course, the study of psychological/social phenomena is still in its relative infancy, as compared to the study of natural phenomena external to humans, but the proper *aim* descriptive of science is already there, at least in some places (if in some branch of scholarship the aim is not there, then that branch is not science but something else; see also sect. 2.2.3n31).

discoveries of new hypotheses and theories; evidential support or lack of support for hypotheses or their features (e.g., their explanatory power); new theories or potential falsification of old ones; statistically significant correlations or lack thereof; things, events, species; or discoveries of mechanisms; regularities; and even laws of nature. In many areas of science there is disagreement about specific theories or their nuances, or data interpretation, but those disagreements are a part of the research process, combatting human fallibility. As a result, with accumulation of further evidence and potential development of new research methods, they tend to bear out the better understanding and scientific knowledge the enterprise strives towards. It is through these many kinds of continuing objectivity-striven processes, keenly aware of human fallibility and bias, that science has been enormously successful in producing, at the very least, pragmatically useful descriptions, explanations, predictions, and associated provisional beliefs and understanding – i.e., scientific knowledge – about the world.[3]

Scientists do not claim that *scientific knowledge* would be true, strictly speaking, nor that we can expect any final truths to be found.[4] As humans appear to be fallible, samples always limited, and our observations (and data interpretations) theory- or model-laden, even the most well-substantiated scientific knowledge is then "merely" a provisional, probabilistic description of the target of research, based on the evaluation of the overall body of scientific evidence at a given time, as evaluated by the scientific community (or some subsection of it, specialized in a given topic). Humility is thus always called for. Still, truth may be considered the ideal aim of science, and something science might

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[3] This general summary of the many characteristics of the scientific method(s) draws from a host of philosophical sources, difficult to segregate outside of a much longer philosophical thesis. It is not intended as a thorough description, especially as many nuances are under constant discussion in philosophy of science, but as a simplified summary of some central characteristics that have been given for the scientific method(s). That said, the varied sources utilized, each containing much more discussion, include the following (with the specific topics of the articles in parentheses):

Hansson, 2013 (for a basic definition of science and pseudoscience); Niiniluoto, 2002, pp. 4–5 (characterization of science); see also Boyd & Bogen, 2021 (theory and observation in science); Carroll, 2020 (laws of nature); Craver & Tabery, 2019 (mechanisms in science); Douven, 2021 (abduction); Eran, 2020 (measurement in science); Fishman & Boudry, 2013 (lack of naturalistic presupposition in science); Frigg & Hartmann, 2020 (models in science); Frigg & Nguyen, 2020 (scientific representation); Henderson, 2020 (the problem of induction); Hepburn & Andersen, 2021 (scientific method); Kelly, 2016 (evidence); Koskinen, 2020 (risk account of scientific objectivity); Longino, 2019 (the social dimensions of scientific knowledge); Reiss & Sprenger, 2020 (scientific objectivity); Schickore, 2018 (scientific discovery); Shermer, 2013 (science and pseudoscience in practice); Winsberg, 2019 (computer simulations in science); Woodward & Ross, 2021 (scientific explanation).

Of course, much more could still be said to describe science. For example, its ideal of internal consistency (or coherence) and strive towards consensus; the importance of communal perspectival or viewpoint diversity in combatting our biases; the ideal of reliable replication to substantiate a potential finding via a larger body of evidence; and understanding the challenging need for experimental control of intervening variables (exemplified in, for example, double-blind studies). And, to end this list, built into the processes of science is the potential cultivation of critical metacognition and intellectual virtues, like intellectual humility, supported by a social context that (ideally) strives to uphold them.

[4] "Truth" here is defined as a definite fact, absolutely *corresponding with reality*, or a final (and certain, infallible) understanding of some part of reality (see Merriam-Webster, n.d.-c; see also Glanzberg, 2021, sect. 1.1).

approach by increasing probabilities via accumulated research, albeit its attainment would be outside the conscious reach of human capabilities (i.e., we may aim for truth, but even if it was possible for us to reach the truth of some matter, it is unclear how we could for certain know we had achieved it; at least when it comes to systems the rules of which we do not know *a priori*, thus potentially excluding some logic and mathematics). Scientific knowledge simply appears to be the best we can epistemically do, in the area it covers. And hence it appears to provide us with the most reliable (i.e., *epistemically most warranted*) statements that can be made, at the time being, on the subject matters it is concerned with. On those subject matters, it appears that if any human activity can be said to be the best indicator or approximation of truth, or truthlikeness, that is scientific inquiry by the scientific community, along with the scientific knowledge it produces.[5]

Even though in philosophy it is a debated question of what the precise epistemic status of our best scientific theories are in relation to the actual nature of the world, there is little debate about their enormous instrumental, practical value (see, e.g., Chakravartty, 2017; Niiniluoto, 2002, p. 11; 2019). Hence, one might think it would not be a stretch to expect that even the most radical science denialists tend to seek, for example, medical doctors when wanting to cure a serious physical ailment, as these are the experts who have produced the best track record of curing people (via systematically studying and applying medical science, like the prevailing germ theory of disease). Alas, many misguided people still avoid health care professionals or neglect their advice, and the result, of course, can be quite tragic (see, e.g., Gorski, 2010, 2021, for how there are even people who still deny the germ theory of disease). To some degree, tendency for common-sense intuitive and magical thinking, as opposed to analytic scientific thinking, may account for these tendencies in some people (see also sect. 6.2.2). This point is particularly emphasized at the time of writing when the global coronavirus

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[5] Hansson, 2013 (for a basic definition of science and pseudoscience); Niiniluoto, 2002, pp. 4–13, 79–85 (characterization of science, fallibility, truthlikeness); Niiniluoto, 2019 (scientific progress); Popper, 1979, pp. 194–204 (the aim of science, explanation, fallibility); Popper, 1994, pp. 3–7 (scientific knowledge, fallibility, uncertainty); see also Boyd & Bogen, 2021 (theory and observation in science); Hájek, 2019 (interpretations of probability); Glanzberg, 2021 (truth); Hetherington, n.d. (fallibilism); Oddie, 2016 (truthlikeness).

Note that this does not mean that science is the only epistemically respectable enterprise, merely that it – within the limited human capabilities we are bound to – appears to produce the most reliable statements that can epistemically be made on the area it covers. Namely, the area of how nature works and what it is comprised of. (Hansson, 2013, 2021; Hietanen & al., 2020; Shermer, 2013; see also note 2 above.) More broadly, Hansson (2018) has distinguished various *fact-finding practices* that all strive to achieve as reliable information as possible in empirical issues. These go far back in human history, and within each practice better and worse ways of going about it can be distinguished (much like science can be distinguished from pseudoscience). Some fact-finding practices distinct from science – that apply largely the same patterns of reasoning as science – include, for example, tracking of animals, investigative journalism, criminal investigation, and troubleshooting in various technological systems. Modern science, in this view, is then further understood as “a collection of unusually resourceful and globalized fact-finding practices” (Hansson, 2020), and as “a universal project, striving for knowledge that is common to all of humanity” (Hansson, 2018).

COVID-19 pandemic is ongoing, and the vaccines are being distributed (Novella, 2020; see also Kaufman & Kaufman, 2018; Novella, 2018, sect. 4).[6]

The advisability to consult science and scientific experts applies not only on the area of medicine but also when wanting to effectively operate on the domains of, for example, architecture, data management, economy, energy production, global warming mitigation, nutrition, pedagogy, service design, space exploration, or broadly on any domain of technology or other area that relies on or can be informed by science. This is formally recognized in *applied sciences* like medicine and the various fields of engineering, who apply various sciences to produce novel social and technological solutions and inventions. Similarly, various artists apply or rely on science to produce novel artistic inventions, teachers to develop more effective ways of teaching, and farmers to yield better crops. And so on. The number of areas of life, where science can beneficially inform us, can hardly be overstated. Thus, it would further be very advisable – to say the least – that science (along with ethics) be consulted when making any political decisions it can inform.

Overall, if it is our goal to attain empirically well supported, pragmatically reliable, critical beliefs that are keenly aware of human fallibility and thus willing to change if accumulation of new critically evaluated objectivity-striven evidence calls for it, the scientific enterprise appears to be the best we have. Thus, it ought to be respected in our decision-making processes – both private and public – as it can ground our decisions with the best available evidence of what those decisions are likely to entail, and thus what decisions are most likely to work towards our goals. To this end, what is needed is the recognition of the importance of our sincerely objectivity-striven, knowledge-forming, and knowledge-structuring tool, and sufficient understanding of it, along with the relevant institutions, processes, and the produced scientific knowledge. In other words, what is needed is the recognition of the importance of science and sufficient scientific literacy. Properly understanding and conveying all this complex information is a constant challenge encountered in science communication and education (e.g., Barzilai & Chin, 2020).

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[6] Corresponding with some of the descriptions of science in this section are the characteristics of *scientific thinking* – closely related to critical thinking – that applies methods or principles of scientific inquiry to reasoning and problem-solving situations (e.g., Zimmerman, 2007, p. 173). This kind of thinking may be contrasted with that of *common-sense thinking*. While both types of thinking are of course fallible, some contrasting characterizations to distinguish these two, respectively, include them being: objectivity-striven vs. subjectivity-centered; analytic vs. intuitive; difficult vs. effortless; disciplined vs. loose; generalizable vs. personal; evidence-driven vs. emotions-driven; testable vs. anecdotal; curious vs. unconcerned; self-critical and -corrective vs. non-critical and dogmatic; conscious of potential bias vs. unconscious of potential bias; serving the needs of striving to find out what is true vs. serving the perceived needs of the individual and/or their perceived in-group; respecting epistemic authorities like the scientific community vs. suspecting them. Of course, strictly speaking, these characterizations are rough ideal types, as they appear to be balanced in various ways in our individual thinking processes in different contexts. (see also [a] characteristics of *scientific skepticism*: Novella, 2018; Sagan, 1995; [b] styles of *scientific reasoning*: Čavojová, et al., 2020; Kind & Osborne, 2016; sect. 2.1.3.2n18; [c] *scientific attitude*: sect. 2.2.3; [d] *Type 1 and Type 2 thinking*, i.e., *System 1 and System 2*: e.g., Evans & Stanovich, 2013.)

2.1.2 Literacy

Literacy is popularly understood to refer to the quality or state of being 'literate'; i.e., the acquired ability (or skill) to read and write textual content, or the state of being well-educated and learned (see Norris & Phillips, 2015; Merriam-Webster, n.d.-a, n.d.-b). However, researchers have a much broader understanding of literacy. While the concept has been widely discussed and debated[7], the general contemporary understanding has been roughly summarized in what appear to be three especially noteworthy sources (Montoya, 2018). These are the definitions published and utilized by [1] the ELINET (European Literacy Policy Network) in their *European Declaration of the Right to Literacy*, authored by Valtin et al. in 2016; [2] the OECD (Organisation for Economic Co-operation and Development) in their *Programme for the International Assessment of Adult Competencies* (PIAAC), in the programme's 1st Cycle of the Survey of Adult Skills in 2011–2018 and the 2nd Cycle in 2018–2023; and [3] the UNESCO (United Nations Educational, Scientific and Cultural Organization), as a result of an expert meeting in June 2003, marking the first year of the United Nations Literacy Decade in 2003–2012 (see UN, 2002; UNESCO, 2005, p. 55). Respectively, these definitions are as follows:

> "Literacy refers to the ability to read and write at a level whereby individuals can effectively understand and use written communication in all media (print and electronic), including *digital literacy* [emphasis added]." (Valtin et al., 2016.)

> "Literacy is understanding, evaluating, using and engaging with written texts to participate in society, to achieve one's goals and to develop one's knowledge and potential." (PIAAC Literacy Expert Group, 2009, p. 8; OECD, 2012, p. 20; 2019b, pp. 17–19; see also OECD, n.d.-a.)

> "Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials *associated with varying contexts* [emphasis added]. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society." (UNESCO, 2004, p. 13; see also UNESCO, 2017, pp. 14–15.)

Out of these definitions, the OECD one appears to be the narrowest: explicitly, it refers only to "[reading of] written [and printed, displayed, and digital] texts", not spoken, and only focusing on the ability to decode, evaluate, and use them towards individual goals, not on producing them (e.g., in

[7] For a historical overview and compilation of a wide array of understandings and definitions of the evolving concept of literacy, along with a historical overview of its measurement, see Ahmed, 2011; UNESCO, 2005, Ch. 6 (see also UNESCO, 2004; 2013b, pp. 20–25; 2017, pp. 14–15, sect. III, V).

writing). In formulating the definition, OECD noted the UNESCO definition to be a good baseline. However, it was determined to be unfitting in scope for the specific purposes of PIAAC as an international assessment needing a well-operationalizable definition to go along with other operationalizations used in the assessment.[8] (PIAAC Literacy Expert Group, 2009, pp. 8, 13–14; OECD, 2019b, pp. 17–20.)

The UNESCO definition likewise only refers to "printed and written materials" but is much broader in the scope of abilities it associates with literacy – including producing (i.e., creating and communicating) with said materials – and is also more explicitly conscious of the varying contexts of literacy, as compared to the OECD definition (though, cf. OECD, 2016a, pp. 23–24; 2016b, pp. 51–52; 2019b, p. 20). However, in their position paper from 2004, UNESCO states that "[a]lthough the term 'literacy' is often used metaphorically to designate basic competencies in domains other than those immediately concerned with written texts, such skills as 'computer literacy', 'media literacy', 'health literacy', 'eco-literacy', 'emotional literacy' and the like do not form part of the plural notion of literacy at issue here". Rather, the plurality of the concept and the "associated varying contexts" in the definition refer to the multitude of meanings and dimensions of the vital competencies of reading, writing, and calculating, situated in many practices of literacy that are embedded in various learning-related cultural processes, personal circumstances, and collective structures (including social, economic, and cultural bounds). This formulation marked the first year of the United Nations Literacy Decade (2003–2012), aiming at promoting global awareness and focus on improving literacy thus conceived. It was intended as a working definition in the context of assessing literacy.[9] In the end, the definition is still rather narrow. (UNESCO, 2004, pp. 5–7, 10; 2005, p. 155; 2017, pp. 14–15.)

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[8] The international Survey of Adult Skills, that is conducted as part of PIAAC, measures adults' proficiency in key information-processing skills – literacy, numeracy, and problem solving – and gathers information and data on how adults use these skills at home, at work, and in the wider community. (OECD, n.d.-a.)

[9] The UNESCO definition seems to have been particularly utilized in their Literacy Assessment and Monitoring Programme (LAMP), started in 2003. The programme developed a proof-of-concept quantitative methodology by the same name over 2006–2011, for assessing the distribution of literacy and numeracy among people aged 15 years and above (UIS, 2017). The definition was also utilized in UNESCO's Literacy Initiative for Empowerment (LIFE) programme (2006–2015). While LAMP – along with third party programmes – provided relevant survey data, LIFE was implemented to support the Education for All (EFA) literacy goals for the United Nations Literacy Decade 2003–2012 (UIS, 2007; UNESCO, 2007, 2015; see also UNESCO, 2005; UN, 2002). LIFE focused especially on empowering women, out-of-school girls, and their families, particularly in rural areas located in 35 developing countries with the lowest literacy rates (UIS, 2007; UNESCO, 2007, 2015).

By the end of LIFE, in 2015, progress towards the EFA goals had been made, but Education for All was not yet achieved (UNESCO, 2015). However, these programmes contributed towards fulfilling the fourth goal in the United Nations Sustainable Development Goals (SDG 4), targeted to be achieved by 2030: ensure inclusive and quality education for all and promote lifelong learning. Especially Target 4.6 is relevant: the achievement of practically universal (functional) literacy and numeracy. (Ritchie et al., 2018; UN, 2015.)

However, an outside interpreter may still conceive the UNESCO definition – as it is written – to be broader than originally intended. That is, some of the "associated varying contexts" could be interpreted to relate to science, while some other contexts would relate to, for example, media, information, data, health, finance, games, or legal or environmental matters. Thus conceived, each of these kinds of areas – also situated in many learning-related processes, circumstances, and structures – would constitute their own area of literacy, overlapping with others (i.e., media literacy, information literacy, etc.; UNESCO, 2005, pp. 150–151; 2017, p. 15). UNESCO has characterized this kind of broader understanding of literacy, consisting of many areas, as being often used as "a shorthand for the capacity to access, understand, analyze or evaluate" the respective areas (UNESCO, 2017, p. 15).

In a similar vein, *numeracy* – or numerical literacy – refers to the ability to approach quantitative matters (UNESCO, 2005, pp. 149–150). At the same time, while there would be various context-specific literacies, the acquired ability to read basic textual content may more precisely be called *basic literacy* (G. A. Miller, 1974, p. 3; Smith, 1977). With the added ability to write textual contents, this would become what could be called *textual literacy*, that with the added ability to do arithmetic would be *fundamental literacy* (Siarova et al., 2019, p. 16). This would be one foundation needed for personal and social development in the more advanced areas of literacy.[10] Further, *functional literacy* – the source for the working definition of "literacy" in UNESCO's 2005 report (pp. 30, 153–154) – can be understood to refer to fundamental literacy that is sufficient for effective functioning in one's community and for enabling continued community- and self-development. Additionally, some distinguish numeracy, textual literacy, visual literacy, understanding of graphs and charts among others to constitute *foundational literacies* that are needed and applied in more domain-specific literacies, like scientific and media literacy, that may further be called *disciplinary literacies* (NASEM, 2016, pp. 15–17, 32). Thus, broadly understood, "literacy" consists of *multiple literacies*, with, for example, functional literacy being only one context-specific form or area of literacy.

It seems that already soon after their initial position paper (2004), UNESCO came to somewhat embrace this sort of broader understanding of literacy, albeit still preferring their original narrower conceptualization (see UNESCO, 2005, pp. 150–151, 155; 2017, pp. 14–15). In any case, both the narrower and broader conceptualization see literacy as a *continuum* whereby people can develop their skills on the respective areas of literacy, given that their larger situated context allows for it. The broader conceptualization helps us see how "literacy" is used in "scientific literacy": to refer to the continuum of literacy that is applied in contexts that have to do with science or scientific matters.

[10] For comprehensive data and graphs on long term positive trends in global "literacy", mostly defined as the ability to read and write (i.e., textual literacy), see Roser & Ortiz-Ospina, 2018.

Even given this sort of broader understanding, there is still one narrow aspect remaining in the UNESCO definition. Namely, it understands literacy to only have to do with using "printed and written materials". Frankly, this is outdated. Specifically, a large proportion of content online is in image, audio, video, and various interactive formats, each potentially broadening the abilities needed to appropriately identify, understand, interpret, create, communicate, and compute, using these *visual* or *displayed* and *auditory materials* associated with the varying contexts (e.g., social media platforms, content production techniques, opportunities for participation, etc.). Thus, a more forward-looking definition might talk about both "printed and written materials" as well as "verbal, visual, auditory, numeric, and kinesthetic" or, in short, *sensory* materials (or multimodal materials).[11] Also, navigation skills could be added to the list of abilities, and *civil* participatory skills might also be emphasized (i.e., it is an ability of its own to efficiently navigate textual and visual content, and to productively participate in the communities surrounding them, both online and offline; see also Kangassalo, 2019).

In this respect, the ELINET definition of literacy seems much more up to date. Even though it explicitly only refers to "the ability to read and write", it also mentions *digital literacy*. This form of literacy is then more precisely defined as follows:

> "Digital literacy is not just reading and writing online but includes specific abilities, including: being able to find information on the internet (identifying key words, searching for phrases, scanning heterogeneous links); using navigation devices (such as assessing the relevance of verbal expressions, understanding the hierarchical structure of information); accumulating information across multiple digital pathways; and critically evaluating sources of information. Digital literacy also includes multimodal skills and knowledge, such as the use of visual and auditory information to produce online texts."[12] (Valtin et al., 2016, p. 11.)

The tradeoff between the broadly understood UNICEF and ELINET definitions appears to be that even though the ELINET appropriately accounts for digital media in addition to written and printed media, it does not appear to account for the multiple literacies outside of – or overlappingly with – digital literacy nor the many personal and societal contexts in which those literacies are situated.

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[11] The Australian Literacy Educators' Association (ALEA) has explicitly noted visual materials in their literacy declaration by adapting the UNESCO definition but supplementing it to include "printed and written *(and visual)* [emphasis added] materials" (ALEA, 2015).

[12] As the United Nations Sustainable Development Goals Indicator 4.4.2 aims to achieve at least a minimum level of proficiency in digital literacy for youth/adults (by 2030), UNESCO has recently taken the first steps towards designing an instrument for the assessment (Laanpere, 2019; see also Ritchie et al., 2018; UN, 2015). In 2019, partly due to UNESCO promotion, and to support further Sustainable Development Goals, 193 countries also officially proclaimed an annual Global Media and Information Literacy (MIL) Week, from 24th to 31st of October (UNESCO, 2013a, 2019a–b).

Thus, to conceptualize literacy in contexts where it is used in the broad sense of the word, we may provide our own combinative definition.

When further considering that "ability" appears to have more of a connotation of relative stability and innateness, whereas "skill" seems to be more clearly something that can be learned and improved, the combinative definition would take the following form: *Literacy refers to the learnable skill to access, search, navigate, identify, understand, interpret, evaluate, create, communicate, and compute using printed, written, sensory, and digital materials on various areas of life situated in varying personal and social contexts. Learning of this skill happens on a continuum that enables individuals to achieve their goals, to develop their knowledge and potential, and to participate fully and civilly in their community and wider society.* More concisely and metaphorically, the plural of literacies – basic literacy, science literacy, media literacy, etc. – may be described as *navigation skills within specific areas of the world that are important for our personal and social lives*.

Thus conceived, "scientific literacy" is one *area* on the multidimensional continuum of literacy: one that involves the above-mentioned abilities and associated skills as utilized on areas of life that relate to science or scientific matters, in the personal and social contexts we live in (see also Miller, 1983, p. 30). However, the concept has, of course, been more specifically defined amongst those who have focused on studying and measuring it.

2.1.3 Scientific literacy

Now that we have a general idea of the concepts of science and literacy, it is easier to approach the concept of *scientific literacy*, sometimes also called science literacy. It has been defined in various ways, with different emphases and subcategories in different sources, and there exists debate about the matter. In general, what is discussed, is the ideal focus of education (especially in formal curricula) called "scientific literacy". In this chapter, I go through a couple of different definitions, to give a sense of the specific conceptualization utilized in this thesis, until settling for a primary definition formulated by Jon D. Miller. (for detailed overviews on the conceptual debate, see DeBoer, 2000; Laugksch, 2000; D. A. Roberts, 2007; see also Hurd, 1998, pp. 411–413; Holbrook & Rannikmae, 2009; NASEM, 2016, Ch. 2; Queiruga-Dios et al., 2020, Figure 1; Siarova et al., 2019, Ch. 2; further, see Norris & Phillips, 2003; Yore et al., 2007.[13])

[13] While many scholars use the terms interchangeably, others distinguish "science literacy" and "scientific literacy" to refer to different ends on a spectrum. According to these views, *science literacy* refers to understanding of the concepts, content, and methods in science. And *scientific literacy* refers to active application of that understanding in everyday life

If we follow the conception of literacy, or multiple literacies, arrived at in the previous section (2.1.2), scientific literacy could roughly be defined as the learnable skill to navigate amidst the parts of the world that have to do with science or scientific matters. Given that a vast proportion of our empirical observations, interpretations, and questions within humanity can be molded, with the right reference frame, into scientifically testable descriptions, hypotheses, and experiments, this would be a very broad definition: most of the world might relate to science and scientific understanding (or the philosophy behind them). That being the case, scientific literacy as the skill to navigate amidst the science-related parts of the world could practically mean the skill to navigate the world. This thought does give some idea of the concept and its importance, especially considering how both our private and collective democratic decisions have an impact on the world which we navigate, and how the navigation behind those decisions can fall on many places on the continuum between them being skillful (~scientifically literate) or unskillful (~scientifically illiterate). However, this gives us only a very abstract and rather arbitrary picture of the concept and its implications. A more explicit and better confined definition is in order, especially in terms of operationalization.

2.1.3.1 Project 2061 definition

Perhaps one of the more influential contemporary definitions of scientific literacy is formulated by educators F. James Rutherford and Andrew Ahlgren in their 1989 book *Science for All Americans*. They summarize the concept as follows:

– in contextual decisions, actions, situations – to reflect them from a critical scientific perspective, and to evaluate and question observations and scientific claims from different perspectives, within a social context as citizens. (e.g., Maienschein, 1998; P. Tan, 2016.)

This distinction between science literacy and scientific literacy, thus described, approximately corresponds to what Douglas A. Roberts (2007) has dubbed as Vision I and Vision II of scientific literacy. In this thesis, the primary interest is perhaps more towards Vision II scientific literacy, though there is much overlap with Vision I, and the survey itself steers more towards Vision I.

In terms of the definitions examined in this section: (1) Project 2061 arguably follows Vision I; while (2) OECD's PISA studies follow Vision II; and (3) Miller's surveys follow Vision I albeit his three-part definition of scientific literacy, that I will come to in this chapter, is more expansive, including Vision II via its third part (Bybee et al., 2009; Roberts, 2007). Vision II is noticeably more difficult to measure than Vision I, and the necessity of measuring it in addition to Vision I has been under considerable debate (see Bybee et al., 2009; Roberts, 2007).

Additionally, there are more recent conceptualizations of "Vision III" of scientific literacy, referring to a value-oriented active science engagement in social, cultural, political, and environmental issues (see, e.g., Liu, 2013; Sjöström & Eilks, 2018; see also Siarova et al., 2019, sect. 2.1). However, while scientific understanding and deliberation should of course be promoted and reflected in our decision-making processes – as already encouraged in Vision II – I am cautious of potential politicization of *science* in society, as well as of potential excessive 'extravertification' of curriculum (cf. Cain, 2012). Thus, I am skeptical of whether Vision III, or some versions of it, brings any added value in addition to Vision I and Vision II, rather than take it away. In the tribal species that is *Homo sapiens*, one should be very careful when balancing one's epistemic and moral endeavors, lest one might risk both (see Kangassalo, 2019; sect. 2.2.3n31, 5.2.3). Still, I suppose by some conceptualizations, my more far-reaching suggestions might be classified as Vision III by some (e.g., Liu, 2013; Siarova et al., 2019), but I would advise against including everything under the banner of *scientific* literacy; rather, it has to do with *ethics* informed by science (cf. Kangassalo, 2019; cf. also sect. 6.2).

> "Scientific literacy – which encompasses mathematics and technology as well as the natural and social sciences – has many facets. These include being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific way of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes." (Rutherford & Ahlgren, 1989, p. x.)

Further, they summarize some of the benefits of applying scientific literacy to everyday life:

> "Scientific habits of mind can help people in every walk of life to deal sensibly with problems that often involve evidence, quantitative considerations, logical arguments, and uncertainty; without the ability to think critically and independently, citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems." (Rutherford & Ahlgren, 1989, pp. vi–vii.)

Produced as a result of a three-year collaboration with hundreds of scientists and other scholars, the whole book appears to encompass an impressively compressed and easy to understand description of the scientific worldview (ca. 1990) along with a decisive long-term plan for a lasting education reform. It is part of the 1985 launched *Project 2061*[14]: "a long-term research and development initiative" by the American Association for the Advancement of Science (AAAS), "focused on improving science education so that all Americans can become literate in science, mathematics, and technology" (AAAS, n.d.). Rutherford, then the Education Director of the AAAS, was – alongside executive officer William Carey – the initiator of the project. He was also the project's director until his retirement in 1998. The above definition of scientific literacy was thus formulated primarily with an ideal content and form of education in mind, specifically focusing on the vision of Project 2061 (see Project 2061, 1993, 2001, 2007; Rutherford, 2005, 2009; Rutherford & Ahlgren, 1989; see also DeBoer, 2000; C. Lange, 2011; D. A. Roberts, 2007).[15] Curiously, after the publication of Rutherford

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[14] The launch year of Project 2061 – 1985 – coincided with the arrival of Halley's Comet, and the project was named after the year it is calculated to arrive the next time.

[15] After his retirement, Rutherford has reflected on what he considers the relatively limited success of Project 2061 thus far and has proposed a reform agenda for the next ~50 years (see Rutherford, 2005, 2009; see also C. Lange, 2011). So far, there has not been as much progress as he would have liked, but Project 2061 continues, and the proposed curricula alongside related materials remain available for all (see Project 2016, 1993, 2001, 2007; Rutherford & Ahlgren, 1989; see also Rutherford, 2005, 2009). (for other takes on the science curriculum, see also Osborne et al., 2018.)

& Ahlgren's *Science for All Americans* (1989), where the term "scientific literacy" was used, Project 2061 has since used the term "science literacy" (see D. A. Roberts, 2007; note 13 above).

In addition to the Rutherford & Ahlgren definition, there are some considerably lengthy and varying lists about the kinds of skills, attributes, and behaviors that would more specifically be characteristic of scientific literacy (see, e.g., Hurd, 1998, pp. 413–414; see also National Academy of Sciences, 1996, p. 33; UNESCO, 1993, pp. 15–17).[16] Due to the length of these lists, they are often very hard, if not impossible, to fully operationalize. To that end, some of the more usable definitions have been described – and used – by the OECD.

2.1.3.2 The OECD's definition in PISA

The OECD *Programme for International Student Assessment* (PISA) is a triennial international study launched in 1997, with the first cycle of the study conducted in 2000. It aims to evaluate education systems worldwide by assessing 15-year-old school pupils' competencies in three key subjects: reading, mathematics, and science (OECD, n.d.-b). Each cycle of the programme rotates the primary focus between these three key subjects. PISA uses the concept of scientific literacy in part to create the tools of assessment for scientific skills and the formulation of the questions concerning science (OECD, 2000, pp. 76–79). Thus, scientific literacy has a special role in evaluating the science competencies in PISA studies. It is considered a key outcome (goal) of education for all students (OECD, 2000, p. 76).

At the time of writing, the data for the latest PISA study was collected during 2018 and the main results published in 2019 (see Schleicher, 2019). However, the latest cycle with focus on the key subject of science was the preceding study, conducted in 2015 and published in 2016 (see OECD, 2018). Thus, it provides the most carefully formulated and explicated definition of scientific literacy by PISA, thus far. It is, however, illustrative to compare the 2015 definition to the one used in the 2006, 2009 and 2012 PISA studies, as the definition was noticeably tweaked for the 2015 study (also utilized in 2018). In the earlier studies, scientific literacy was defined as follows:

[16] Some of the varied definitions do not recognize the *continuum* of (scientific) literacy, instead trusting on a dichotomous classification. This does not appear to be ideal, considering the UNESCO literacy definition and promotion for abandoning dichotomous classification (UNESCO, 2004, p. 13; 2005, pp. 150–151; 2017, pp. 14–15), along with the combinative definition arrived at in the previous section (2.1.2). Still, dichotomous classification can be useful for public awareness in some conceptualizations, like Miller's conceptualization of a measure if people can be expected to be able to readily read and understand the science section of *The New York Times* (J. D. Miller, 2006, 2016).

"PISA … defines *scientific literacy* in terms of an individual's:

- *Scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues.* For example, when individuals read about a health-related issue, can they separate scientific from nonscientific aspects of the text, and can they apply knowledge and justify personal decisions?
- *Understanding of the characteristic features of science as a form of human knowledge and enquiry.* For example, do individuals know the difference between evidence-based explanations and personal opinions?
- *Awareness of how science and technology shape our material, intellectual and cultural environments.* For example, can individuals recognise and explain the role of technologies as they influence a nation's economy, social organisation, and culture? Are individuals aware of environmental changes and the effects of those changes on economic and social stability?
- *Willingness to engage with science-related issues, and with the ideas of science, as a reflective citizen.* This addresses the value students place on science, both in terms of topics and in terms of the scientific approach to understanding the world and solving problems. Memorising and reproducing information does not necessarily mean students will select scientific careers or engage in science-related issues. Knowing about 15-year-olds' interest in science, support for scientific enquiry, and responsibility for resolving environmental issues provides policy makers with early indicators of citizens' support of science as a force for social progress."[17]

(OECD, 2007, pp. 34–35; see also OECD, 2009, pp. 14–15, 128–131; 2014, pp. 28, 216.)

In the 2015 PISA study, the concept was explicated more, and noticeably refined in a streamlined fashion. The newly paid focus on the concept was due to the key focus of the study being again on science, for the first time since 2006:

"Scientific literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen.

A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to:

[17] For an in-depth scientific literacy scholar dissection of the PISA 2006 study, see Bybee & McCrae, 2011.

Explain phenomena scientifically – recognize, offer and evaluate explanations for a range of natural and technological phenomena.

Evaluate and design scientific enquiry – describe and appraise scientific investigations and propose ways of addressing questions scientifically.

Interpret data and evidence scientifically – analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions."

(OECD, 2016a, p. 20; see also OECD, 2016a, pp. 17–28; 2016b, pp. 50–55; 2019a, p. 27.)

The most noteworthy difference between the 2006 and 2015 PISA studies appears to be the added concepts of "*content knowledge*", "*procedural knowledge*", and "*epistemic knowledge*" to the 2015 definition (though, there is similarity to the 'three dimensions of scientific literacy' outlined already in the 2000 definition; see OECD, 2000, p. 76). These three types of knowledge (about science) correspond, respectively, with the three above-mentioned types of competencies that a scientifically literate person should have (OECD, 2016a, pp. 19, 26–28; for a summary description of the seven levels of science proficiency utilized in PISA, see also OECD, 2016a, pp. 42–43; 2019a, pp. 112–113).[18] These competencies emphasize scientific literacy as a set of skills (on a continuum) that are important for reflectively thinking about and scientifically understanding natural and technological phenomena, as well as for understanding the value of science as a tool for an active and enlightened citizen both on the private and public spheres. In these regards, similarities to the Rutherford & Ahlgren definition (1989, p. x) can be seen.

The PISA definition of scientific literacy appears to be well understandable and operationalizable. As such, it can be useful. However, it is a bit narrow in the sense that it does not –

[18] See Kind & Osborne (2016) for further explication on the three types of knowledge (see also OECD, 2016a, pp. 19, 26–28). For example, they outline that, *roughly*, 'scientific reasoning' aims to answer three questions: [1] the ontic question (what exists?), [2] the causal question (why it happens?), and [3] the epistemic question (how do we know?) (with a further technological or applied, contra scientific, question being "what can we do with such knowledge?"). Respectively, these three questions roughly correspond with content knowledge (explain phenomena scientifically; to answer what [phenomena] exists), procedural knowledge (evaluate and design scientific enquiry; to answer why it happens), and epistemic knowledge (interpret data and evidence scientifically; to know how we know).

Kind & Osborne (2016) argue that the significance of either procedural knowledge, epistemic knowledge, or both have long been neglected in accounts of scientific reasoning, and in teaching and learning of scientific reasoning, with the focus having been on content knowledge (see also Davis, 1935). With their construct of "six styles of scientific reasoning" they aim to address this shortcoming: the six styles of reasoning each represent six styles of (successfully) answering the ontic, causal, and epistemic questions, albeit each with their *distinct* forms of content knowledge (knowledge of appropriate domain-specific concepts used in reasoning), procedural knowledge (knowledge of the procedures and associated constructs used to establish claims to know), and epistemic knowledge (knowledge of the epistemic constructs and values and how they are used to justify claims to know). These six styles of reasoning, each utilizing their distinct forms of content, procedural, and epistemic knowledge, include: (1) mathematical deduction, (2) experimental evaluation, (3) hypothetical modeling, (4) categorization and classification, (5) probabilistic reasoning, and (6) historical-based evolutionary reasoning. (Kind & Osborne, 2016; see also Osborne et al., 2018.)

at least not explicitly – note the importance of psychological/social sciences (for explaining, evaluating, and interpreting psychological and social phenomena). That is, unless we assume the definition uses a broad understanding of "natural and technological phenomena" (as psychological and social phenomena *are* natural phenomena), but we do not have any reason to do so, considering OECD's own illustrative list of contents of science on focus (see OECD, 2016a, p. 26). This is unlike in Rutherford & Ahlgren's definition, in which they explicitly mention social sciences (1989, p. x); as well as unlike a conceptualization used in a recent study that encourages the EU to start taking steps towards promoting scientific literacy (Siarova et al., 2019; see also sect. 2.1.1n2, 2.2.4).

Ironically, this is a bit paradoxical, as OECD itself notes the importance of various social phenomena in their plea to strive towards better learning results, intergroup cooperation, and "global competence" (see OECD, 2020). In this regard, the PISA operationalization might in the future ideally be expanded: to *also* focus on students' competency and knowledge of and about psychological/social sciences (see also sect. 2.1.1n2). Moreover, focus could perhaps be expanded on the students' tendency for related virtuous self-reflection that could facilitate more pro-social daily activities on, for example, the increasingly interconnected, multicultural, and multi-ideological contemporary social media (see, e.g., Kangassalo, 2019, sect. 1.1–1.2; 2021a–b; sect 2.2.5).[19] That said, for the purposes of the present thesis, the PISA definition can be understood in the broad sense – encompassing both natural and psychological/social sciences – and yet simplified by, in a sense, going back to the roots of contemporary research about scientific literacy.

2.1.3.3 Jon D. Miller's expanded traditional definition

The political scientist Jon D. Miller is an influential figure in early measurements of scientific literacy, and its conceptualization and operationalization. For example, he has designed and been involved in conducting a part of the biennial *Science and Engineering Indicators* poll in the US, gathered by the National Science Board since 1979 (see sect. 2.2.4). He is also the three-decade standing Director of the International Center for the Advancement of Scientific Literacy (ICASL), founded by the Chicago Academy of Sciences in 1991, now located at University of Michigan (D. A. Roberts, 2007; https://cps.isr.umich.edu/people/jondm/). In 1983, Miller described in his classic article *Scientific Literacy: A Conceptual and Empirical Review* a three-part definition that could be called *Miller's expanded traditional definition of scientific literacy*. Miller describes the traditional definition of

[19] Arguably, a construct and measure of philosophical or ethical literacy could also be useful. However, especially the latter might be quite hard to formulate in a consensual manner among philosophers, due to various (meta)normative uncertainties concerning its constituents and implicit philosophical commitments.

scientific literacy to be constituted by (1) understanding of the norms of science, and (2) knowledge of major scientific constructs. He then adds his own expansion to the traditional definition: (3) awareness of the impact of science and technology on society and the policy choices that must inevitably emerge.[20] (J. D. Miller, 1983, p. 31.)

Miller's expanded traditional definition of scientific literacy can be seen to contain many of the aspects found in the Rutherford & Ahlgren and PISA definitions. For example, Miller's three-part list can *roughly* be connected to the three types of knowledge in the latest PISA definition: the first can be seen to relate to understanding of procedural knowledge (how to evaluate and design scientific enquiry), the second to understanding of content knowledge (how to explain phenomena scientifically), and the third to understanding of epistemic knowledge (how to interpret data and evidence scientifically *and* recognize appropriate policy implications). Apart from not explicitly containing a requirement for the *willingness* of people to apply their understanding, knowledge, and awareness of the three constituents into their lives and social decision-making, Miller's definition appears to be a solid basic definition (especially when science is understood in the broad sense, as in Rutherford & Ahlgren's 1989 definition, and as I do in sect. 2.1.1(n2)). It is also well operationalizable, as all three aspects have been explicitly used to measure scientific literacy already at the time of Miller's paper (J. D. Miller, 1983, pp. 36–41).

However, most studies – e.g., Miller's studies – often focus on the second aspect: knowledge of major scientific constructs (which most closely corresponds with content knowledge in the latest PISA definition; see also note 18 above; D. A. Roberts, 2007). This is, of course, relatively easy to measure: the survey needs only to contain questions that find out if participants are up to date with important scientific constructs (or, in the PISA formulation of content knowledge, they need only measure if participants can explain phenomena scientifically by recognizing, offering, and evaluating explanations for various natural and technological phenomena). While this does omit measuring

[20] It is worth underlining that each of the examined definitions of scientific literacy – Rutherford & Ahlgren (1989, x), PISA (OECD, 2016a, p. 20), and J. D. Miller (1983, p. 31) – feature not only knowledge of science but also of science-based *technology*. They do so even though technology is in fact merely connected to science, in virtue of it being a product of *applied science* like engineering (see sect. 2.1.1). If one would want to strictly measure literacy relevant to science proper, or strictly *technological literacy*, this might be something to consider.

However, (i) as technology is a product that is dependent on the workings of nature, that science aims to reveal, and (ii) thus, as many technologies would not exist if it were not for scientific discoveries, and (iii) as our best scientific theories are in many cases deeply dependent on utilizing technology in research; the two are so closely connected that often knowledge of one affects the quality of our considerations concerning the other. For example, our knowledge of scientific theories can affect our choice of technology when constructing a treatment plan (e.g., should we choose a homeopathic treatment or radiation therapy if we get cancer), while our knowledge of technology can inform us of what the best scientific theory might be (e.g., if we look at the Moon with a high magnification telescope, we can fairly certainly rule out the hypotheses of it being made of cheese or occupied by aliens). Relatedly, both can also help us make better private and public decisions. Thus, understanding of both science and technology are important and may justifiably be included under "scientific literacy". (see also Franssen et al., 2018, sect. 2.1–2.2.)

understanding of the norms or processes of science, and recognition of what conclusions and policy choices should be drawn from given data and evidence (and given ethical background assumptions), it can be revealing by providing a temporal snapshot of public understanding of scientific constructs.[21]

In this thesis, a similar emphasis is used, as it focuses on examining possible support for Miller's findings on media consumption habits that might support the kind of scientific literacy he has focused on measuring (e.g., J. D. Miller, 2006, 2016). While focusing on measuring knowledge of major scientific constructs, what Miller has more specifically focused on is *civic scientific literacy*.

2.1.4 Civic scientific literacy

Before Miller's expanded traditional definition of scientific literacy in 1983, in 1975, physicist Benjamin Shen suggested that scientific literacy could be differentiated into three categories of focus: (1) *practical/consumer scientific literacy*, (2) *civic scientific literacy*, and (3) *cultural scientific literacy*. The first relates to the possession of practically useful scientific knowledge, for example in the role of consumer when acquiring goods and commodities such as foods, medicines, chemicals, computers, and so on. The third relates to the understanding and appreciation of the broad role of science in society, as a wide set of achievements by humanity to better understand the world we live in (and that lives in us); "[i]t is to science what art appreciation is to art".[22] And the second one, *civic scientific literacy*, relates to the minimum level of understanding necessary to follow and make sense of public-policy issues involving science or technology. These categories may further imply different types of interest in science, with potentially different sources of information as well as individually varying level of 'literacy' being involved in each type. (Shen, 1975, pp. 45–50; see also Lucas, 1983, pp. 1–3; J. D. Miller, 2010a, p. 243.)

After Shen's tripartite categorization, Miller adopted the concept of civic scientific literacy (CSL) into regular use and has concentrated on it much of his career by further operationalizing and

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[21] What is also omitted is a measurement of public understanding of the basics in philosophy of science (or related epistemology). This might be important for properly understanding the norms of science but does not appear to be well recognized in the prevailing lines of studies. (see also sect. 2.1.1.)

[22] The physicist James Trefil (2008) has further described a fourth category: *aesthetic scientific literacy*, referring to the appreciation of the wonder of nature, and the beauty of scientific ideas and discoveries. Something akin to this – and overlapping with cultural and civic scientific literacy as well – is perhaps exemplified in the mesmerizingly poetic writings of the astronomer and science popularizer Carl Sagan (1934–1996; e.g., 1980, 1994, 1995).

Another approachable example is the TV series Sagan co-wrote and hosted in 1980, *Cosmos: A Personal Voyage*, created with his spouse and writing partner Ann Druyan, and astrophysicist Steven Soter. In 2014, the series was revived for a second and third season, in *Cosmos: A Spacetime Odyssey*, and *Cosmos: Possible Worlds* (2020), with science popularizer and astrophysicist Neil DeGrasse Tyson as the new host, with then widowed Ann Druyan, Steven Soter, and Brannon Braga as the writers. (see also sect. 5.2.5n55.)

measuring it (J. D. Miller, 2010a, pp. 243, 251–253). Thus, more specifically, Miller's definition can be understood to relate to CSL, in the spirit of which he has especially focused on measuring people's knowledge of major scientific constructs that are important for CSL. That is, the constructs measured by Miller include some of the central scientific constructs that are necessary to follow and make sense of public-policy issues involving science or technology, for example in being able to readily read and understand the science section of *The New York Times* (J. D. Miller, 2006, 2010a, 2016).

In the present study, I likewise focus on measuring people's understanding of major scientific constructs, and largely those that Miller has also measured. Thus, the study may more specifically be regarded to have to do with *civic* scientific literacy, as understood by Miller (2010a). However, in line with the general contemporary usage of the concept, I proceed to continue to write about scientific literacy mainly with the general term.[23]

2.2 Historical Overview: The Quest for (Scientifically) Informed Decision-Making

This section contains a deeper look into why scientific literacy, broadly understood, matters; what sort of historical and cultural contexts it can be considered to relate to; what are some current promotion efforts in the US, EU, and elsewhere; and how there has arisen some relevant challenges in our contemporary media landscape online. The objective is to provide a wider historical context in which to understand the significance of the topic.

Specifically, in section 2.2.1, I take a glimpse into prehistory and antiquity, to give a taste of some small part of the developments that have led us to where we currently are, and how something resembling scientific literacy has been an important part of our past for perhaps a much longer time than what one might intuitively think. In section 2.2.2, I compact some aspects of our scientific development starting from the Scientific Revolution and illustrate some aspects of our current situation that call for the recognition of the importance of scientific literacy among the public. In

[23] Notice, however, that the aspect of (civic) scientific literacy Miller and I are measuring – i.e., knowledge of major scientific constructs relevant for public-policy issues involving science or technology – does not necessarily tell much of people's proficiency in the other aspects of scientific literacy, even though there is considerable overlap, and the aspects can support one another. Specifically, it doesn't necessarily tell us much about people's proficiency in [A] the other areas of Shen's tripartite view (i.e., practical and cultural scientific literacy); [B] the other aspects of scientific literacy in Miller's expanded traditional definition (i.e., understanding of the norms of science, and awareness of the impact of science and technology on society and the policy choices that must inevitably emerge); let alone [C] the other various conceptualizations or operationalizations of scientific literacy, like the one used by OECD in PISA. Nevertheless, one can see overlap and implications for the other aspects via people's awareness of the measured scientific constructs. Also, there is one question in the present survey that measures whether people are aware of why control groups are important, which has to do with the norms of science, and a few questions that can be seen connected to practical scientific literacy (see Appendix 3, sect. 3; see also sect. 3.1).

section 2.2.3, I provide a closer look into how the specific concept of "scientific literacy" emerged in the 20th century and illustrate some of the developments it has gone through. In section 2.2.4, I outline some current promotion efforts that are taking place in the US, EU, and elsewhere. And, finally, in section 2.2.5., I describe some of the recent developments our media landscape has gone through, and how they are something to consider when thinking about media effects on scientific literacy.

2.2.1 Echoes of the past: From prehistory to Aristotle

Arguably, the importance of something kind of resembling scientific literacy can be seen to have been relevant since prehistory, for at least as long as there has been the species *Homo sapiens*. Already the discovery and spreading of the idea of harnessing fire – for warmth, visibility, and cooking – seems to have required an ability to make rudimentary sense of new discoveries, and to practice reflection when spreading them as (proto-)technological utilities for a larger social or tribal context.[24] For our ancestors, the same seems to have applied to numerous inventions and discoveries that we now tend to take for granted. For example, in many places early on, we successfully acquired and spread the realization of how we could make physical tools to extend our physical abilities, and how we could build weapons for hunting, and develop complex language for communication. In a span of what was likely over 100,000 years, we continued to explore our environment, and devise and communicate how to make clothing for protection; create art for expression; construct boats for traversing the waters; domesticate wolves for guards, hunting, and company; make pottery for vessels; develop agriculture for food security and nutrition; and use money for trade. It was only around 3500 B.C.E. when we first started to learn how to build wheels, for pottery and transportation, possibly in Mesopotamia (Bakker et al., 1999). Eventually, in many civilizations, the first of us learned to put words into writing, for storing and conveying information. We were then able to send messages into the future and distant lands, and to develop complex ideas across generations. As can be seen, we managed to break the barriers of time and space.[25]

[24] The discovery or invention of producing, controlling, using, and maintaining fire – or the gradually acquired ability to do so – may have happened already among much earlier species of the genus *Homo*, over 400 kya (thousand years ago), possibly even over a million years ago (Berna et al., 2012; Chazan, 2017; Gowlett, 2016). For reference, the earliest currently known potential fossil representatives of *Homo sapiens*, found in Northwest Africa (Morocco), have been dated to ~300 kya; with other particularly old fossils, with less morphological uncertainty, found in South and East Africa, dated between ~260–195 kya (Mounier & Lahr, 2019; see also Delson, 2019; Hublin et al., 2017; Richter et al., 2017). Current evidence further suggest that it was between ~120–50 kya, perhaps early activity happening even before 210 kya – around the late Middle to early Late Pleistocene – when some groups of our species started to migrate out of Africa and eventually spread around the globe (Delson, 2019; Groucutt et al., 2015; Harvati et al., 2019).

[25] For an ambitious chronicle of the history of human thought and invention, see Watson, 2001, 2005. For how culture and cultural evolution have played and continue to play important roles in our innovations, see also Henrich, 2016, 2020.

In the written history of the Western world, one of the earliest mentions of something reminiscent of scientific literacy is mentioned by the ancient Greek philosopher Plato (428/427–348/347 B.C.E.), in Book VII of his last dialogue *Laws*. Insofar as the dialogue reflects his own thoughts, he seems to have been troubled by the population's low level of understanding of the latest ideas and discoveries about the world. Written approximately 350 B.C.E., Plato, of course, does not use the term "scientific literacy". But the message within the words, spoken through the character of an Athenian Stranger, has an unmistakably familiar echo. Plato writes:

> "[W]ho is unable to count one, two, three, or to distinguish odd from even numbers, or is unable to count at all, or reckon night and day, and who is totally unacquainted with the revolution of the Sun and Moon, and the other stars . . . All freemen, I conceive, should learn as much of these branches of knowledge as every child in Egypt is taught when he learns the alphabet. In that country arithmetical games have been invented for the use of mere children, which they learn as pleasure and amusement . . . I . . . have late in life heard with amazement of our ignorance in these matters; to me we appear to be more like pigs than men, and I am quite ashamed, not only of myself, but of all Hellenes." (Plato, ca. 350 B.C.E./1892, VII.818c–819e.)

Perhaps the more famous sentiment, however, regarding the value of being learned and concerned with the latest (*proto-*)scientific knowledge, is expressed by Plato's student Aristotle (384–322 B.C.E.) – who is considered by many to be the father of logic and many branches of *natural philosophy* (i.e., proto-science)[26]. In the *Nicomachean Ethics*, also written circa 350 B.C.E., Aristotle

[26] Aristotle himself appears to have regarded Thales of Miletus (ca. 620–ca. 546 B.C.E.), the founder of the Ionian School, as the father of natural philosophy; as an empirical approach to studying the cosmos (i.e., the order of the universe, or nature) (Aristotle, ca. 350 B.C.E./2016, *Met.* I.3.983b20–21). He particularly credits Thales for having been the first to empirically postulate the primary nature (i.e., *first principle*) of matter, as water, and thus for sparking the question to be discussed further, critically, via different postulates by Thales's successors (*Met.* I.3.983b17–26). Arguably, as far as we know, Thales was the first person in written history to abandon tradition and myth (i.e., theology) as sources for revealing principles of the cosmos. Instead, he appears to have opted for an alternative approach: one of independent observation and reasoning. (Curd, 2020, sect. 2; O'Grady, n.d.)

Based on the account of the proto-historian Herodotus (ca. 484–ca. 425 B.C.E.), Thales has also been said to have been the first to predict a solar eclipse, by recognizing a pattern in the celestial bodies. According to Herodotus, the eclipse, foretold by Thales, interrupted a battle between Lydians and Medes, leading to a peace agreement. Modern astronomy has confirmed the total solar eclipse of May 28, 585 B.C.E., visible from Asia Minor, to be the only plausible candidate. However, there is dispute over Herodotus's account of both the prediction and the battle. It is unclear how Thales could have made the prediction by the means we are aware of to have been available to him, and Herodotus's non-contemporary account is the earliest extant source of the battle. (ibid.; Herodotus, ca. 430 B.C.E./1920, I.74; see also Aristotle, ca. 350 B.C.E./2014, n447.)

Insofar as we know (with much uncertainty), it was only the Babylonian astronomers who first acquired the ability to predict solar eclipses, with fair accuracy, circa 300 B.C.E., some 300 years after Thales. It has been postulated that it was around this time that they had discovered the 223-lunar month Saros cycle as documented in extant clay tablets with cuneiform accounts known as the *Astronomical Diaries*. This feat of patient observation, among others, was later built into the remarkable *Antikythera Mechanism* (ca. 205–60 B.C.E.) by ancient Greek engineers, perhaps consulting or considers that to pursue human flourishing or life lived well (in Greek: *eudaimonia*), that is desirable for its own sake, is to pursue life lived practicing rational activity in accord with virtue (*aretê*), and especially contemplation (*theôria*, *theôrein*) in accord with the *highest virtue*. (Aristotle, ca. 350 B.C.E./2014, p. xiii–lvi, *NE* I.7, VI, X.6–9; Kraut, 2018, sect. 6, 10; Parry, 2020, sect. 3; Pakaluk, 2005, pp. 316–331; see also Kangassalo, 2019, sect. 2.1n33, n43, 6.6.2.)

One virtue that Aristotle writes about is craft knowledge (*technê*; the root for the word "*technology*"), and he indicates that people who are or want to become versed in crafts (i.e., in making things) – or, as we might nowadays say, for example, in engineering of technology, creation of art, writing of books, or production of goods – should also keep in mind or, in a sense, *apply* the highest virtue while practicing their craft (insofar as it concerns their craft). And he appears to express that the highest virtue is *theoretical wisdom* (*sophia*) that is defined in terms of demonstrable, deductive '(proto-)scientific knowledge' (*epistêmê*) derived from indemonstrable inductive understanding (*nous*) of the universal and necessary first principles (*arche*, *archai*) that 'scientific knowledge' builds on (see, e.g., note 26 above for Thales's and Democritus's first principles of matter). Thus, for Aristotle, human flourishing (*eudaimonia*) especially has to do with active contemplation and utilization of one's mind in accord with theoretical wisdom, and thus of being concerned with learning and contemplating 'scientific knowledge' (and the first principles). (ibid.)

This contemplation in accord with theoretical wisdom is aided not only by added character-related virtues, that would ideally habitually steer us to the ethically right direction, but simultaneously and chiefly by *practical wisdom* (*phronêsis*) which is a kind of perception,

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building on the ideas and inventions of someone like Parmenides (born ca. 515 B.C.E.), Archimedes (ca. 287–ca. 212 B.C.E.), Hipparchus (ca. 190–ca. 120 B.C.E.), and/or Posidonius (ca. 135–ca. 51 B.C.E.). This complex clockwork mechanism for an astronomical calendar – for predicting the motion of the Moon, the Sun, and the wanderers (in Greek: *planētai*; i.e., the five known planets at the time) – was recovered from an ancient shipwreck near the Greek island of Antikythera in 1901, and its function has been reconstructed only in the early 2000s (with the aid of applying novel imaging methods to the surviving fragments). This revolutionized our understanding of the level of technology ancient Greeks were capable: it is the first analog computer we know of, predating its successors of similar complexity some 1500 years. (Freeth et al., 2021; Seiradakis & Edmunds, 2018; Steele, 2000.)

Some have further considered Democritus (ca. 460–ca. 370 B.C.E.) worthy of being called the father of science, as he famously elaborated an ancient atomist theory originated by his teacher Leucippus (ca. 5th century B.C.E.), with a similar theory also elsewhere developed by the Indian philosopher Kanada (date unclear, ca. 600–400 B.C.E.). Democritus reasoned that there must be indivisible smallest bodies from which everything else is composed, moving about in an infinite void. He called these bodies *atoms* (in Greek: *átomos* or *átomon*, "indivisible"). The theory – of which we only know fragments – describes them to be indivisible, indestructible, perfectly solid, eternal in age, infinite in number, and various in size and shape (and in mass, though this seems disputed). While perpetually moving in the infinite void, they repel one another when they collide; or combine into clusters when they get entangled by their tiny hooks and barbs, forming endless combinations. Democritus viewed that there exists nothing except atoms and void. Some 2200 years later, after the British scholar John Dalton (1766–1844) revived the atomic theory in chemistry, we started to realize that Democritus was way ahead of his time. The existence of what Dalton had named "atoms" was convincingly indirectly confirmed – their motion predicted, and size calculated – by physicist Albert Einstein (1879–1955) in one of his famous 1905 papers, the one on Brownian motion. However, the "atoms" turned out to be not indivisible after all, and their (quantum) properties to be more complex than Democritus could have imagined. (Berryman, 2016; Rovelli, 2017.)

continuously honed by experience, that concerns skillful deliberation about what is good for oneself and others in each contextual situation, and doable in action. It appears that the prescriptive practical wisdom facilitates our character to take skillful steps towards the right direction that the habitual character-related virtues target at, in the social world we live in, and in such a way as to ultimately aid in us being able to practice contemplation in accord with theoretical wisdom, and thus overall support *eudaimonia*. In other words: properly cultivated character-related virtues, guided by practical wisdom, seem to enable us to function in human society in such a way as to enable the actualization of social conditions and habits that allow us to also practice contemplation in accord with theoretical wisdom. Of course, theoretical wisdom, together with practical wisdom, may in turn guide us in our practical and ethical endeavors, also including *technê*.[27] (ibid.)

Moreover, to support this kind of human flourishing, Aristotle viewed that the society should aim at cultivating its citizens to internalize virtues via (continuous) learning, practice, and habituation, along with sufficiently supporting necessary externalities like health, wealth, and family. He especially emphasizes the importance of politics (and considered, habituating legislation), public education (for all ages), and skillful upbringing in creating a propitious societal context where children can grow up to flourish.[28] (ibid.)

Based on this characterization, we may loosely apply Aristotle's framework to an elective democratic context: Our practical deliberations and decisions cannot be well calibrated to aim towards a flourishing society, nor individual life, if we lack the sufficient virtues (both character-related and intellectual). For example, our flourishing is in jeopardy, if we lack the willingness to seek and contemplate the best *contemporary* scientific knowledge available, and properly note it in our considerations (both among the electorate in voting and personal life, and among the elected in

[27] Aristotle describes there to be two kinds of virtues: character-related virtues (or moral virtues) and thinking-related virtues (or intellectual/epistemic virtues) that support each other. Although he is a bit obscure on this point, it does appear that he considers the latter primary, and the former secondary. All the specific virtues mentioned in this context, in the body text – *sophia*, *phronêsis*, *technê* – are intellectual virtues. (*NE* I.13, II, VI, X.7–8; see also Kangassalo, 2019, sect. 2.1n33, n43, 6.6.2.)

[28] Aristotle's dense writing is difficult to lay out in any definitive sense, let alone in this short space. Thus, the descriptions presented here should not be taken as too authoritative. Rather, they are merely my own rough and provisional summarizing interpretations of some aspects of his text that are key for seeing how he approximately thought about the importance of (proto-)scientific knowledge, as well as crafts that in part concern what we would nowadays call technology and engineering. (see also Burbules, 2019; Parry, 2020, sect. 3.)

Notably, in addition to Aristotle and the Peripatetic school that derived from his teachings, there are many other schools of philosophy from ancient Greece that also value virtues and knowledge. For example, the Cynics, Epicureans, and Stoics; and, in a distinct skeptical manner, Academic Skeptics and Pyrrhonists. These are all quite different in details, of course, but all worth examining to this day (along with many other virtue traditions outside of ancient Greece, for example Buddhism, Confucianism, and Daoism from the East; see Flanagan, 2017; Kangassalo, 2019, sect. 6.6.2). For instance, the Stoics, as compared to Aristotle, not only have a slightly different list of virtues but view them to be both necessary and sufficient for a flourishing life, whereas Aristotle views virtues to be necessary but not sufficient as some externalities – like sufficient health, wealth, and family – are also needed (Stephens, n.d.).

governance). Thus, if we want democracy and its people to thrive, sufficient education of the populace in cultivating virtues needs to be our aim, for example via a persistent education system and promotion of proper interpersonal conduct (i.e., character-related virtues), along with proper science communication supporting scientific literacy (i.e., intellectual virtues). This can be read as a solution, at least a partial one, to the lament of the Athenian Stranger. (see also Kangassalo, 2019.)

Behind the lament of the Athenian Stranger, the proposed solution via Aristotle's virtue ethics, and in the practically globally adopted nature of the innovations in our prehistory, can be read what appears to be a very human attitude: when news of what seem to be useful novel discoveries, innovations, and ideas reach our awareness, many of us feel the urge to adopt them ourselves, assure that "our group" does so too (ideally wisely), and, perhaps, to eventually surpass that which we have come to adopt from others (see also E. M. Roberts, 2003). At first, some may resist new ideas or find them difficult; but those thoughts or the people themselves tend to die off, sooner or later. Some ideas may turn out to be ill conceived – socially or environmentally – yet find a life of their own in our tribal beliefs and actions.[29] Until new ideas may overturn them, hopefully for the better.[30] In other words, our situation appears to be one of constantly seeking for the next iteration; followed by a social dance of push and pull; and the next iteration. And so it goes: the delicate balance of either standing ever taller on the shoulders of giants or falling from greater heights than ever before. In the complex system of nature, the threat of unintended consequences always lurks.

Nowadays, this willingness to look at the horizon and outdo each other appears to have only accelerated and grown to apply as much to scientific discoveries as it has for a long time applied to mathematical and technological innovations. In such a time, the importance of scientific literacy can only become increasingly important as our globally networked scientific and technological societies of the 21st century, along with their democratic and other political systems, continue to thrust towards the next millennium. To build our future on solid ground, to obstruct ill-conceived ideas and ignorance, we must be vigilant to try to base our decisions and systems on up-to-date understanding of the problems we face and of our abilities regarding the solutions they require.

[29] For example, think of the demise of Classical Greece, the destruction of the Library of Alexandria, the historically widespread practice of keeping slaves from neighboring tribes, the historically poor treatment of women, the many dictatorships and wars in history, the building of the atomic bomb, and our practices that contribute to anthropogenic global warming.

[30] Think, for example, the conception of music and other forms of art, the dawn of agriculture, and later the birth of writing, followed by the emergence of systematic study of the cosmos via philosophy, mathematics, and (proto-)science in ancient Greece and other places around the world (e.g., in ancient China, Egypt, Indus Valley, India, and Mesopotamia).

2.2.2 From the Scientific Revolution to the 21st century

Since the dawn the Scientific Revolution in the 16th century, the Enlightenment in the 17th, and the emergence of the Industrial Revolutions in the 18th, 19th, and 20th, humanity has, by and large, been living in an era of exponential technological and scientific development. During this brief blink in our existence, we have witnessed huge leaps in the evolution of our media landscape, communication methods, administrative systems, institutions, and the science and technology we rely on every day. The (proto-)science of the ancient world has evolved into contemporary science and philosophy of science, via many novel innovations, ideas, and concepts (see sect. 2.1.1). Our self-understanding has risen along with countless of groundbreaking insights in biology, chemistry, physics, and medicine—as well as psychology, neurology, and communication technologies. And our morality seems to have also shifted: for example, violence seems to have long been in global decline (Pinker, 2011); equal gender rights, animal right, and nature conservation efforts continue to achieve legitimacy; and, as it happened, the year after Charles Darwin published his *On the Origin of Species*, the last American slave ship sailed from the coast of Africa to Alabama (in 1860; Bourne, 2019). And since then, we have glimpsed to the beginning of the universe, travelled to the Moon, and sent robot emissaries to travel outside our Solar System and to orbit or fly by every planet in it (and Pluto). In the senectitude of the 21st century Information Age, and amidst the continuing globalization of the Internet and the emerging forms of Artificial Intelligence, not only does this explosive development of scientific knowledge and technology seem to be increasingly fast, also the connection between people is more rapid, wider spread than ever before, and only expanding (World Bank, 2019; see also sect. 2.2.5).

But despite all the apparent positives, there still exists a lot of negatives. A global inequality has risen to replace some of the local inequalities of the past, while some of the latter also still linger (World Bank, 2018). We have only just started to realize how fossil fuels, that we have depended on especially since the beginning of the Industrial Revolution, are negatively affecting our ecosystem, our habitat, environment, and fellow creatures of the Earth. We have learned about the scarcity of fresh water and about anthropogenic global warming in an age of unprecedented population growth. (WWF, 2020; see also IPCC, 2014, 2018; Ritchie et al., 2018; UN, 2015, 2016.) We developed the atom bomb and even dropped two in the middle of human settlements in the last century; and still in some parts of the world continue to harvest them like we are waiting for a dooms day to arrive (SIPRI, 2021, Ch. 10). Relatedly, some of us continue to wage wars for various ideological, conspiratorial, resource-based, territorial, political, religious, racist, and other reasons springing from all kinds of in-group–out-group biases and related worldviews and dogmas. And we surround ourselves with news media that is covered with words and images focused on these negatives, often in unhelpful, divisive ways (see, e.g., Bellovary et al., 2021). Moreover, some of the most popular contemporary forms of social media appear to facilitate intergroup conflict via moral outrage and consequent political and affective polarization, as well as facilitating the spread of misinformation, conspiracy theories, and pseudoscience, at least in the English-speaking Western world (see, e.g., Brady et al., 2020, 2021; Carpenter et al., 2021; Iyengar & Krupenkin, 2018; G. Miller, 2021; Van Bavel et al., 2021). Consequently, we seem much too distracted and misguided to collectively focus on the issues that should unite us all. (see also Kangassalo, 2019, sect. 1.1–1.2; 2021a–b.)

With all this vastness of events within just a few hundred years, an outside observer might easily presume we are *at least* acutely aware of our strengths and shortcomings, problems, and possible solutions – especially in the privileged developed nations of the world. Unfortunately, however, it seems that such a presumption would be in error, given the prevalence of low level of scientific literacy (see Ch. 1). If Miller's criteria are valid – and if the results have globally changed in the last ~15 years as little as they have in the US – in Sweden, the country with the highest degree of civic scientific literacy, around 65 % of the adult population cannot readily read and understand popular scientific articles (J. D. Miller, 2006, p. 6; 2016). Additionally, education appears to make little difference in the prevalence of epistemically unwarranted beliefs, like beliefs in pseudoscience, conspiracies, or the paranormal (Dyer & Hall, 2019; Fasce & Picó, 2019). Yet, in this highly developed scientific and technological age, we count on each other to make decisions every day that would not jeopardize the future of humanity and other life on Earth.

In the very near future, we will most likely have to make many substantive collective decisions concerning the scientific and technological solutions we are developing today, and we will likely need to make these decisions faster and on a wider scale than any decisions made in the past – politically or otherwise. Particularly, critical global questions that concern all of humanity – such as global warming, energy production, pandemics, potential impact events, financial collapse, nuclear or otherwise largescale wars, disruptive technology (e.g., badly controlled artificial intelligence(s) or poor utilization of biotechnology), and unknown risks – emphasize the kind of issues our future decisions need to address, collectively (Bostrom & Ćirković, 2008; WEF, 2018; WHO, 2019; WWF, 2020; see also Ord, 2020). Moreover, many of the most crucial elements in our global civilization – transportation, communications, and basically all other industries; agriculture, medicine, education, entertainment, environmental protection, and the key democratic institution of voting – profoundly depend on science and technology. And yet, few understand science and technology as vast majority of people on this planet appear to be effectively *scientifically illiterate*, by Miller's criteria. Controversies, as well as clearly bad – and dangerous – private and democratic decisions are *inevitable* when most people do not understand what the critical questions or solutions are about. For us to be able to make the best decisions concerning these issues, it is crucially important for us to collectively develop our skills, to keep up-to-date, and learn to sufficiently understand the underlying problems and the proposed solutions for them. Or, at the very least, we need to be knowledgeable enough to be willing to delegate decision-making in these matters to actual experts – and none of us can be an expert on everything. (see also Clough, 2011, pp. 6–7; J. D. Miller, 2006, pp. 8–9; 2010a, p. 241; Rutherford & Ahlgren, 1990, pp. v-ix; Sagan, 1995.)

Overall, in the present moment, it seems we have come very far, but have still long ways to go if we are ever to confidently solidify the continuation of our story. From the humble beginnings of first sparking a flame to start a fire and wandering around the world; to the intentional act of endeavoring to travel into space, and everything in between; the journey of *Homo sapiens* continues to depend on our grasping of our situation, the wisdom of the goals we set, and the solutions that our understanding can find. To succeed in our trek, rather than fail, understanding of science and technology has never been more paramount. There cannot be seen any remedy for the increasing need for scientific literacy within humanity.

2.2.3 A brief history of the concept of scientific literacy

Quite removed from contemporary definitions (sect. 2.1.3), the concept of "scientific literacy" has an illustrative history worth outlining. In his article *Scientific Literacy: A Conceptual and Empirical Review* (1983, pp. 29–30), Jon D. Miller traces the concept back to the biologist *Thomas Henry Huxley* (1825–1895) and his 1880 lecture *Science and Culture*. Miller writes that Huxley was the first to ponder whether a person who understands the written language perfectly, but who does not know anything about science, can be consider learned – and vice versa. In its historical context, Huxley's lecture can be considered a plea to advocate social sciences. This was then followed by a line of discourse stretching all the way to 1950's, when C.P. Snow continued to ponder the argument in his 1959 lecture *The Two Cultures*, and 1960's, with F. R. Leavis's 1962 answer to Snow in *The Two Cultures? The significance of C. P. Snow*. But Miller emphasizes that this discourse focused on the definition of being learned, instead of the substantive thing of communicating science to a wider audience.

Although the discussion about the (arguably false) dichotomy between different branches of learning is still, by some measure, alive – for example, in the perceived separation of the technical and humanistic institutions and subjects in many places – in a way Huxley and Snow *did* win the debate. They were advocating for the incorporation of formal science training into the collegiate programs of Cambridge, and they won a *de facto* victory. Although graduate education does remain specialized, the undergraduate curriculum of arts and sciences colleges now include both humanities and the sciences almost universally in the United States, and in some places in Western Europe and elsewhere.[31] (J. D. Miller, 1983, p. 30; see also J. D. Miller, 2004.)

An interest to study the development of population's scientific learnedness began in the 1930's, when the philosopher John Dewey published an article *The Supreme Intellectual Obligation* (1934). In it, Dewey declared that science has a responsibility that cannot be fulfilled with methods that are primarily concerned about the self-perpetuation of individual specialized fields of science. According to him, this kind of a setup neglects influencing a larger populace to adopt such attitudes that are characteristic of the *scientific attitude*; namely, what he considered to include open-mindedness, intellectual integrity, observation, and interest in testing one's opinions and beliefs. (ibid.)

Following Dewey's opener, many science educators began to think about a formal definition and measuring of the scientific attitude. For example, Miller describes how Ira C. Davis (1935) considered that a person with a scientific attitude is one who will "show a willingness to change his opinion on the basis of new evidence; . . . search for the whole truth without prejudice; . . . have a concept of cause and effect relationships; . . . make a habit of basing judgment on fact; and . . . have the ability to distinguish between fact and theory."[32] Further, Victor H. Noll (1935) and A. G. Hoff

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[31] Queue 2021, almost 40 years after Miller's article, at least in Finland – and broadly in the European Union – there does remain numerous technical institutes, engineering colleges, art schools, and universities that continue to largely exclude one or the other from their curricula. Moreover, seeming to spring from the US and facilitated by both traditional and social media, there have arisen some notable tensions within certain disciplines, with some circles in social sciences and humanities having disputes on what *telos* – an end to which to thrive – they should ultimately follow: truth or "justice" (see, e.g., Friedersdorf, 2018; Haidt, 2015; Lukianoff & Haidt, 2018, pp. 253–255; see also German & Stevens, 2021; Hansson, 2020; Lewandowsky, 2021; Pluckrose & Lindsay, 2020; Stanovich, 2020, 2021; Wikforss, 2020). To some degree, this kind of a social phenomenon might be in the process of being exported to natural sciences as well (see Krylov, 2021; cf. Ball, 2021), and to wider literary culture not only in North America and parts of Europe but potentially all the way in English-speaking places like Nigeria (see Adichie, 2021; Harper's Magazine, 2020; cf. The Objective, 2020).

Three important points to address this contemporary issue: *Firstly*, justice is easily corrupted or misguided if not guided by respect for descriptive scientific evidence. For example, we may strive towards mitigating global warming, but insofar as we do not understand the basics of nuclear power, fossil fuels, or green energy, our endeavors can be warped into something deeply counterproductive. Or, similarly, for our activist methods to be productive for our goals, rather than counterproductive, it is profoundly beneficial to understand descriptive social, political, and moral psychology. *Secondly*, the whole scientific enterprise, at least in the eyes of the public, can be corrupted if some department or another is heavily and/or willfully politicizing it, for example by upholding or smuggling prescriptive dictums or dogmas about non-epistemic ideals like justice, under the banner of science. At the same time, the whole enterprise, regardless of the telos in any given department, is made a target for fund restricting external politics (risking throwing the baby out with the bathwater). And, *thirdly*, to politicize science is to hamper its epistemic authority – thus, also contributing to science denialism or apathy, and to deflating the epistemic role of science in both private and public decision-making processes. All of this is to say that truth – i.e., proper descriptive(-aiming) science as its proxy – needs to guide justice, not the other way around, lest we risk not only the descriptive epistemic goals of science but also our own moral goals. (Do note that ethics and applied science are still immensely important, but – strictly speaking – they are different beasts from science; albeit they benefit from being aware of science that concerns them, and vice versa. (see also Kangassalo, 2019, 2021a–b; sect. 2.1.1, 6.2.))

[32] Davis lists a total of fourteen specific objectives – formulated by a science committee of more than 350 teachers in Wisconsin – that would be telling of an individual having acquired (1) a scientific attitude, (2) a scientific method of procedure, and (3) a fund of information, all needed for them to be able to solve the problems that confront them. Some

(1936) gave a similar definition to scientific attitude and began to develop methods for measuring it.[33] Nearly all of the empirical work done before the Second World War focused on developing 'scientific attitude'. (J. D. Miller, 1983, pp. 30–31.)

After the war, the number of standardized tests began to grow generally. It was then that many science educators and test developers began to pay attention to the level of comprehension of basic scientific constructs and terms. A growing number of studies began to map out the level of scientific knowledge among various groups within the US population. This can be seen as the beginning of the traditional survey study, that was – still at the time of Miller's writing – often associated with measuring scientific literacy. (J. D. Miller, 1983, p. 31; see also J. D. Miller, 2004.) The actual term "scientific literacy" appears to have been coined twice in 1958, independently by both Paul deHard Hurd and Richard C. McCurdy (Hurd, 1958; McCurdy, 1958; see also DeBoer, 2000; Holbrook & Rannikmae, 2009, p. 275; NASEM, 2016, pp. 26–27; Norris & Phillips, 2015).

In 1964, the US *National Assessment of Educational Progress* (NAEP) began, and in 1969 it started to collect national random samples of precollegiate students' scientific knowledge, along with some other categories. One aspect that motivated the interest towards the scientific ability of the US students was the Cold War, and the era in Space Race following the Soviet launch of Sputnik in 1957. These studies were the first to systematically measure the understanding of the norms, processes, and knowledge of science. The two dimensions of understanding of the norms (incl. processes) and constructs of science may be considered as the classical definition of scientific literacy. (J. D. Miller, 1983, p. 31; Rutherford, 1998; see also NAEP, 2021; Neidorf & Sheehan, 2015; Wissehr et al., 2011.)

Miller emphasizes in his 1983 article that the classical two-part definition is lacking and suggests a third dimension to be added: awareness of the impact of science and technology on society and the policy choices that must inevitably emerge. He describes that the importance of this aspect rose beginning especially from the 1960s, when environmental groups began to emerge and find out

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further items from the overall list include familiarity with [scientific] laws, principles, and theories; ability to make observations; ability to formulate workable hypotheses; freedom from superstitions; interest in science; and appreciation of the contributions of science, as well as appreciation of natural beauty, of our place in the Universe, and of possible future developments of science. (Davis, 1935.)

In the article, Davis reports how the list of fourteen was narrowed down into the five that are descriptive of a 'scientific attitude' in Miller's quote (in the body text), via a questionnaire sent to 250 teachers in the US (with 92 qualified for the final treatment). The article further describes the construction of some preliminary tests to measure them, for the ultimate aim of improving teaching that it considers to over-rely on content knowledge. (ibid.)

[33] For example, Noll (1935) describes the scientific attitude to include six habits of thinking: (1) accuracy in all operations, including accuracy in calculation, observation, and report; (2) intellectual honesty; (3) open-mindedness; (4) suspended judgment; (5) looking for true cause and effect relationships; and (6) criticalness, including that of self-criticism. Interestingly, some of these are or resemble what many consider intellectual virtues (at present) that can be taught and cultivated, even though Noll does not mention the concept of virtue at all (see also Dewey, 1934). Thus, if one were to become interested in how intellectual virtues might be measured, some of the old literature on measuring the scientific attitude might be a useful reference (though, see also, e.g., Meyer et al., 2021).

that some minimal level of scientific knowledge was necessary if individuals were to understand the issues and be able to make informed judgments concerning them. Miller also mentions the case of water fluoridation, in the 1950s, when scientifically illiterate voters were able to win referenda on the issue in the US. (J. D. Miller, 1983, p. 31.)

Unlike in the 1960s, when significant motivators for measuring scientific literacy were the Cold War and Space Race, in the 1980s – in the second wave of measuring scientific literacy – the focus shifted towards general societal development and studying it, and a strong motivator began to be competition in international trade and in international educational assessments. For example, the rise of Japan in world trade seems to have been an early motivator, alongside poor standing of the US in international comparisons of science achievement (Laugksch, 2000; Rutherford, 1998). However, despite these largely political and economic incentives – the kind that have continued to this day – on the background there has long been a genuine worry about the state of the world, shared by many scientists (see, e.g., Dewey, 1934; Davis, 1935; Rutherford, 1998). For example, in 1969, the neurophysiologist Robert S. Morison wrote a description that fittingly describes some of those worries, and which unfortunately remain relevant today:

> "Science can no longer be content to present itself as an activity independent of the rest of society, governed by its own rules and directed by the inner dynamics of its own processes. Too many of these processes have effects which, though beneficial in many respects, often strike the average man as a threat to his autonomy. Too often science seems to be thrusting society as a whole in directions in which it does not fully understand and which it certainly has not chosen.
>
> The scientific community must redouble its efforts to present science – in the classroom, in the public press, and through education-extension activities of various kinds – as a fully understandable process, 'justifiable to man,' and controllable by him." (Morison, 1969.)

2.2.4 Current promotion efforts in the US, EU, and elsewhere

Since the 1980s, there has been a considerable amount of discussion about the topic of scientific literacy (for historical overviews, see DeBoer, 2000; Laugksch, 2000; Roberts, 2007; see also NASEM, 2016, Ch. 2; Siarova et al., 2019, Ch. 2; sect. 2.1.3(n13)). In terms of promotion efforts, there have emerged a few distinguishable branches that regularly advocate and/or measure scientific literacy. Below, I introduce some of the current efforts, from the US, EU, and elsewhere.

In the United States, the leading advocate appears to be the American Association for the Advancement of Science (AAAS) and their *Project 2061* (1985–), aiming to increase mathematical, technological, and science literacy (AAAS, n.d.). At the same time, the US *National Assessment of Educational Progress* (NAEP), administered by the National Center for Education Statistics (NCES), within the Institute of Education Sciences (IES) of the U.S. Department of Education, continues to gather quadrennial data on precollegiate students' scientific knowledge, along with some other categories (1964–; see NAEP, 2021; Neidorf & Sheehan, 2015). Moreover, in the US, the *Science and Engineering Indicators* (SEI) report series by the National Science Board (NSB), in collaboration with National Science Foundation's (NSF) National Center for Science and Engineering Statistics (NCSES), gathers biennial data on public understanding of scientific terms and concepts, reasoning and understanding of the scientific process, along with public attitudes, interest, and more (1979–; see Besley & Hill, 2020). The part of the SEI report series dealing with public understanding of, and attitudes toward, science and technology was originally designed by Jon D. Miller with Kenneth Prewitt (J. D. Miller, 2004). (see also sect. 2.1.3(n13); Siarova et al., 2019.)

The most notable worldwide branch is the Organisation for Economic Co-operation and Development (OECD) via its *Programme for International Student Assessment* (PISA). PISA implements scientific literacy as an operationalized part of the triennially measured 15-year-old students' competencies (1997–; see OECD, n.d.-b, 2019a).[34] Science is one of the three key areas on focus, the others being reading and mathematics, with primary focus rotating each cycle. PISA also rather uniquely follows what Douglas A. Roberts has dubbed as Vision II of scientific literacy, that does not merely measure (and promote) understanding of concepts, content, and methods in science, like Vision I, but also their active application in our lives and social contexts (Bybee et al., 2009; Roberts, 2007; see also 2.1.3n13). Both visions can help us function as effective democratic citizens, and despite some tensions, they can support each other (Liu, 2013; Roberts, 2007). (ibid.)

Although Project 2061, in the US, has visibly implemented scientific literacy (or science literacy) as a part of its aims in curricular development – though, with limited success of adaptation thus far (cf. Impey et al., 2017; J. D. Miller, 2016)[35] – some other areas of the world have not been as active on the matter. For example, in the European Union (EU), the European Parliament's

[34] Additionally, the International Association for the Evaluation of Educational Achievement (IEA) conducts the *Trends in International Mathematics and Science Study* (TIMSS): a quadrennial international assessment of the mathematics and science knowledge of 4th and 8th grade students around the world (1995–). However, TIMSS focuses primarily on (natural) science curriculum standards, thus measuring the level of scientific knowledge of students via an assessment instrument formulated with core curricular topics in mind that are common across the participating countries. The assessments are also updated with each cycle in collaboration with the countries, as the curricula develop. Consequently, TIMSS does not appear to use the concept of scientific literacy let alone operationalize it. (see Mullis et al., 2016, 2020.) In this regard, PISA is a much wider test, going beyond curriculum, and explicitly operationalizing scientific literacy.

[35] It may be argued, however, that Project 2061 has played some significant role in the US civic scientific literacy rate among adults increasing from around 10 % in 1988 to 28 % in 2005 or 2008. Though, in 2016, the rate had remained at the 2008 level. (J. D. Miller, 2006, 2010a, 2016.)

Committee on Culture and Education (CULT) has only recently requested a study that encourages to take steps to reinforce scientific literacy, broadly understood, during the next 10 years (see Siarova et al., 2019, pp. 7–9). This is suggested to become a part of *Erasmus+* and *Horizon Europe* projects, while aiming at the design, piloting, and exchange of new teaching practices to develop scientific literacy among all citizens (Siarova et al., 2019, pp. 37, 49–51). *Erasmus+* is the EU's programme to support education, training, youth, and sport in Europe, with the latest cycle taking place in 2021–2027. *Horizon Europe* is the EU's key research and innovation funding programme, succeeding its predecessor *Horizon 2020* as of January 2021 until 2027.

In terms of domain-specific literacies before the study by Siarova et al. (2019), focus seems to have been given almost solely to media literacy in educational planning by the EU (European Commission, 2021), though the European Literacy Policy Network (ELINET) has also advocated digital literacy (Valtin et al., 2016) and there is a lot of variety between countries. Recently, a report has also been commissioned on computer and information literacy (see European Commission, 2019).

It is also noteworthy that, at least in Finland, an enormous amount of focus has been given to the arguably overbroad and ambiguous hypernym of "*multiliteracy*" or "*multiliteracies*" (in Finnish "*monilukutaito*"; see Halinen et al., 2015; Rasi et al., 2019). Unfortunately, the overbroad umbrella term and concept may lose many of the intricate nuances of its better confined subordinates; risking losing focus from the specifics that matter for different forms of literacy (cf. Kupiainen, 2017; Mertala, 2017; Palsa & Mertala, 2019; see also sect. 2.1.2–2.1.3). It may also force some very important forms, like scientific literacy, to be lost in the crowd.[36]

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[36] In Finland, scientific literacy (Finnish: *tieteellinen lukutaito*), science literacy (*tiedelukutaito*), or their derivatives are mentioned exactly twice in the latest national Core Curriculum for General Upper Secondary Education (for *lukio*) – and even then, only passingly in the contexts of physics and chemistry, in the form "luonnontieteellinen lukutaito" (Engl. "natural science literacy"). In the national Core Curriculum for Basic Education (for *perusopetus*), the concept is not mentioned even once; though, "thinking skills in natural science" ("*luonnontieteellinen ajattelutaito*") is mentioned in the context of biology, and "thinking skills in geography" ("*maantieteellinen ajattelutaito*") in the context of geography. Compare this to multiliteracy, which is mentioned, in one form another, 84 times in the general upper secondary curriculum and 69 times in the basic education curriculum! It thus seems that the important tree of scientific literacy is easily missed for the forest of multiliteracy, if at all recognized. For comparison, media literacy – which is also important – is mentioned 13 and 2 times, respectively. (see Ministry of Education and Culture, n.d.; Opetushallitus, 2014, 2019.)

Of course, some aspects of scientific literacy can be seen to be implicitly included into the subject specific goals within the curricula, but this is not making the concept and its importance explicit, nor does it necessarily include other aspects than content knowledge. For example, inclusion of procedural and epistemic knowledge regarding science seems less certain, as does inclusion of consumer, cultural, and aesthetic scientific literacy (see sect. 2.1.3–2.1.4).

However, outside of the curricula, in Finland the research programme LITERACY (2020–2026), consisting of five projects, is currently studying various aspects of literacy – broadly understood – to support both individual and societal decision-making and actions. For example, the project FINSCI (*Fostering Finnish Science Capital*) aims to develop science-based methods for formal and informal science learning and education, CRITICAL (*Technological and Societal Innovations to Cultivate Critical Reading in the Internet Era*) aims to find ways to support "critical reading skills" (i.e., ~critical basic literacy) to help children and adolescents deal with mis-/disinformation, and DataLit (*Data Literacy for Responsible Decision-Making*) to develop data literacy. Some of the FINSCI research explicitly refers to "science literacy", while thus far the others have done so only implicitly. (FINSCI, n.d.; LITERACY, n.d.)

Hopefully, the EU projects, along with Project 2061 in the US, will eventually come through, and not only in terms of primary and secondary education curricular development but also more widely in public education for adults. Of course, similar efforts should be promoted around the globe, and to some degree they already are, for example via the OECD's PISA studies.[37] These efforts have become especially important in recent years, as the rise of contemporary social media seems to have facilitated more rapid spread of misinformation and polarization (see Kangassalo, 2019; sect. 5.2.3).

2.2.5 Rising challenges of the contemporary media landscape

2.2.5.1 The shift in media culture 1990–2021

As Miller's analysis indicated that Internet consumption best supports scientific literacy – as compared to print media and television (Appendix 1; J. D. Miller, 2010b) – the *shift in media culture* during the past few decades seems to be something to consider. By this, I refer to the cultural shift of going from the traditional unidirectional, relatively slow, and largely local consumer media of the 20th century – from newspapers, magazines, radio, and television – to the increasing usage of the omnidirectional, fast, and global participatory new media, found on the Internet, especially via the World Wide Web information system, and accessed with ubiquitous modern technological devices like personal computers and smartphones.

The early stages of this transition began in the 1990s, when the Internet started to take its first steps towards spreading around the world. An especially monumental event was the invention of the World Wide Web by the computer scientist Tim Berners-Lee while he was working at CERN (European Council for Nuclear Research) in Switzerland: after first envisioning the idea in a 1989 memorandum, and eventually developing the necessary tools (e.g., the first web browser and server), the Web became accessible to the public in August 1991. But for where we have come since, particularly the late 2000s are relevant, as it was then when the first generations of what were to become widespread *smartphones* were introduced: Apple's iPhone in 2007 and Samsung's Galaxy in 2009. These slick mobile devices, with their touchscreens, built-in cameras, and wireless access to the Internet, were more appealing and affordable for many people than the bulky personal computers and their monitors that were, up until then, mostly used to browse the Web. It was then that *social media* started to pick up, with adoption especially accelerating in the early 2010s, as smartphones and

[37] See also local Chinese (Wu et al., 2018), Japanese (Kawamoto et al., 2013), as well as Brazilian, Canadian, Indian, Israelian, Malaysian, Russian, South Korean, Swiss, and other promotion efforts (via: Bauer, 2008, Table 1; Besley & Hill, 2020, Table 7-1). In the case of PISA, it is noteworthy that without exceptional care – that OECD of course aims for – the translation process of the test-units can produce subtle variation in different language areas in how the units are interpreted (see Serder & Sørensen, 2014).

tablets properly took off (IDC, 2021; Gartner, 2021). Various social networking services (SNS) – i.e., social media sites or platforms, such as Instagram, Facebook, Twitter, YouTube, etc. – then started to widely reshape human interaction and sharing of information around the world, via their user interfaces (UIs). (Internet World Stats, 2021; Ortiz-Ospina, 2019; World Bank, 2019; see also Kangassalo, 2021a–b; Ritchie & Roser, 2017; Roser et al., 2015.)

For some perspective: Between 2005–2021, the percentage of US adults who own a smartphone rose from below 2 % in 2005; to 35 % in 2011; all the way to 85 % in 2021 (Comscore, 2017; Pew Research Center, 2021c). Similarly, the percentage of US adults using at least one social media site increased from 5 % in 2005; to 50 % in 2011; all the way to 72 % in 2021 (Pew Research Center, 2021d). And as *Facebook* (est. 2004) covered around 1.5 % of the world population in 2008, that number has risen to around 36 % as of Q2 of 2021 (Facebook, 2021). Generally, estimated percentage of world population using the Internet has increased from 5.0 % in March 2000; to 30.7 % in March 2011; to 65.6 % in March 2021 (Internet World Stats, 2021). As of January 2021, over 53 % of world population now use some social media, and this is projected to rise to over 65 % in 2025 (Kemp, 2021; Statista, 2021). Of these users, over 90 % do so via smartphones, albeit two-thirds also use laptops or desktop computers (Kemp, 2021; We Are Social et al., 2021b). (see also DataReportal, 2021; Ortiz-Ospina, 2019.)

Among the accumulating Internet users, the average time spent on social media has also increased: going from an average of 1h 30min per day in 2012 to an average of 2h 25min per day in 2020, albeit with considerable variation between countries (Kemp, 2021; We Are Social et al., 2021a). More generally, amongst Internet users, time spent online 2013–2020 increased from an average of 6h 4min to 6h 54min (GlobalWebIndex, 2019; Kemp, 2021). Internet use *per capita* worldwide 2011–2021 rose from 1h 15min to 3h 12min (Zenith, 2019b). At the same time, use of traditional media has kept declining: between 2011–2021, daily time spent watching television per capita worldwide has decreased from an average of 2h 59min to a forecast of 2h 45min, while time spent reading newspapers and magazines has more than halved from 31min to an estimated 13min (Zenith, 2019a–b).[38] In the US, time spent using the new digital media per capita 2008–2018 increased from 2h 42min to 6h 18min (Ortiz-Ospina, 2019). It was in 2018 when, for the first time in the US, average time spent per day with digital media overtook the time spent with traditional media, with the crossing trend continuing towards a projected 8h 2min versus 5h 18min for 2022, respectively (eMarketer, 2021). (ibid.)

[38] The figures for 2019–2021 by Zenith (2019a–b) are forecasts made pre-2020. Thus, they do not yet account for the potential effect of quarantines during the COVID-19 pandemic.

There has thus been an extraordinarily rapid shift of people to the sphere of the new media and away from the traditional media; at first especially of Western younger age cohorts (i.e., Millennials, Gen Z), but increasingly others as well (Kemp, 2021; Palm & Pilkington, 2016; Pew Research Center, 2021d; Westcott et al., 2018). This has enabled the emergence of disruptive new services and ways of interaction on the many platforms and communities that have been built on the Internet. For example, *Wikipedia* (est. 2001) has single-handedly changed how a successful encyclopedia functions, and even what is understood by encyclopedia (Burke, 2012, p. 273; Wales, 2005). As another example, *YouTube* (est. 2005) has created a whole new cultural ground for an omniopticon-like (contra panopticon or synopticon) audiovisual communication, where the many are watching the many. Currently, as of May 2019, over 500 hours of video – of various quality – is uploaded to YouTube *every minute* (YouTube & Tubefilter, 2019). Compare this to how long it took to share the same amount of information in the 1970s analogue television system, with, for example, three channels running 24/7 taking almost *seven days*. And similar explosion of information has happened via other platforms as well (see https://www.internetlivestats.com/). Alongside these various services, whole new glocal cultures have also emerged, for example an active Internet meme culture that has taken our human tendency to remix ideas to a whole new level (Miltner, 2018; see also Ferguson, 2016, 2021; Tiffany, 2018). (see also Kangassalo, 2021a; Ortiz-Ospina, 2019.)

2.2.5.2 Connecting humanity: From optimism to doubt to seeking solutions

On the Internet, there can be seen an acceleration of a widely connected and diverse activity of sharing of information that, at its scale and speed, is unquestionably unique in the history of media and humanity. This explosion of information has many effects, including it giving potentially ubiquitous access to practically all the knowledge humanity has ever produced, along with facilitating further production, and potentially encouraging a rise of collective critical self-examination of the authoritarian systems within humanity. Whereas Wikipedia has long represented the former, the latter was, in the late 2000s and early 2010s, manifestly represented by *WikiLeaks* (est. 2006) and movements like the Arab Spring in 2010–2012. Already in the late 1990s, Tim Berners-Lee called the emerging overwhelming flood of open information – specifically the rise of information about information – as "the beginning of the new enlightenment". The Internet could be seen as a vehicle to positively connect humanity and empower everyone. (Burke, 2012, pp. 271–274.)

These kinds of accounts and visions about the shift in media culture are, of course, extremely promising. However, much of this optimistic enthusiasm was expressed before the mid-2010s. Starting from around that time, it seems to have become increasingly clear that there are some unexpected problems that can be either generated or facilitated by the new media landscape (see, e.g., Haidt & Rose-Stockwell, 2019; Iyengar & Massey, 2019; Packer & Van Bavel, 2021). For example, it has been found that the current design of social media platforms and algorithms, combined with human psychology, can facilitate the contagion of many interconnected negative group phenomena, like formation of *echo chambers* (e.g., Bright et al., 2020; Cinelli et al., 2021; Nguyen, 2020b); *intergroup moral outrage* (Brady et al., 2020, 2021; Brady & Van Bavel, 2021; Carpenter et al., 2021; Crockett, 2017; Marwick, 2021; Rathje et al., 2021); *political and affective polarization* (Iyengar & Krupenkin, 2018; Pereira et al., 2021; Pew Research Center, 2017c; Reiljan, 2019; Van Bavel et al., 2021); as well as *spread of misinformation, conspiracy theories, and pseudoscience* (Iyengar & Massey, 2019; G. Miller, 2021; Pereira et al., 2021; Vosoughi et al., 2018). These phenomena further contribute to our *lack of face-to-face interaction* and related *lack of productive intergroup communication* (see Christ & Kauff, 2019; Turkle, 2015). The platforms and the ubiquitous devices used to access them may, partly via these sorts of phenomena and increasing screen time, further contribute to various *mental health problems*. Some of these seem to have increased in tandem with the emergence of social media and smartphones (see Haidt & Twenge, 2021; Kross et al., 2021). (see also Kangassalo, 2019; 2021a–b; sect. 5.2.3.)

Among others, also Berners-Lee has expressed concerns about the current state of the online space. For example, concerns about the spread of misinformation and about some corporations – like Facebook and Google – having gathered too much power in controlling people's personal data. Even though these undermine his earlier optimism, they have encouraged him to explore potential avenues to help fix the issues. (Harris, 2021; Lohr, 2021.) Likewise, Jimmy Wales, the co-founder of Wikipedia, has expressed concerns, leading to an attempt to form a new social media platform *WT:Social* (est. 2019) to tackle some of the issues (Bradshaw, 2019). Generally, since the mid-2010s, the negative affordances of contemporary social media have gathered increasing attention amongst many key influencers of the tech world, albeit viable solutions to address the issues seem slow to emerge and implement into the design of the most popular platforms. Concurrently, many scientists have started to seriously delve into these matters, some even considering collective behavior as a *crisis discipline* like climate science, conservation, and medicine (e.g., Bak-Coleman et al., 2021).

2.2.5.3 The effect on scientific literacy

All in all, it seems that there are two opposing informational forces at work in the contemporary media landscape: [1] the tribalistic human psychology that is easily captured by and motivated to spread polarizing moral-emotional content along with related misinformation (e.g., Brady et al., 2020, 2021), even though, at the same time, we have [2] an unprecedented access to practically all of the scientific and other knowledge humanity has ever produced. For the moment, partly due to prevailing design of social media platforms, it seems that the former dominates our consciousness while the possibilities of the latter are often left unused. These two opposing forces further put into question the average effect Internet use might have on people's scientific literacy. *Prima facie*, one could imagine the effect being anything from a negative to positive to neutral. Likewise, it's not immediately clear what effect traditional media (e.g., television, print media), that people are shifting away from, might have. Still, Miller's data from 2007 suggests that general Internet consumption has a positive effect on scientific literacy, as compared to traditional media consumption (Appendix 1; J. D. Miller, 2010b–c), and the same is suggested by more recent data from 2012 by Takahashi & Tandoc (2016).

Of course, the effect the new media landscape has on scientific literacy likely depends on specific individuals and how they are using the new media. It seems clear that there are better and worse ways to use *any* media, in the hope of supporting scientific literacy. For example, the effects of an individual's information diet are likely to be different depending on whether they solely spend their time on Wikipedia versus web sites about conspiracy theories or celebrity gossip. Therefore, it is important to pay more attention to what those better and worse ways of using the Internet, or any media, might more specifically be. This is something that the survey of the present study examines, especially via the qualitative questions (sect. 3.3.2, 4.2, 5.1.3). Once better ways are discerned, they could be promoted via appropriate public education and general educational work.

What is especially noteworthy for the survey in this thesis is that it was conducted in 2014. And as outlined, the time around the mid-2010s was a watershed moment for social media: it seemed to be around that time that the bulk of the moral outrage phenomenon, related polarization, spread of mis-/dis-/malinformation, echo chambers, and other negative phenomena online started to gather either wider traction or salience, and consequently shift the general view of the new media landscape more towards pessimism, away from the optimism that was still widely prevalent in the early 2010s (see Pew Research Center, 2010a–b, 2011; cf. 2017b–c, 2020d, 2021a). Thus, the sample presented in the next chapter may be thought as being one from around the time of the turning point. This should be noted when interpreting the results, especially in comparison to other samples (e.g., from 2007 by J. D. Miller (2010b–c), and 2012 by Takahashi & Tandoc (2016)). While scientific literacy has only become more important in an age where misinformation may more easily spread, the developments online since 2014, and their potential significance for interpreting the results of the survey, are considered more specifically in the discussion chapter (particularly in sect. 5.2.3 & 5.2.4.4).

3 METHODOLOGY

3.1 Construction of a Three-Part Survey

To study the relationship between scientific literacy and media consumption habits, the methodological approach of a cross-sectional survey was utilized. To reach people from varying backgrounds of media consumption, the survey was gathered live, in paper format. It was considered that a risk in online surveys, in the context of these topics, is not only their relatively low response rate (see Daikeler et al., 2020), but also that they might only reach users who already use Internet a lot, plus the participants may be tempted to look up the right answers on Google when filling out the scientific literacy part of the survey unsupervised. This approach was chosen even though the downside in live paper survey (contra online) is that conducting the survey and manually transferring the answers to be analyzed is rather time consuming. The survey was divided into three parts, the relations of which were examined: background information, habits of media consumption, and scientific literacy (see Appendix 3; henceforth abbr. A3; or, alternatively, see Appendix 2 for the Finnish version of the survey that all participants used).

In the background information section of the survey, standard information was gathered (incl. sex/gender [in the Finnish language the term "sukupuoli" can denote both], year of birth, level of education), along with the participants' religious affiliation[39], second language proficiencies, as well as the quality of primary Internet connection (see A3, sect. 1). These additional questions were added to gather wider background information, and to substantiate some past results that have implied there to be a connection between scientific literacy and language skills (e.g., Carrejo & Reinhartz, 2012; Martinez-Hernandez et al., 2015), religious views (e.g., A1; J. D. Miller, 2010b; Sherkat, 2011), and – via religious views – quality of Internet connection (e.g., Downey, 2014; McClure, 2020). In part, this also aimed to substantiate the representativeness of the data in relation to prior research.

To measure the habits of media consumption, a new prototype survey was constructed (see A3, sect. 2). It was partly modeled after the Likert scale survey of media sources for science news, and the media source categorization, used by the Tieteen tiedotus ry (Finnish Society for Scientific Information) in their triennial survey *Tiedebarometri* (lit. *Science barometer*), in 2010–2019 (see in English: Tieteen tiedotus, 2019, p. 13; in Finnish: Kiljunen, 2019, pp. 18, 20, 22, 24–25). The purpose was to survey media consumption more carefully than Miller did in his path model, where he used

[39] The formulation for the question about view of God was taken directly from Question 19 of the Richard Dawkins Foundation for Reason and Science (UK) *Religious and Social Attitudes of UK Christians in 2011* survey (see Ipsos MORI, 2012; A3, sect. 1).

only general categories of media consumption: Internet, print media, TV (see A1; J. D. Miller, 2010b). Specifically, in the present study, categories of different reasons for different media usage were listed and their use frequency surveyed with a 5-point Likert scale (e.g., measuring how often a participant uses television to watch news, documentaries, or science-related programs; or how often they produce content for the Internet, etc.; see A3, sect. 2). Additionally, the primacy of specific media sources (e.g., television, Internet) for specific tasks (e.g., following news, learning new knowledge) were surveyed (A3, sect. 2). Also, radio and digital games were added to the prime sources of media, while print media was divided into several more specific ones (newspapers, magazines, non-fiction, fiction). Further, "pay television" (e.g., cable) was added alongside plain "television".

In addition to the quantitative questions in measuring media usage, two qualitative questions were also formulated to try to measure more specific sources under the prime categories. The questions asked the participants to briefly describe what kind of media contents they *like to use*, and what kind of media contents they feel they *learn the most* knowledge from, respectively (A3, sect. 2). These questions served the purpose of trying to survey if there might be found some similarities in the more specific media sources of users with higher level of scientific literacy versus lower.

In the scientific literacy part of the survey, traditional questions utilized in prior surveys were combined with a couple of new ones that attempted to better account for measuring people's understanding of some basic concepts in some *social* sciences (A3, sect. 3). Scientific literacy has been traditionally surveyed for a long time, but often focusing only on content knowledge concerning natural sciences (see sect. 2.1.3). Overall, in the present study, there were 28 questions that were utilized in the final analysis. Out of these, eighteen were standardly used true/false questions (A3, sect. 3, q1–18), one was a non-standardly used true/false question (q19)[40], four were standardly used multiple choice question (q21–24), and five were multiple choice questions formulated for this study (q25–29). (see also Impey et al., 2017, pp. 62–64; J. D. Miller, 2006, p. 5; 2010a, p. 246.)

To the nineteen true/false questions, also an option to answer "I'm not sure" was added, unlike in prior surveys. However, only the right answers were counted towards the participants' level of scientific literacy. There was also one more additional true/false non-standard question formulated

[40] The scientific status of homeopathy was not used in Miller's international sample (in Miller, 2006). Thus, it was added to the questionnaire, as it is, like astrology, a paradigmatic example of pseudoscience, yet hailed by many to be an effective way of treating diseases (likely due to some combination of the placebo effect, illusion of causality, scientific ignorance, and unjustified trust in anecdotes). (see, e.g., Blanco & Matute, 2018; Pigliucci & Boudry, 2013b; sect. 2.1.1.)

In retrospect, also a question about vaccines or herd immunity would have been useful to add, as vaccine hesitancy seems to have been gathering wider attention in the last few years, especially during the COVID-19 pandemic in 2020–2021 (see, e.g., Howard & Reiss, 2018; Novella, 2020). Still, there is an included standardly used question about whether antibiotics kills viruses as well as bacteria (they do not). A false belief in that matter might already have detrimental effects for willingness to get vaccinated.

for the study (q20), but it was removed from the final analysis due to it being determined as too ambiguous to produce valid answers, based on post-survey considerations and participant feedback (014, 043, 047, 075, 080, 091).[41] No other question generated such feedback.

Out of the five multiple-choice questions newly formulated for this study, three were based on *qualitative* open-ended questions utilized in previous studies (q25–q27; corresponding with, e.g., J. D. Miller, 2010a, p. 246), while two were completely new questions utilized in this study (q28–q29; though, Miller has mentioned using an open-ended measure for "neuron" in his more recent studies of the American public; J. D. Miller, 2010a, pp. 244–245). The question concerning the rationale for control groups when testing medicine (q25) was a substantially modified and confined formulation of the original qualitative question where a participant should provide a correct open-ended definition of "what it means to study something scientifically" (cf. J. D. Miller, 2006, p. 5; 2010a, p. 246). It was due to the already demanding length of the three-part survey that the open-ended questions were reformulated into multiple-choice format. Although not ideal, as open-ended questions provide better measure of understanding (cf. J. D. Miller, 1998), this does counter some weak criticisms that the qualitative questions utilized in past studies might raise, regarding people possibly not being able to properly answer them when prompted, even when they might be able to sufficiently understand them in contexts where it matters (cf. Bauer, 2008; Laugksch, 2000). The additional new questions about socialization (q28) and neurons (q29) were formulated to better account for understanding of some basic constructs in psychological/social sciences in addition to natural sciences and economics.

The null hypothesis was formulated after Miller's path model (see A1; see also J. D. Miller, 2010b): (certain type of) Internet media consumption has a more positive correlation with scientific literacy, as compared to (certain type of) TV consumption that has a more negative correlation, while (certain type of) print media consumption would fall somewhere in between (see also Huber et al., 2019; Nisbet et al., 2002; Takahashi & Tandoc, 2016).

[41] The question, or claim, removed from the final analysis was "AIDS can be transmitted to another person by sexual intercourse" (12 % of the sample disagreed with the claim, while 87 % agreed). How the question seemed invalid to measure the intended scientific content knowledge, one participant answered "false" but wrote beneath "(HIV can)" (080), while another answered "true" but wrote beneath "(HIV)" (091). This is illustrative of the general confusion generated by the question. It appeared that participants with correct understanding of the underlying science could produce different answers due to different interpretations of the claim, and hence it was considered invalid for the study.

Even though it might strictly speaking be only HIV (*human immunodeficiency virus*) that can be *transmitted* by sexual intercourse, not AIDS (*acquired immunodeficiency syndrome*), HIV does still slowly weaken the immune system to the point of AIDS if untreated. In other words: HIV does cause AIDS if untreated; but sexual intercourse can cause AIDS only by HIV being transmitted first, and then the HIV not being treated to prevent AIDS. Consequently, whether the claim should correctly be considered true or false seems to be contingent either on our theory of causation (see Broadbent, n.d.), our understanding of "transmission", and/or our familiarity with the difference between HIV and AIDS. Had the claim been formulated as "HIV can be transmitted by sexual intercourse", it would have been quite unambiguously true.

3.2 Sample

The final sample size was 138, consisting of 78 males and 57 females along with three participants who opted not to reveal their sex/gender (or who opted for a third sex/gender category). The live paper surveys were collected in 2014 at Tampere and Jyväskylä, Finland, in three facilities, during nine sessions. The sessions consisted of (1) three sessions at the University of Tampere in the spring, one on a basic course on psychology with 38 participants, one on an advanced course on pedagogy with 10 participants, and one on an advanced course on psychology with 11 participants; (2) one session at Jyväskylä in the summer, among a work community primarily of engineering background, with 21 participants; and (3) five sessions at the vocational school of Tampere Adult Education Centre TAKK in the fall, on courses concerning service activities, electrical and automation engineering, automation technology, electrical work, and property maintenance, with 14, 16, 5, 13, and 10 participants, respectively.[42]

Majority of the participants in the final sample were likely Finnish – indicated by the fact that 123 participants reported Finnish as their native language, and everyone filled out the survey in Finnish even though availability of English forms was always mentioned. One participant reported English as their native language, but still filled out the survey in Finnish (with "outstanding" understanding of Finnish, placing in the top quartile of scientific literacy); and one reported both Finnish and Swedish, one Swedish (with "outstanding" Finnish), and thirteen reported no native language (with four "good", six "excellent", and three "outstanding" in Finnish). The ages varied from 20 to 66 (approximately, representing year of birth). Between the ages of 23 and 38 there were quite an even number of participants in every age group (with 2–7 participants per every single age), but there was a clear spike of participants aged 21 and 22 due to the largest group of simultaneous participants being the class of students on a basic university course on psychology. Notably, there were also 21 participants who chose not to share their age. These were mostly from the samples of engineering work community and the last vocational school sessions, not university students, and judging by other participants in their groups, more likely of relatively older age (>35, maybe mostly >40). (See Table 1; *Mdn* = 31; *Mo* = 22, *M* = 32.42.)

[42] The initial sample size was 139, but one participant was excluded. The exclusion criterion was poor understanding of the Finnish language that the participant used to fill out the survey. This aimed to ensure sufficient understanding of the questions in the final sample (see Wenz et al., 2021). Only those who answered that their understanding of the Finnish language is "good" (Finnish: *hyvä*) or better (>=3) were included (see A3, sect. 1), as they appeared to qualify for sufficient understanding in general. The one excluded had reported their understanding to be "below average" (*välttävä*; 1), and this seemed to be clear in their answers. This exclusion did not significantly affect the results (and a tighter exclusion would not have affected them much either; see sect. 5.2.2).

Age distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20–24	36	26.1	30.8	30.8
	25–29	18	13.0	15.4	46.2
	30–34	16	11.6	13.7	59.8
	35–39	21	15.2	17.9	77.8
	40–44	11	8.0	9.4	87.2
	45–49	6	4.3	5.1	92.3
	50–54	6	4.3	5.1	97.4
	55–59	2	1.4	1.7	99.1
	66	1	.7	.9	100.0
	Total	117	84.8	100.0	
Missing	System	21	15.2		
Total		138	100.0		

Table 1. Age distribution.

The most common highest degree of education in the sample was the Finnish Matriculation Examination ($n = 44$); which is a Finnish national standardized examination based on the curriculum for the Finnish upper secondary school. The results of the exam are often utilized to apply for higher education institutions (see Ylioppilastutkintolautakunta, 2021). Thus, the commonness in the sample is explained by the fact that many participants were undergraduate students at a university. Still, there was also a decent amount of vocational education, applied sciences (i.e., polytechnic), and university degrees (lower: bachelor's; higher: master's, licentiate, or doctorate) represented. (see Figure 1.)

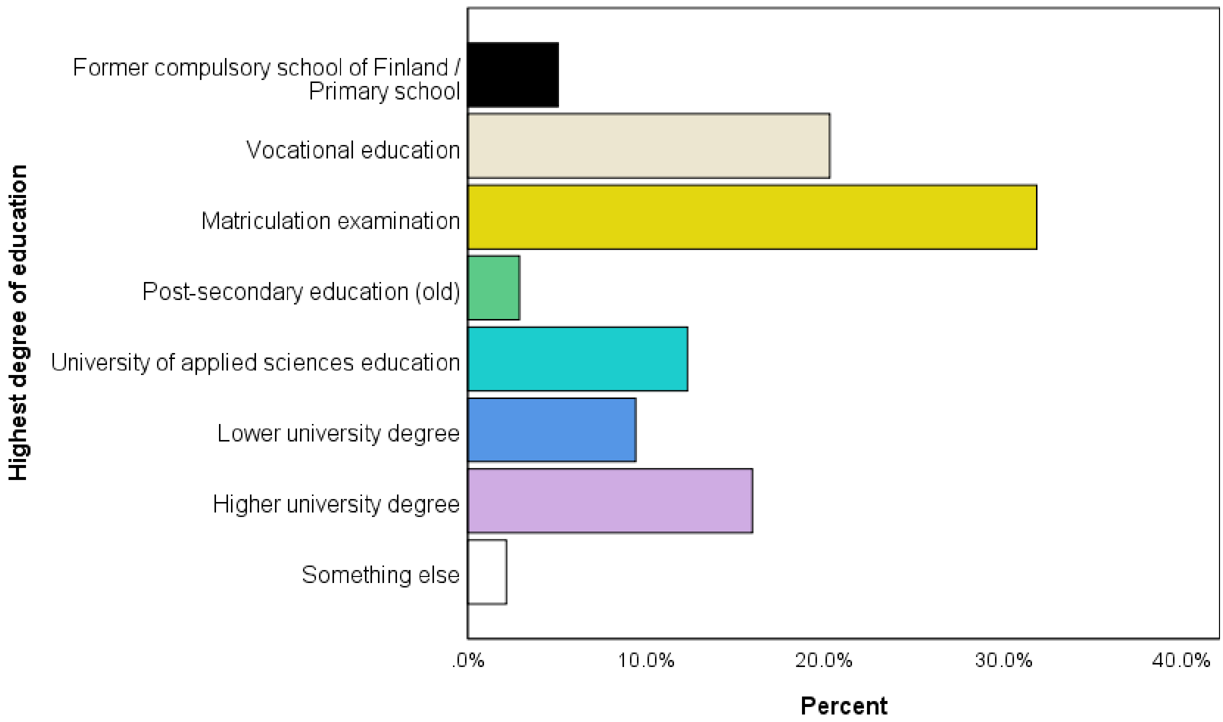

Figure 1. Education distribution.

3.3 Data Analyzing Methods

The data was analyzed by a combination of quantitative and qualitative analyses. The qualitative analysis ended up containing also mixed quantitative analysis, but generally these processes could be distinguished as per analysis performed on the quantitative questions of the survey and the qualitative questions of the survey. Below, I go through both processes, respectively.

3.3.1 Quantitative part of the survey

Unlike in some previous research – including Miller's (cf. J. D. Miller, 2006, 2016) – the answers in the scientific literacy section were not analyzed in dichotomous terms, of whether the participants were considered civic scientifically literate versus not. This was due to the focus of the study being relative measurements in relation to media consumption habits, not absolute measurements in terms of civic scientific literacy, and as a continuum understanding of literacy may be preferable in any case (see sect. 2.1.2). Thus, the participants' *level* of scientific literacy was analyzed in relation to their habits of media consumption and background information. (see A3.)

In the scientific literacy part of the survey, the number of correct answers could be counted, and thus a participant's level of scientific literacy on this survey was represented by a continuum of 0–28 correct answers. The number of correct answers revealed to be rather evenly distributed between 13 and 22, with a clear peak on 24 and 25 and a slight peak on 17 and 18 (*Mdn* = 22; *Mo* = 24, *M* = 21.15). Prior analysis, to even out the distribution, the results were recoded into evenly distributed quartile frequencies, with the values ending up as 9–17, 18–22, 23–25, and 26–28 (see Table 2). The quartiles could not be completely even, however, with a slightly higher percentage on the 23–25 quartile and a slightly lower percentage on the highest 26–28 quartile. Each of the 28 scientific literacy questions along with the percentage of participants who answered them correctly can be seen on the next page, in Table 3.

Scientific literacy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	9–17	36	26.1	26.1	26.1
	18–22	34	24.6	24.6	50.7
	23–25	43	31.2	31.2	81.9
	26–28	25	18.1	18.1	100.0
	Total	138	100.0	100.0	

Table 2. Evenly distributed quartiles of scientific literacy.

Table 3: Percentage of correct answers to the scientific literacy questions[43]

	Correct (%)
Agree: "Over periods of millions of years, some species of plants and animals adjust and survive while other species die and become extinct."	96
Indicate an understanding of the meaning of the probability of one in four.	96
Agree: "The center of the Earth is very hot."	94
Agree: "The continents on which we live have been moving their location for millions of years and will continue to move in the future."	94
Indicate that Earth goes around the Sun.	92
Agree: "Light travels faster than sound."	91
Agree: "If the present rate of fossil fuel use continues, serious long-term environmental damage will occur."	90
Agree: "All plants and animals have DNA."	86
Disagree: "Ordinary tomatoes do not have genes, but genetically modified tomatoes do."	86
Indicate an understanding of what is socialization.	84
Agree: "Human beings developed from earlier species of animals."	81
Indicate an understanding of inflation in relation to prices.	80
Disagree: "All radioactivity is manmade."	78
Disagree: "Radioactive milk can be made safe by boiling it."	78
Indicate that one (Earth) cycle around the Sun takes one year.	77
Indicate an understanding of what is a neuron.	76
Agree: "The universe began with a huge explosion."[44]	76
Disagree: "The earliest humans lived at the same time as Tyrannosaurus Rex."	75
Indicate an understanding of what is DNA.	72
Disagree: "Antibiotics kills viruses as well as bacteria."	70
Indicate an understanding of what is a stem cell.	70
Agree: "Electrons are smaller than atoms."	67
Indicate an understanding of why control groups are important.	65
Disagree: "Lasers work by focusing sound waves."	51
Disagree: "Homeopathy is an effective way of treating diseases."	51
Agree: "Astrology is not scientific."	49
Disagree: "Nuclear power plants destroy the ozone layer."	47
Agree: "More than half of human genes are identical to those of mice."	44
Number of cases	138

[43] I omit any more specific analyses of these statistics. For example, considerations of what believing that "nuclear power plants destroy the ozone layer" – even by many university students – might do to our efforts to mitigate global warming via less pollutant forms of energy production than, say, burning coal. Or, what believing that "homeopathy is an effective way of treating diseases" might do to our personal health goals, or how not acknowledging that "astrology is not scientific" might affect our evaluations of fellow humans based merely on their date of birth (although, it may be that some mix up "astrology" with "astronomy"). Suffice it to say that many of our evaluations and decisions can be counterproductive even for our own individual and societal moral goals if we lack this kind of civic scientific literacy. (see also sect. 2.1.1, 2.2.2; see also Kangassalo, 2019; for how these cannot be directly compared with Miller's results, see also sect. 5.2.4.3.)

[44] To be precise, the Big Bang theory does not entail an explosion per se, but rather a very rapid *expansion* of spacetime that is nevertheless colloquially often referred to as an "explosion" (e.g., Moskowitz, 2010). Due to the colloquial use of the word, and this formulation being used in earlier studies (e.g., J. D. Miller, 2006), it was retained as is. Still, future studies should perhaps adjust the wording. (No one in the sample raised this point, so it is not relevant in that sense.)

To help the analysis of specific habits of media consumption, especially in the spirit of testing the findings of Jon D. Miller, the reported media habits of the participants were recoded to reveal different degrees of *general or overall usage* between different media. For example, every media consumption question concerning the Internet was counted and added to a new variable, keeping score of the level of general Internet usage per participant. If the question was, for example, how often the participant uses the Internet for reading the news, the answer "rarely or never" was added to the new variable "Internet" as 1, and the opposite answer "at least once a day" was added to the variable as 5. Thus, every question concerning the usage of Internet increased the general usage of Internet with a value from 1 to 5. The primary media sources items further increased the value with 5 each time Internet was mentioned. The same was then done to the rest of the media consumption sources. This was a coding of consumption of different *forms of media*, which overall consisted of Internet, television, print media (including general consumption of written media in both paper and electronic formats), radio, newspapers, magazines, written non-fiction, written fiction, and video games (i.e., digital games).[45]

Another similar kind of recoding was done to the *types of contents* that were being consumed (partly overlapping with the above-mentioned). For example, every time a participant gave a value 1–5 answer to a question concerning the use of some medium to learn knowledge (e.g., via reading non-fiction, or searching information from the Internet), the value was added to a new variable "knowledge", counting the usage of any medium for that purpose, i.e., for learning knowledge. The overall types of contents here were news, communication, knowledge(/science), entertainment, and organization.[46]

Finally, the new variables, both of different media sources and of the types of contents, were each recoded into evenly distributed quartile frequencies (titled by comparative use frequencies of "never or rarely", "occasionally", "often", and "very often"). The only exceptions were the forms of media 'magazines' and 'video games', and types of content 'news' and 'organization': these did not fit neatly enough into quartile frequencies. Instead, a tertile frequency recoding was opted for 'news' ("occasionally", "often", "very often"); and as magazines and organization included only one variable

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[45] The following items in the survey section 2 were included in the different *forms of media* (see A3, sect. 2): Internet (items 5–11); television (1–3); print media (14–17); radio (4); newspapers (14); magazines (17); written non-fiction (16); written fiction (15); video games (solo: 12; online: 13) (+ corresponding media sources if mentioned in the primary source question).

[46] The following items in the survey section 2 were included in the different *types of contents* (see A3, sect. 2): news (items 5, 14); communication (7–8, 11); knowledge(/science) (3, 6, 16); entertainment (1–2, 4, 9, 12–13, 15, 17); organization (10).

each, they were used instead (A3, sect. 2, item 10 for organization, and item 17 for magazines); and as video games included only two variables, those were used instead (A3, sect. 2, item 12 for solo gaming, and item 13 for online cooperative gaming). By examining the two new sets of variables – media sources and types of contents – along with the participants' scientific literacy and background information, relevant correlates could be discerned via bivariate and partial correlational analyses.

3.3.2 Qualitative part of the survey

Qualitative content analysis was performed to the two qualitative questions (see A3, sect. 2; Cho & Lee, 2014). In practice, the analysis was first done by general inductive examination of the answers to the questions by the top scoring participants versus the lowest scoring quartile in scientific literacy, to make any potential differences subjectively best stand out (see Thomas, 2006). Particular attention was paid to the differences between the forms of media contents mentioned by the two subgroups.

The analysis was then expanded via systematic classification of all the answers in the sample, in accordance with an inductively observed pattern that was in line with theoretical deductions made of the pattern. This process made it possible to perform a quantitative analysis of the qualitative questions, following their classification. Specifically, as the inductive analysis appeared to reveal differences in the number and uniqueness of *social learning-related Internet platforms, channels, and forums* (SLIPs) mentioned between the examined subgroups, a scoring of the answers of the whole sample was done into a new numeric variable per question. The scores given were between 0–4, per question, with the score depending on whether the following were mentioned, with only the highest applicable score given to each participant per question. These represent a scale for increasing tendency to use better quality, more unique, and/or more numerous *social* learning-related platforms, channels, and/or forums online (also including social groups, social feeds, and other forms of community):

0 = no mention of social media (or only generic mention of "Internet", "web search", or "Google", also including "Google Scholar" that was mentioned by one participant)

1 = social media platforms or newspaper websites (where there is most likely to be general conversation: e.g., "Facebook", "Twitter", "YouTube", "newspaper websites")

2 = Wikipedia, podcasts (mostly Wikipedia, as podcasts were mentioned by only four people in the sample, of which only one mentioned them in the second qualitative question)

3 = social learning-related sites, also including *generic* mentions of educational channels or forums and *singular* mentions of specific educational channels or forums (e.g., TED, educational channels on YouTube, educational forums, science-related Facebook groups)

4 = unique social learning-related sites, channels, or forums for the sample; and/or clear indication of using *many* social learning-related sites, channels, or forums (e.g., MOOCs like "Coursera" and "Khan Academy"; explicit mentions of many educational channels on YouTube or elsewhere; Wikipedia article editing hobby; explicitly science-related social areas like "Reddit science-subreddits", "Twitter science feeds")

Both qualitative questions were scored in a similar manner, into their own variables. However, if a participant clearly mentioned educational spaces in the first qualitative question and gave an answer to the second question that referred to the first question, the educational spaces in the first question were also counted to the scoring of the second question. Additionally, the sum of the resulting two variables was added into a third variable. These variables were then quantitatively analyzed via bivariate and partial correlational analyses.

4 RESULTS

In this chapter, I present the results of the survey. In sections 4.1 and 4.2, I lay out the analyses of the quantitative and qualitative items, respectively. In section 4.3, I summarize the results.

4.1 Analysis of the Quantitative Items

Below, in sections 4.1.1 and 4.1.2, I present the results of how scientific literacy and media consumption habits, respectively, relate to the background information of the participants in the quantitative part of the survey. In section 4.1.3, I present the results regarding the relationship between scientific literacy and media consumption habits.

4.1.1 Scientific literacy and background information

As could be expected based on prior research (e.g., A1; J. D. Miller, 2010b, 2010c; Takahashi & Tandoc, 2016), there was a significant correlation between scientific literacy and level of education ($r = .354$, $p < .001$). The higher the education level of the participant, the more likely they were to belong to a higher quartile of scientific literacy. For example, 50 % of the participants in the lowest quartile had vocational education as their highest level of education, and 16.7 % had primary school, whereas none of the participants with a higher university degree belonged to the lowest quartile.

There was also a significant positive correlation between scientific literacy and the participants' self-reported level of understanding of the English language (see Table 4; see also Figure 2). Further, there were correlations between scientific literacy and understanding of the Finnish language ($r = .251$, $p = .003$) and Swedish language ($r = .204$, $p = .02$), but, for the purposes of this study, these were not as interesting as the English correlation. In closer examination, the Finnish correlation seemed to just imply that the sample was majority native speakers ($n = 123$), and if one was not a native speaker, they were more likely of a minority lower education immigrant background. And the Swedish correlation seemed to convey that the lowest quartile of scientific literacy was overrepresented in the "below average" (Finnish: *välttävä*) proficiency[47], but that most people in all

[47] Swedish is an official language in Finland – spoken by a 5.2 % minority natively (Statistics Finland, 2021b) – that all Finnish speakers study as a 'second national language' (Finnish: *toinen kotimainen kieli*) starting in primary school. In practice, it is usually the third language after Finnish and English. Likewise, all native Swedish speakers in Finland study Finnish as a second national language. Consequently, most of the non-native Finnish speakers in the sample knew little Swedish ($n = 15$, with one native Swedish speaker, two who reported no understanding of Swedish, and two with "average" and the rest "below average" understanding).

quartiles of scientific literacy still had lower than "good" (*hyvä*) Swedish proficiency. Controlling for either education or Finnish proficiency eliminated the significance of Swedish proficiency. When excluding lower than "outstanding" Finnish speakers from the sample, the correlations with both Finnish and Swedish disappeared. The English correlation, however, was indicative of a robust pattern of mutually increasing scientific literacy and understanding of English (see Figure 2) that remained at the same significance level after controlling for education or when excluding those with lower Finnish proficiency.

Correlations

		Scientific literacy	Understanding of the English language
Scientific literacy	Pearson Correlation	1	.363***
	Sig. (2-tailed)		.000
	N	138	137
Understanding of the English language	Pearson Correlation	.363***	1
	Sig. (2-tailed)	.000	
	N	137	137

***. Correlation is significant at the 0.001 level (2-tailed).

Table 4. Scientific literacy and understanding of the English language.

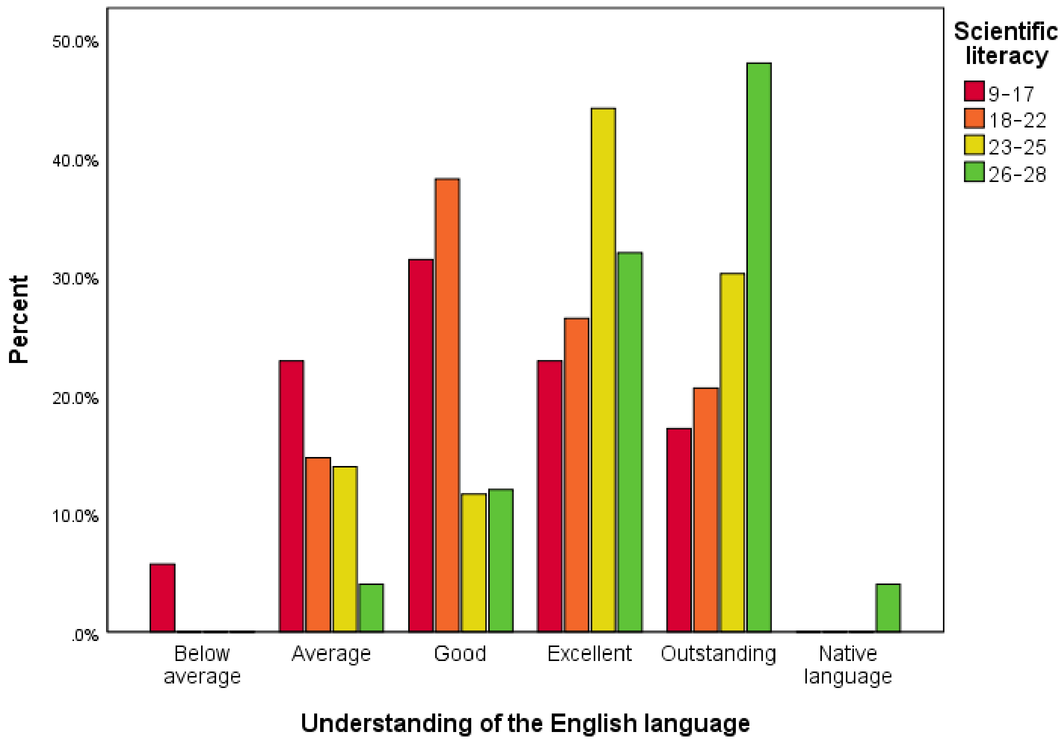

Figure 2. Scientific literacy and understanding of the English language.

In prior research, there have been implications of bilingual proficiency that includes English as a second language being potentially connected with higher level of scientific literacy (Carrejo & Reinhartz, 2012; Martinez-Hernandez et al., 2015), as well as to other cognitive benefits (Weiler, 2015). The current sample was in line with these implications: there was no significant correlation between scientific literacy and the overall number of languages studied, nor a durable significant correlation between scientific literacy and proficiency in Swedish as a second language after Finnish, but there was a robust positive correlation between scientific literacy and proficiency in English language as a second language (Figure 2; Table 4). This suggests that scientific literacy can be supported with bilingual proficiency specifically when that proficiency includes the English language (as a second language).

There was further a clear indication that those with vocational education as their highest level of education were not, on average, as proficient in English as those who had done matriculation examination or had a university degree. Education positively correlated with both English and Swedish proficiency (respectively: $r(137) = .183$, $p = .032$; $r(129) = .214$, $p = .015$). Moreover, both the correlations of understanding English ($p < .001$), and education ($p < .001$), with scientific literacy, remained when controlling for the other. Prior research has connected education to interest in science – indicative of science curiosity – and this seems likely to be connected to understanding of English as well (Takahashi & Tandoc, 2016).

Self-reported understanding of the English language also correlated with the participants' age cohort ($r(117) = -.336$, $p < .001$). People from younger cohorts were more likely to report themselves as being better in understanding English, and people from older cohorts were more likely to report being not quite as good. However, age cohort did not overall significantly correlate with scientific literacy, although belonging to an older cohort was predictive of being more likely to give the right answer to the specific question concerning nuclear power plants (A3, sect. 3, item 17; $r(117) = .326$, $p < .001$); and to giving wrong answers to the questions regarding DNA (item 26; $r(116) = -.241$, $p = .009$), evolution (item 12; $r(117) = .182$, $p = .049$), and genes (item 14; $r(117) = .197$, $p = .033$) (see also sect. 3.3.1, Table 3). Controlling for education affected these correlations only minimally, with the DNA question remaining at $p < .01$ and the rest at $p < .05$ (with a notable drop in the nuclear power plants significance level).

Another notable result was a significant negative correlation between scientific literacy and belonging to a church, religious community, or religious group (see Table 5). Not belonging to any such community was predictive of higher scientific literacy (see Figure 3), even when controlling for education. This is also in line with prior research (e.g., A1; Čavojová et al., 2020; Miller et al., 2010b, 2021b; Sherkat, 2011).

Correlations

		Scientific literacy	Which church, religious community or religious group do you consider belonging to?
Scientific literacy	Pearson Correlation	1	-.204*
	Sig. (2-tailed)		.016
	N	138	138
Which church, religious community or religious group do you consider belonging to?	Pearson Correlation	-.204*	1
	Sig. (2-tailed)	.016	
	N	138	138

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5. Scientific literacy and belonging to a church, religious community, or religious group.

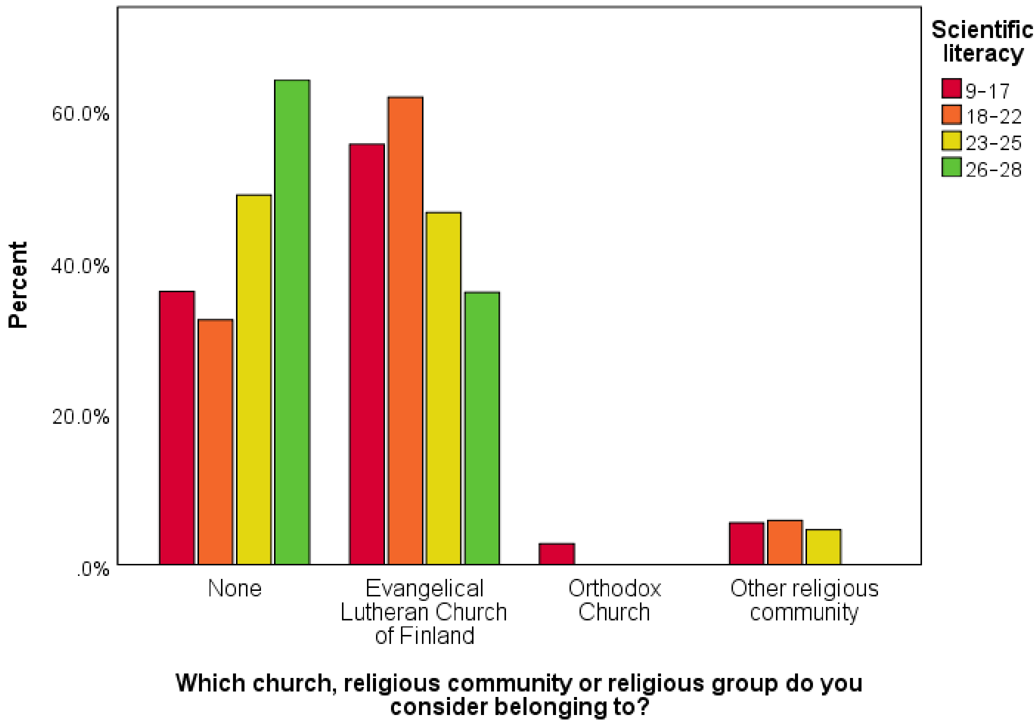

Figure 3. Scientific literacy and belonging to a church, religious community, or religious group.

It is important to note, however, that belonging to a religious community does not necessarily say anything about a person's belief, or lack thereof, in a "supernatural" God or gods. For example, in the comparatively secular Finland, it is still relatively common to belong to the Evangelical Lutheran national church only due to inheritance of tradition from parents – and often this does not entail belief in a deity. Nevertheless, a significant positive correlation between belonging to a religious community and view of God(s) was found ($r = .345$, $p < .001$). Further, scientific literacy negatively correlated with view of God(s) (see Table 6; see also Figure 4)[48]. A closer examination revealed that the answer "I do not believe in God" contained a 60 % majority of the people in the highest quartile of scientific literacy, although the highest concentration of people in the lowest quartile of scientific literacy were also atheists (32 %). A high concentration of people in the second lowest quartile of scientific literacy could be found in Christianity (38 %, both weak and strong Christianity put together). Even though controlling for education did not moderate the relationship between scientific literacy and belonging to a religious community, it did moderate the relationship between scientific literacy and view of God(s) (bringing it to $r(136) = -.133$, $p = .122$). View of God(s) negatively correlated with education ($r = -.212$, $p = .012$). (see Figure 4.)

Correlations

		Scientific literacy	View of God(s)
Scientific literacy	Pearson Correlation	1	-.196*
	Sig. (2-tailed)		.021
	N	138	138
View of God(s)	Pearson Correlation	-.196*	1
	Sig. (2-tailed)	.021	
	N	138	138

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6. Scientific literacy and view of God(s).

[48] More confined categorizations of the views of God(s) also showed significant correlations. Specifically, grouping the answers either as (1) atheist/pantheist, agnostic, theist/deist, something else, prefer not to say; or as (2) atheist/pantheist, agnostic, theist/deist/polytheist, something else, prefer not to say; yielded significant negative correlations with scientific literacy (respectively: $r = -.177$, $p = .038$; $r = -.239$, $p = .005$).

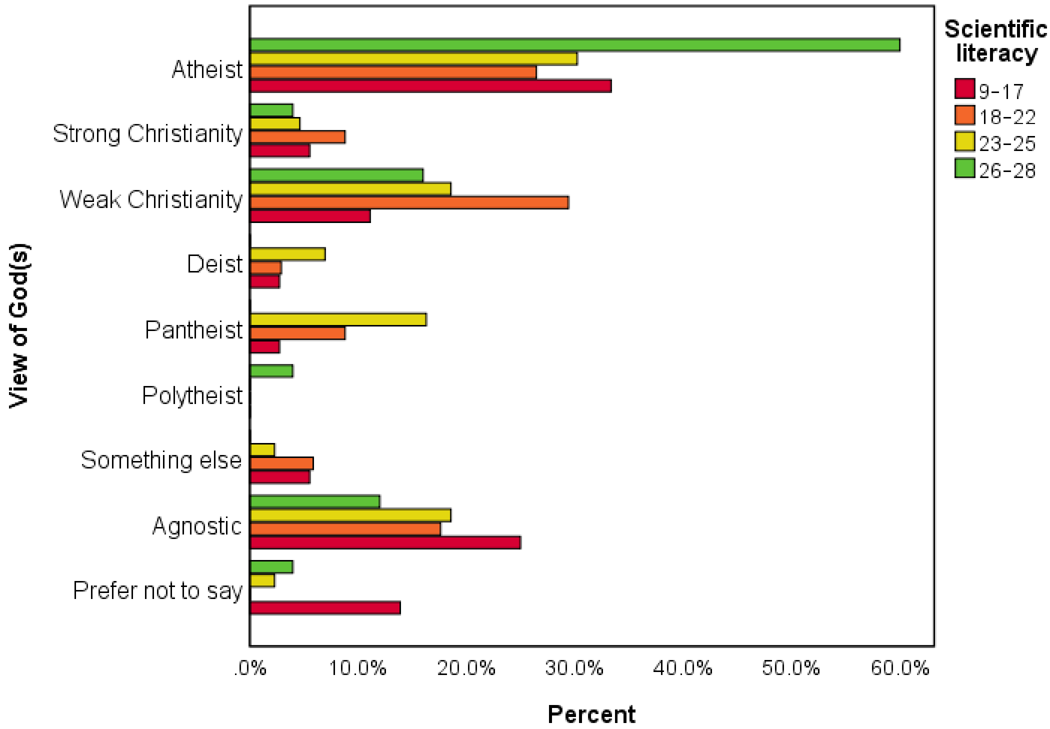

Figure 4. Scientific literacy and view of God(s). Note that the original choices were descriptions (see A3, sect. 1). For example, the term "Atheist" was used in the analysis and figures for brevity, and to give a name for the original description "I do not believe in God".

Finally, it should be noted that unlike in some previous research in the US in favor of males (cf., e.g., A1; Besley & Hill, 2020; J. D. Miller, 2004, 2010b; Takahashi & Tandoc, 2016) or in favor of Finnish females in OECD's PISA studies (cf., e.g., OECD, 2016b, p. 35; 2018, p. 4; Ministry of Education and Culture, 2016), there was no significant correlation between participants' sex/gender and scientific literacy in this Finnish sample. This result held when controlling for education, age, or both.

4.1.2 Habits of media consumption and background information

In terms of habits of media consumption, there was a significant inverse correlation between the levels of consumption of television and the Internet (r = -.435, p < .001), even when controlling for education, age, or both. The more television a participant consumed, the less Internet they were likely to consume – and vice versa. As could be expected by differing generational experiences, as well as differences of media consumption habits between different age cohorts in prior research, there were also significant correlations between age and media consumption habits (though generations have been converging since 2014 when the sample was collected: Palm & Pilkington, 2016; Pew Research Center, 2021d; Westcott et al., 2018).

Specifically, older cohorts were more likely to watch TV overall ($r(117) = .386$, $p < .001$). Younger cohorts were more likely to report watching TV less, and more likely to report frequent use of communication items ($r = -.283$, $p = .002$), specifically using Internet for communication with others ($r = -.296$, $p = .001$) and smart devices ($r = -.222$, $p = .016$). People who were more likely to watch TV more were also more likely to be *less* proficient in English ($r(137) = -.33$, $p < .001$), which is notable considering the result that English proficiency (as a second language) was positively correlated with scientific literacy.[49] Younger cohorts also reported being more proficient in English ($r = -.336$, $p < .001$), but there was no significant correlation between age and scientific literacy. Older cohorts were, however, prone to report more consumption of knowledge/science items overall ($r = .273$, $p = .003$), though most of this is explained by a stronger correlation with only one of the knowledge/science items, namely that of watching TV news/documentaries ($r = .401$, $p < .001$; A3, sect. 2, item 3). Older cohorts were also prone to report more consumption of overall news items ($r = .198$, $p = .032$) and radio ($r = .213$, $p = .021$), and they were more educated ($r = .330$, $p < .001$).

There was no significant correlation between TV consumption and level of education, nor was there one between Internet consumption and level of education. This is unlike in some previous research where education has been found to negatively correlate with TV consumption, and positively with Internet as well as newspaper consumption (cf. Nisbet et al., 2002; Takahashi & Tandoc, 2016). There was no significant correlation between education and newspaper consumption nor overall news consumption either. Moreover, education did not significantly correlate with overall print media consumption nor written non-fiction consumption. However, the more educated were more likely to report consuming more overall knowledge/science items ($r = .219$, $p = .01$); written fiction ($r = .204$, $p = .016$), particularly fictional books ($r = .245$, $p = .004$); and organization of life via Internet ($r = .277$, $p = .001$). Furthermore, they were less likely to play video games (solo: $r = -.169$, $p = .047$; online: $r = -.222$, $p = .009$).

Regarding sex/gender, female participants in the sample, as compared to males, reported consuming more written non-fiction ($r(135) = .294$, $p = .001$), fiction ($r = .218$, $p = .011$), and print media in general ($r = .337$, $p < .001$), as well as more frequent use of Internet for organizing life ($r = .255$, $p = .003$). Males, on the other hand, reported to more frequently play video games ($r = -.341$, $p < .001$), listen to radio ($r = -.209$, $p = .015$), consume overall knowledge/science ($r = -.222$, $p = .01$) and news ($r = -.183$, $p = .034$) and entertainment items ($r = -.190$, $p = .027$), watch TV

[49] In Finland, where the sample was gathered, subtitles are used in all foreign language TV programs and movies targeted for adults (i.e., there is no dubbing for adults).

news/documentaries (*r* = -.281, *p* = .001) and pay television (*r* = -.268, *p* = .002), and to more frequently use smart devices (*r* = -.176, *p* = .041). However, it was considered that some of these sex/gender differences in the sample may be explained by the third variable of education, as females with matriculation examination as highest degree were overrepresented in the sample (53 % of the females in the sample), as were less educated males (with 32 % of males in the sample having vocational education as highest degree). Still, controlling for education did not meaningfully affect any of the abovementioned results. An important caveat, though, is that pay television use was generally very low (with most people, >60 % in both sexes/genders, reporting frequency of "rarely or never"), whereas smart device use was very frequent (with most people, >70 % in both sexes/genders, reporting using them "at least once a day").

When examining preferred media sources, it was found that females in the sample, as compared to males, were significantly more prone to report preferring non-fiction books for learning new knowledge, whereas males were more prone to report using the Internet (*r* = .293, *p* = .001), even when controlling for education. On average, females preferred Internet and non-fiction books in balance, whereas males were more likely to prefer Internet over non-fiction books. However, there was no significant difference in the reported general consumption of neither TV nor Internet between the sexes/genders.

Regarding media usage habits and religiosity in terms of [a] the participants' belonging to a church, religious community, or religious group, and [b] their views on God(s), the latter was negatively correlated with overall Internet consumption (*r*(138) = -.18, *p* = .035). Particularly, atheists and pantheists were more likely to report using more Internet, especially as compared to 'weak Christians' who were prone to avoiding it. Moreover, and more significantly, participants' views on God(s) were negatively correlated with quality of Internet connection (*r* = -.322, *p* < .001), as was their reported belonging to a religious church or community (*r* = -.20, *p* = .019). Controlling for education, the correlation with Internet consumption disappeared, but the correlations with Internet connection held. Education was negatively correlated with view of God(s) (*r* = -.212, *p* = .012), thus moderating the effect.

Overall, for the purposes of this study, the most important results regarding habits of media consumption and the participants' background information appear to be the following. In the sample, TV and Internet consumption were inversely correlated: the more a participant reported to consume one, the less they were likely to consume the other (*p* < .001). As compared to younger cohorts, older cohorts reported more general TV consumption (*p* < .001), and more consumption of knowledge/science items overall (*p* < .01), particularly TV news/documentaries (*p* < .001), and news items overall ($p < .05$), but they were not significantly less likely to generally use the Internet. The more educated were likely to consume more knowledge/science items (p < .01), fictional books ($p < .01$), and to organize life via Internet ($p < .01$), but neither overall TV, Internet, nor print media consumption significantly correlated with education. While controlling for education, females and males in the sample had various preferences – for example, females, on average, preferring more print media and males preferring various more sensory contents – but there was no significant correlation between sex/gender and general consumption of neither TV nor the Internet. And, finally, religiosity in terms of view of God(s) negatively correlated with Internet consumption ($p < .05$), moderated by education; yet education did not moderate the connection between religiosity and quality of Internet connection (belonging to a religious community $p < .05$; view of God(s) $p < .001$).

4.1.3 Scientific literacy and habits of media consumption

As was implied by the null hypothesis, there was a significant negative correlation between overall television consumption and scientific literacy in the sample (see Table 7; see also Figure 5). This finding was maintained when controlling for age or education or both; and moderated by English proficiency that was positively correlated with scientific literacy ($p < .001$) and negatively with television consumption ($p < .001$). Specifically, controlling for English proficiency brought the correlation to a non-significant negative level of $r(134) = -.130$, $p = .132$. English proficiency appears to help scientific literacy via two primary paths: [A] it supports alternative or additional media consumption habits to TV consumption that better support scientific literacy ($p < .01$; see sect. 4.2.2, 5.1); and [B] it is further connected to education ($p < .05$) that supports scientific literacy ($p < .001$).

Correlations

		Scientific literacy	Television
Scientific literacy	Pearson Correlation	1	-.244**
	Sig. (2-tailed)		.004
	N	138	138
Television	Pearson Correlation	-.244**	1
	Sig. (2-tailed)	.004	
	N	138	138

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7. Scientific literacy and television consumption.

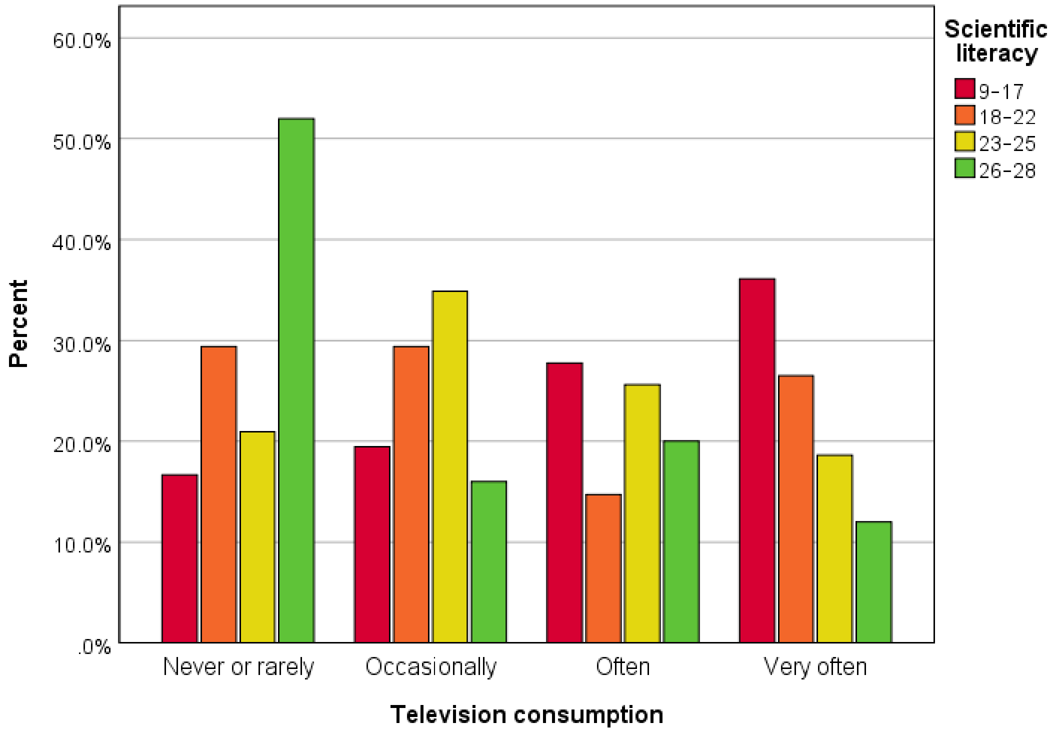

Figure 5. Scientific literacy and television consumption.

However, while the results support the hypothesis that TV consumption is correlated more negatively with scientific literacy than Internet consumption, there was no significant correlation found between general Internet consumption and scientific literacy ($r = .069$, $p = .423$). This general result held when controlling for education or age, and even when eliminating Internet use for entertainment purposes (i.e., when eliminating A3, sect. 2, item 9, and media source primacy item 7, from overall Internet use; see sect. 3.3.1n45–46). Still, there was a significant positive correlation between scientific literacy and the participants' reported frequency of organization of life via Internet ($r = .244$, $p = .004$). Yet, this correlation was moderated when controlling for education (bringing it to $r(135) = .163$, $p = .057$), with education positively correlating with organization of life via Internet ($r(138) = .277$, $p = .001$).

There was no significant correlation between general print media consumption and scientific literacy either ($r = .132$, $p = .124$), and this too held when controlling for education or age. However, the more specific category of written non-fiction consumption did have a significant positive correlation with scientific literacy ($r = .202$, $p = .018$). Particularly, the bottom quartile of scientific literacy was clearly overrepresented in the "never or rarely" use frequency category. Yet, education did slightly moderate this correlation: when controlling for education, it was weakened to $r(135) = .167$, $p = .051$. When considering that [a] written non-fiction did not distribute neatly into quartile frequencies (see Table 8), [b] significance of the original scale variable before quartile frequency recoding held fairly well after control ($r(135) = .205$, $p = .016$ after control; $r(136) = .222$, $p = .009$ before), and as [c] no significant correlation was found between education and written non-fiction, the relationship between scientific literacy and written non-fiction seems to hold at around the threshold of statistical significance ($p < .05$) even after controlling for education.

Written non-fiction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never or rarely	44	31.9	31.9	31.9
	Occasionally	32	23.2	23.2	55.1
	Often	36	26.1	26.1	81.2
	Very often	26	18.8	18.8	100.0
	Total	138	100.0	100.0	

Table 8. Quartile frequencies of written non-fiction consumption.

A significant correlation was also found between scientific literacy and the participants' answers to the question "Which media source do you consider your primary source for learning new knowledge?" ($r(138) = .279$, $p = .001$; see A3, sect. 2). Specifically, 52 % of the people in the top quartile of scientific literacy answered "Internet", and 48 % answered "non-fiction books"; while a clear majority of the participants in the bottom quartile answered "Internet" (77.8 %; see Figure 6). The correlation largely held when controlling for education ($p = .004$) and English proficiency ($p = .013$). This suggests that, compared to the bottom quartile, people in the top quartile likely had either more varied media sources for knowledge acquisition, better Internet sources, or – most likely – both. Their primary source for learning seemed to be evenly balanced between Internet and books, whereas the bottom quartile was skewed towards the Internet. A related inverse correlation was found between consumption of Internet and written non-fiction ($r = -.384$, $p < .001$) as well as consumption of Internet and general print media ($r = -.374$, $p < .001$). Further considering that non-fiction consumption positively correlated with scientific literacy ($p < .05$), this suggests that overreliance on certain type of Internet might hinder scientific literacy, but in proper balance with non-fiction book consumption or with specific type of Internet use (see sect. 4.2) scientific literacy may be supported.

Furthermore, there was a significant correlation between scientific literacy and the primacy of media source for following news ($r = .20$, $p = .019$). Specifically, people in the lowest quartile were slightly overrepresented in reporting primacy of television (with 30.6 % of the lower quartile), yet most people still preferred Internet (>60 % in all quartiles). This general result also held when controlling for education.

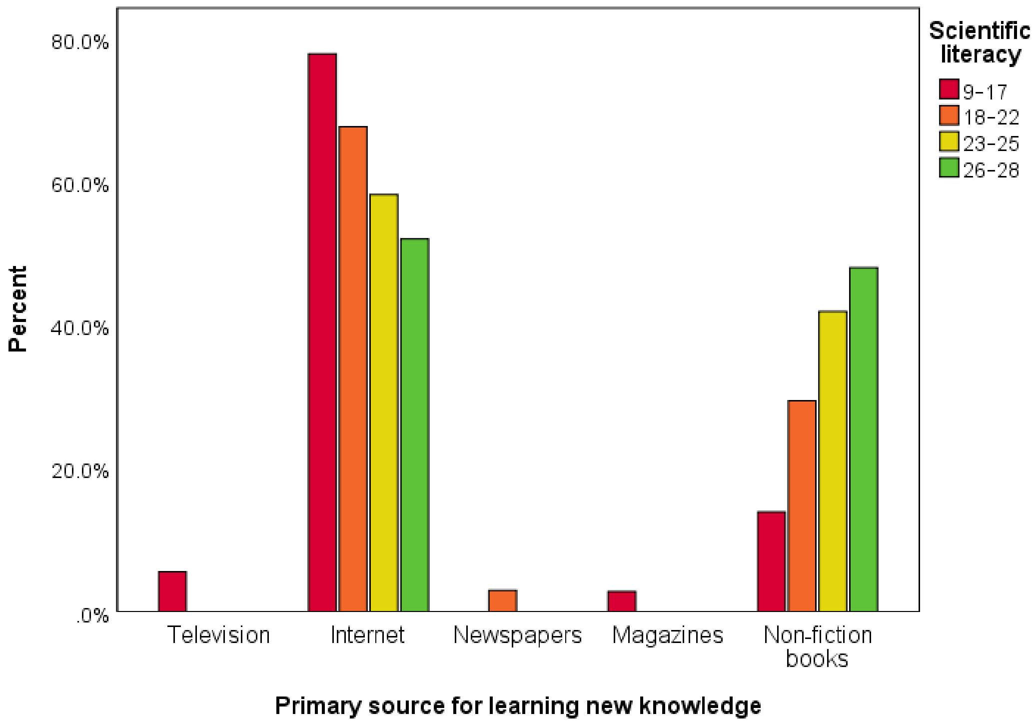

Figure 6. Scientific literacy and primary source for learning new knowledge.

There was also a significant negative correlation between scientific literacy and reported frequency of playing digital games (solo: $r(136) = -.214$, $p = .012$; online: $r(136) = -.230$, $p = .007$). However, the reliability of this particular result seemed somewhat questionable because the survey did not reach very many players, nor very educated ones. There were overall very few people who reported playing games "at least once a week" or more in the sample (solo: 38; online: 20; with a lot of overlap). And nearly half of them had vocational education or lower as their highest level of education (solo: 16/38; online: 10/20), which education level was predictive of both lower scientific literacy ($p < .001$) and higher tendency to play digital games (solo: $p < .05$; online: $p < .01$). Yet, controlling for education seemed to support this questionability only partly, as it did considerably moderate the effect but only bringing it to the threshold of statistical significance (solo: $r(135) = -.168$, $p = .05$; online: $r(135) = -.166$, $p = .052$). Moreover, controlling for age moderated the correlations (solo: $r(114) = -.137$, $p = .144$; online: $r(114) = -.162$, $p = .082$), even though age did not significantly correlate with either. Controlling for sex/gender did not much moderate the correlations (solo: $r(132) = -.193$, $p = .025$; online: $r(132) = -.210$, $p = .015$). All in all, based on the present sample, it seems that the frequency of playing digital games *might* significantly negatively correlate with scientific literacy, but before this is tested with a larger and more diverse gamer sample, it seems safest to consider this particular result as inconclusive. The relationship between digital games and scientific literacy do not seem to have been measured before, but prior research has shown there to be multiple factors involved in science learning outcomes even through educational games (see Morris et al., 2013; Voulgari, 2020).

Overall, Miller's findings regarding the relationship between habits of media consumption and scientific literacy were supported. TV consumption was found to be negatively correlated with scientific literacy ($p < .01$), even when controlling for education and age. English proficiency moderated the relationship, while correlating negatively with TV consumption and positively with scientific literacy (both $p < .001$). No correlation between general Internet consumption and scientific literacy was found, though a positive relationship was present between scientific literacy and organization of life via Internet ($p < .01$), moderated by education. Likewise, no correlation was found between scientific literacy and general print media consumption – but the more specific category of written non-fiction was positively correlated with scientific literacy ($p < .05$), and the more scientifically literate participants did value non-fiction books relatively more in learning new knowledge ($p < .01$). Furthermore, scientific literacy was hinted to have a significant negative correlation with digital games consumption, but due to confounding variables and low number of gamers reached, this result was considered inconclusive.

4.2 Analysis of the Qualitative Items: Media Consumption That May Support Scientific Literacy

Even though the null hypothesis of the study was supported – i.e., TV consumption correlating negatively with scientific literacy, while Internet and print media consumption not – there is of course variation between people from all kinds of media consumption backgrounds. For example, presumably it is not impossible for a person to develop their scientific literacy via television consumption, insofar as the specific contents they consume support it. Likewise, there are many kinds of contents one finds on the Internet, on many platforms, some of which undoubtedly better support scientific literacy than some others.

To find out what kind of more specific contents of consumption may best support scientific literacy, below I present the analysis of the two qualitative questions in the survey. In section 4.2.1, I conduct the initial general inductive analysis, comparing the answers of the people with top scores in scientific literacy to the answers provided by those in the bottom quartile, to see what subjectively best stands out. And in section 4.2.2, I present the results of the more careful quantified analysis of all the answers in the sample. This latter analysis was formulated based on the inductive analysis (see sect. 3.3.2). As a reminder, the first qualitative question concerned what kind of media contents one *likes to use*, and the second question concerned what kind of media contents one considers they *learn the most* amount of new knowledge from (see A3, sect. 2).

4.2.1 Inductive analysis of the answers by top scorers vs. bottom quartile in scientific literacy

In the final analysis, there were 11 participants who answered all 28 scientific literacy questions correctly. Each of them mentioned specific media contents in their qualitative answers. One of them was the only participant to mention *LibriVox* (est. 2005): a public domain audiobook website and community, where people can freely both produce readings of and listen to public domain audiobooks (in multiple languages, but vast majority of the content is in English). However, the participant (006), who was the only native English speaker in the sample, did not mention whether they tend to read and thus produce content for the site, or only listen to content others have produced. If they did produce content, it would seem likely that it both supports their high proficiency in English language (that positively correlates with scientific literacy) and them learning what they produce as teaching can be a highly educative activity. Of course, already listening to audiobooks can help in learning, and in developing and maintaining strong English skills that can help find information on the Internet.

Other notable media contents mentioned *only* by a top scorer were MOOC (Massive Open Online Course) platforms (016), specifically those of *Coursera* (est. 2012) and *Khan Academy* (est. 2006), while several people also from lower quartiles mentioned *TED Talks* (est. 2006). Four top scoring participants explicitly mentioned educational content on *YouTube* (est. 2005) (006, 016, 080, 082). *Wikipedia* (est. 2001) was also frequently mentioned (by eight of the eleven top scorers). Also, books, especially non-fiction, were mentioned often (five out of the eleven explicitly mentioned books, but in the quantitative section six of them reported non-fiction books as their primary source for learning new knowledge, while five reported the Internet). One top scorer was only one of four in the entire sample to mention podcasts, and the only one to mention podcasts in the second qualitative question (080). Another participant (015) who answered 27 questions correctly also mentioned some unique media contents for the sample, specifically science-oriented subreddits on *Reddit* (est. 2005), and MMORPG and strategy games “like Civilization IV” (that came out in 2005).

Judging by the unique media contents mentioned by some of the top scoring participants, it could be that the Internet provides unique affordances for supporting one’s scientific literacy via it providing many kinds of places – often *social* – for that purpose, insofar as one is proficient in media literacy and related English language (most of the mentioned contents were specifically in English). Relatedly, eight of the eleven top scorers reported their English proficiency as “outstanding”, two as “excellent”, and one was a native speaker. Moreover, all the top scorers had in minimum matriculation examination as their highest degree (likely being undergraduate students), with five having a higher university degree and one a lower. Age-wise, they were spread quite evenly between 22–49 (Mdn = 31; Mo = 31, M = 30.45), with six males, four females, and one no answer (/other).

Why and how people find these comparably unique online spaces that may support their scientific literacy could further be explained by their antecedent curiosity about (or interest in) scientific questions, combined with skills in media literacy and English proficiency. Insofar as one has sufficient media literacy and related English skills, *science curiosity* can lead one to explore and successfully find social spaces, from the plentiful affordances of the Internet, that can cyclically feed that curiosity via scientific information (see A1; Kahan, 2018; Kahan et al., 2017a; J. D. Miller et al., 2021a, p. 89; Takahashi & Tandoc, 2016, p. 11). The social spaces may then not only support science curiosity and scientific literacy, but also media literacy and English skills, and consequently facilitate finding even more science-related content one is or becomes curious of.

Of course, finding these kinds of social places on TV is not similarly possible due to the unidirectional nature of the medium, versus the collective multidirectional nature of the Internet. Still, with the right content, TV can feed curiosity as well, though not as socially. And it too was often mentioned by the top scorers, but not nearly as often as Internet content: while only one top scorer mentioned TV content in the more relevant second qualitative question (082, mentioning Finnish Broadcasting Company, YLE, documentaries), seven did mention them in the first question (e.g., TV series, movies, news) – whereas nine top scorers mentioned Internet content in the second question, and eight in the first (note that there was an inverse correlation between TV and Internet consumption, $p < .001$, and a negative correlation between TV consumption and scientific literacy, $p < .01$; see sect. 4.1.2–4.1.3). In other words, the top scorers tended to dismiss TV contents as something to learn new knowledge from, even though they did like to consume some comparably small amount of TV for more so casual entertainment or leisure purposes. At the same time, they embraced many notably social contents on the Internet for learning new knowledge, and for entertainment.

In contrast to the top scorers in scientific literacy – characterized by consistently high English proficiency, education, and quite Internet-focused media preferences – people in the bottom quartile were, on average, less agile in English, had lower education, and did not report consuming any unique media contents. Vocational education was clearly overrepresented in the bottom quartile, as was "average" or lower English proficiency. Of course, this is no surprise as there was a significant positive correlation found in the quantitative items between scientific literacy and level of education ($p < .001$), and scientific literacy and self-reported understanding of the English language ($p < .001$).

The media consumed in the bottom quartile were quite broad, also scientific documentaries and written non-fiction being often mentioned. Facebook, YouTube, Wikipedia, and/or online news pages were also mentioned by several participants in the bottom quartile. But what stood out was the lack of the *unique* social places on the Internet that were mentioned by some of the top scoring participants.

4.2.2 Quantified analysis of the qualitative questions: Usage of SLIPs

Finally, a more careful quantified analysis was performed to the two qualitative questions in the entire sample (see A3, sect. 2). With the described method, building on the inductive analysis (see sect. 3.3.2), it was revealed that scientific literacy had a significant positive correlation with the amount and uniqueness of *social learning-related Internet platforms, channels, and forums* (SLIPs) mentioned by the participants (see Table 9). Focusing on the most relevant second question, the overall graph is quite neat (see Figure 7), but the general picture described in the inductive analysis above can be emphasized by presenting the difference between the top scorers versus the bottom quartile (see Figure 8).

Correlations

		Scientific literacy	What kind of media contents do you like to use?	From what kind of media contents do you consider learning the most amount of new knowledge?	Sum of the qualitative questions
Scientific literacy	Pearson Correlation	1	.158	.343***	.299***
	Sig. (2-tailed)		.064	.000	.000
	N	138	138	138	138
What kind of media contents do you like to use?	Pearson Correlation	.158	1	.485***	.837***
	Sig. (2-tailed)	.064		.000	.000
	N	138	138	138	138
From what kind of media contents do you consider learning the most amount of new knowledge?	Pearson Correlation	.343***	.485***	1	.884***
	Sig. (2-tailed)	.000	.000		.000
	N	138	138	138	138
Sum of the qualitative questions	Pearson Correlation	.299***	.837***	.884***	1
	Sig. (2-tailed)	.000	.000	.000	
	N	138	138	138	138

***. Correlation is significant at the 0.001 level (2-tailed).

Table 9. Correlations between scientific literacy and SLIPs mentioned in the qualitative questions.

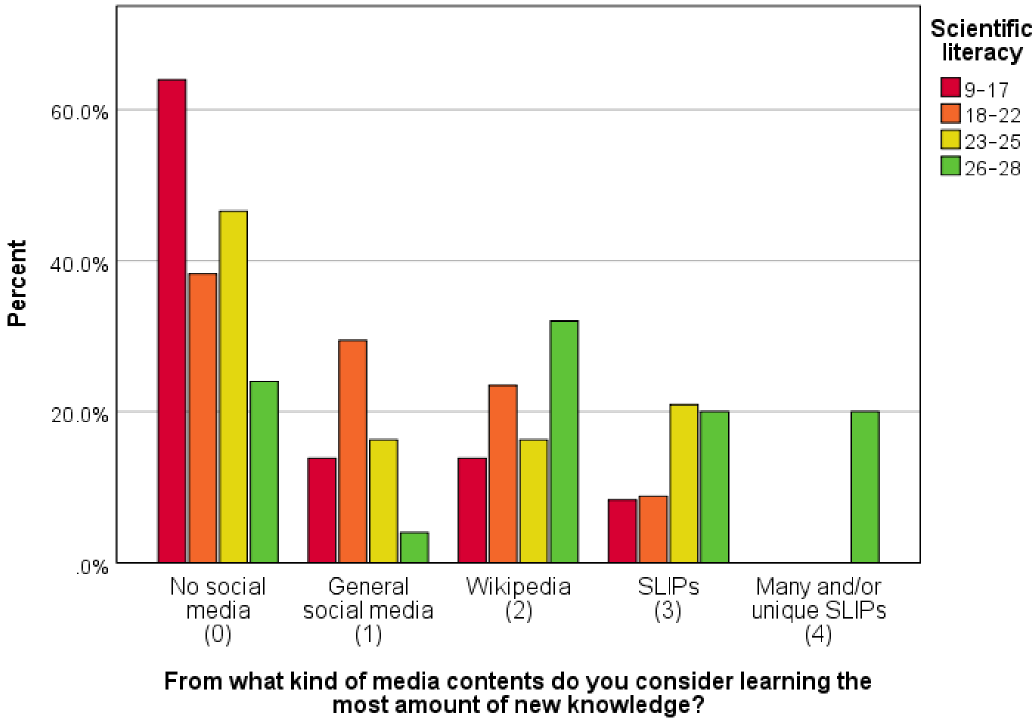

Figure 7. Relationship between scientific literacy and SLIPs mentioned in the second qualitative question.

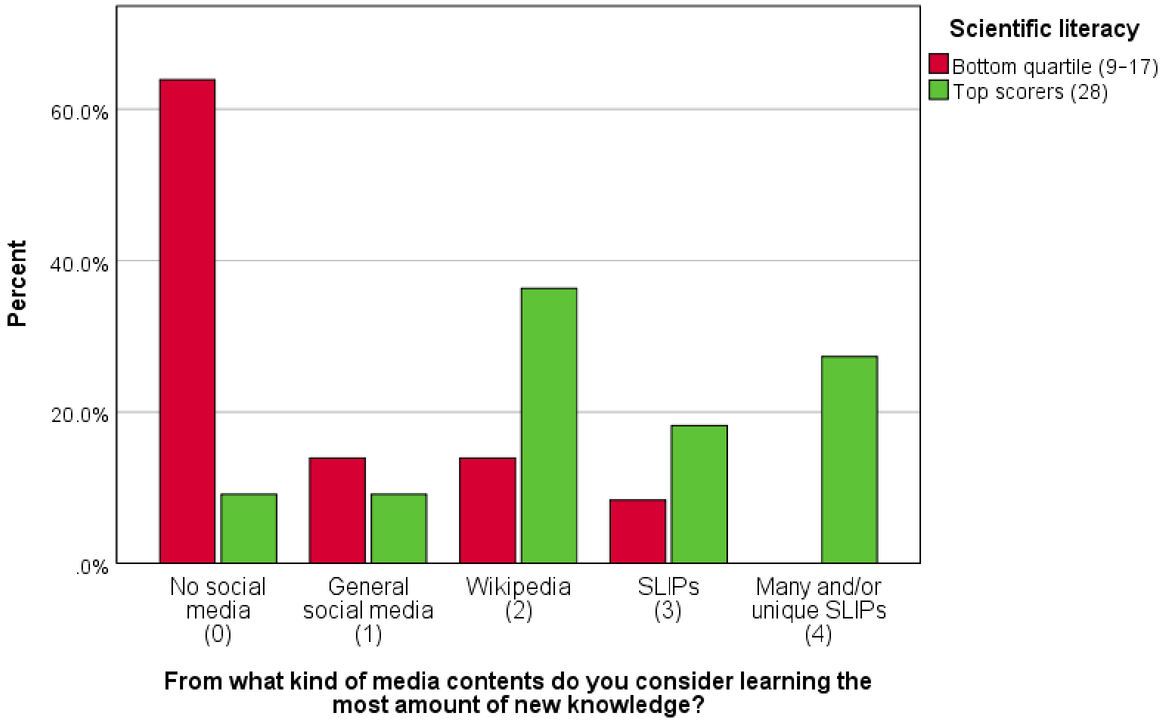

Figure 8. SLIPs mentioned in the second qualitative question by the bottom quartile versus top scorers in scientific literacy ($r(47) = .581$, $p < .001$).

As could be expected, the SLIPs mentioned in both qualitative questions individually, and their sum, positively correlated with reported overall Internet consumption in the quantitative questions (first question: $r = .260, p = .002$; second: $r = .319, p < .001$; sum: $r = .338, p < .001$), and they correlated negatively with reported overall TV consumption (first: $r = -.249, p = .003$; second: $r = -.264, p = .002$; sum: $r = -.298, p < .001$). Focusing more specifically on the second question, the SLIPs mentioned there further negatively correlated with radio consumption ($r = -.312, p < .001$) and newspaper consumption ($r = -.191, p = .025$), and positively with education ($r = .190, p = .025$) and English proficiency ($r(137) = .272, p = .001$). There was no significant correlation between education and the first question or sum, but only with the second question, while the others in the previous sentence also had significant correlations of the same direction with the first question and sum (first question: radio $r = -.175, p = .04$; newspaper $r = -.189, p = .026$; English $r = .205, p = .016$; and sum: radio $r = -.288, p = .001$; newspaper $r = -.220, p = .009$; English $r = .280, p = .001$).

Moreover, the SLIPs in neither question nor their sum significantly correlated with sex/gender, nor with reported Finnish or Swedish proficiency. Only the first question and sum correlated with age, negatively (first: $r(117) = -.248, p = .007$; sum: $r(117) = -.220, p < .017$); as *in the first question* older cohorts were more represented in the no social media (0) category, and as younger cohorts were more represented in the general social media (1) category and the only participant in category 4 SLIPs was of the youngest 20–24 age cohort, but otherwise categories 2 and 3 were rather even per age. Likewise, only the first question and sum correlated with communication items (first: $r = .197, p = .02$; sum: $r = .186, p < .029$), as in the first question the no social media (0) participants were overrepresented in the “never or rarely” use frequency category of communication items, and category 4 SLIPs participants were all in the “occasionally” category.

Religiosity in terms of view of God(s) significantly negatively correlated with the *second* qualitative question and sum (second: $r = -.196, p = .021$; sum: $r = -.168, p = .049$), but not with the first. This appeared to be largely due to atheists being very overrepresented in the category 3 and 4 SLIPs of the second qualitative question: atheists comprised 80 % of the participants in category 4 and 50 % of participants in category 3 SLIPs, with the one remaining category 4 participant being agnostic. However, controlling for education significantly moderated both correlations (respectively bringing them to non-significant negative levels of $r = -.162, p = .058$; and $r = -.144, p = .093$). The five participants in category 4 SLIPs of the second question (in Figure 7) were further characterized by 20–31 years of age ($Mdn = 24$, $Mo = 31$, $M = 25.60$); matriculation examination in minimum, two university degrees (one with lower and one with higher); three males, one female, one no answer (/other); and two with “outstanding”, two with “excellent”, and one with native English proficiency.

Noting that also many people from the second highest quartile of scientific literacy (with 23–25 correct answers) did not mention any social media contents in the second question – thus being the only standout section of the otherwise neat picture in Figure 7 – a brief targeted analysis was performed on them. As a result, it seems likely that many of them did not answer the question very specifically – i.e., only answering "Internet" instead of more specific contents – as in the quantitative question most of them still mentioned Internet as their primary source for learning new knowledge (out of the twenty targeted participants, eleven mentioned Internet and nine mentioned non-fiction books as their primary source; see also sect. 4.1.3, Figure 6). Also, eleven out of the twenty reported in their quantitative items that they read non-fiction "often" or "very often", even though not necessarily considering non-fiction books as their primary source for learning new knowledge. Only one of the twenty had vocational education as educational background, with everyone else having in minimum done matriculation examination; and in terms of age, nine were above 35, with seven being below 25 (one did not disclose their age; *Mdn* = 33, *Mo* = 44, *M* = 34.11). Fourteen of the twenty had "excellent" or better English proficiency. Thus, it seems that the group was situated where it was due to a combination of not giving very specific answers to the qualitative questions and tending to read a decent amount of non-fiction (that correlates with scientific literacy, $p < .05$). The same seems to apply to others in the no social media (0) category as well, though in the lower quartiles written non-fiction consumption is less prevalent ($p < .05$), and television consumption more prevalent ($p < .01$).

As people in the no social media (0) category may not have provided very specific answers to the qualitative questions, combined with the participants in category 4 SLIPs being relatively educated, it was considered that the prevalence of SLIPs among the highest quartile of scientific literacy might be explained, to some degree, by the more educated being prone to answer the qualitative questions more carefully. Thus, if correct, and the no social media (0) category had answered more carefully, the distribution could have been more even. However, it appears that this was not the case as controlling for education did not meaningfully affect the strength nor significance between scientific literacy and the second question nor sum (second question holding at $r(135) = .301$, $p < .001$; the sum holding at $r(135) = .272$, $p = .001$), nor did it affect the non-significance between scientific literacy and the first question. Thus, scientific literacy significantly positively correlated with usage of SLIPs in the second question – in learning new knowledge – when controlling for education ($p < .001$).

Further, as reported understanding of the English language positively correlated with both scientific literacy ($p < .001$) and the SLIPs in all the qualitative questions (first: $p < .05$; second and sum: $p < .01$), it was considered that English proficiency might moderate the correlation between scientific literacy and usage of SLIPs. However, controlling for English proficiency only minimally moderated the connection: there was no significant connection between scientific literacy and the first question in the first place, and the second question and sum were only minimally affected (second going from the $p < .001$ to $r(134) = .267$, $p = .002$; and the sum going from the $p < .01$ to $r(134) = .211$, $p = .014$). Thus, scientific literacy significantly positively correlated with usage of SLIPs in the second question – in learning new knowledge – when controlling for English proficiency, albeit it did minimally moderate the correlation ($p < .01$). Furthermore, controlling for both education & English proficiency yielded the same result.

Overall, it thus appears that scientific literacy significantly positively correlates with usage of SLIPs in learning new knowledge ($p < .001$), even when controlling for education and English proficiency ($p < .01$). Still, as education and English proficiency both positively correlated with scientific literacy (both $p < .001$) as well as with usage of SLIPs (education: $p < .05$; English: $p < .01$) – and education and English proficiency also correlated with each other ($p < .05$) – it appears they can mutually support scientific literacy, for example either indirectly via SLIPs or in some other manner. It may be that people who are more proficient in English can more easily find and use SLIPs (as many are in English), while the more educated may be more likely motivated to initially find them (in virtue of science curiosity that education may predict and/or cultivate; see A1; J. D. Miller, 2010b, p. 198; J. D. Miller et al., 2021a, p. 89; Takahashi & Tandoc, 2016, p. 11). Of course, in addition to the motivating science curiosity, education may also support scientific literacy itself ($p < .001$), English proficiency ($p < .05$), and – overlapping with each – media literacy, which can all support finding better SLIPs to further support scientific literacy.

4.3 Summary of Key Results

The null hypothesis of the study was supported: TV consumption had the most negative relationship with scientific literacy, and while general print media and Internet consumption did not significantly correlate with it, *certain type of* print media had a positive relationship, and *certain type of* Internet consumption had the most positive relationship with scientific literacy. No type of print media nor Internet consumption measured had a significantly negative relationship with scientific literacy, and no type of TV consumption measured had a positive relationship with scientific literacy.

More specifically, when comparing between quantitatively reported activity of using different general types of media, TV consumption had a significant negative correlation with scientific literacy ($p < .01$, moderated by self-reported understanding of the English language as a second language), while print media and Internet consumption had no significant correlation with scientific literacy. However – on the part of print media – significant positive correlations were found between scientific literacy and the more specific categories of written non-fiction consumption ($p < .05$), and valuing non-fiction books relatively more in learning new knowledge ($p < .01$). On the part of the Internet, significant positive correlations were found between scientific literacy and the more specific categories of 'organization of life via Internet' ($p < .01$, moderated by education), and mentions of social learning-related Internet platforms, channels, and forums (SLIPs) in the answers to the qualitative questions ($p < .001$).[50] Thus, Miller's general findings concerning media consumption and scientific literacy were supported (A1; J. D. Miller, 2010b, p. 198; 2010c, p. 55), even though no significant positive correlations were found between scientific literacy and general print media nor Internet consumption. Expanding on Miller's categories of media, scientific literacy was also hinted to negatively correlate with digital games consumption; but, until potential corroboration, this result is considered inconclusive as the survey reached only relatively few and homogenous gamers.

Furthermore, consistent with Miller's findings, TV and Internet consumption were inversely correlated: the more time a participant reported to consume one, the less they were likely to report consuming the other ($p < .001$). Especially older cohorts in the sample were more likely to report consuming more TV overall ($p < .001$), as compared to younger cohorts, though they did report consuming more knowledge/science items overall ($p < .01$), and news items overall ($p < .05$), and were more educated ($p < .001$). Also, females in the sample, as compared to males, when controlling for education, were more likely to report frequently consuming print media ($p < .001$), while males tended to prefer more sensory contents. However, the participants' sex/gender was not significantly correlated with their general consumption of neither TV nor the Internet. Neither age nor sex/gender correlated significantly with scientific literacy.

Analysis of the answers given to the qualitative questions revealed that among the participants with top scores in scientific literacy, there were [1] a noticeable number of mentions of *social learning-related Internet platforms, channels, and forums* (SLIPs), and, especially, [2] ones that were *unique* to the sample, while also [3] non-fiction books were often mentioned but [4] television was mentioned comparatively rarely, and especially for the purpose of learning new knowledge (as opposed for entertainment). The top scorers were further consistently characterized by high English proficiency and high education. The bottom quartile had the opposite characteristics to all of these.

[50] Notably, consumption of general knowledge/science items did not correlate with scientific literacy. Clearly, the contents classified as type "knowledge(/science)" in the analysis were not as exclusively science based as might have been ideal (see sect. 3.3.1n46; A3, sect. 2).

Quantitative analysis of the qualitative answers, via classification of the answers, confirmed there to be a significant positive correlation between scientific literacy and SLIPs mentioned ($p < .001$).

In terms of background information and scientific literacy, in line with previous research, a few notable results were found. Self-reported understanding of the English language as a second language positively correlated with scientific literacy ($p < .001$), as did education ($p < .001$), all the while there was a weaker correlation between education and English proficiency ($p < .05$). It was further found that religiosity correlated negatively with scientific literacy (both in terms of belonging to a religious community $p < .05$, and view of God(s) $p < .05$, with the latter moderated by education). It was also found that Internet consumption was negatively correlated with view of God(s) ($p < .05$), and quality of Internet connection was negatively correlated with both view of God(s) ($p < .001$) and belonging to a religious community ($p < .05$). Education moderated only the connection with Internet consumption, not with quality of Internet connection. Usage of SLIPs for learning new knowledge was also negatively correlated with view of God(s) ($p < .05$), moderated by education.

5 DISCUSSION

5.1 Findings of the Study

In this section, I discuss in more detail what emerged from the analysis. I highlight some of the most noteworthy findings, linking them to previous research, and illustrate how they help us in telling what kind of media consumption habits may best support scientific literacy.

5.1.1 Scientific literacy, education, and understanding of the English language

The results revealed a significant positive correlation between scientific literacy and both education and understanding of the English language as a second language (both $p < .001$). Education and English proficiency were also correlated with each other ($p < .05$), and their connection with scientific literacy remained after controlling for the other. The education finding was highly expected, as it is commonly reported that education tends to support scientific literacy (e.g., A1; J. D. Miller, 2010b, 2021b; Takahashi & Tandoc, 2016). However, even though the English language connection is also implied in prior research (Carrejo & Reinhartz, 2012; Martinez-Hernandez et al., 2015), it does not seem to have been previously well documented nor directly quantitatively reported.

It might be that strong English skills helps in searching and understanding of information on the Internet, and other media, and therefore supports scientific literacy. For example, the English Wikipedia is generally much more specific and up to date than Wikipedia of smaller languages, such as Finnish, and the educational culture on social media strives in English whereas it is much less prominent in small languages (e.g., on YouTube: Saurabh & Sairam, 2013; Stokel-Walker, 2019; see also sect. 5.2.5n55). English is, after all, the most spoken language worldwide, with ~1.35 billion native or second language speakers (Ethnologue, 2021). For instance, it is spoken by well over two hundred times more people than Finnish (~6 million speakers). Moreover, it is currently the universal language of science, and thus likely of the most comprehensive science news and discussions.

Of course, the correlation may also work the other way around, with people who are already highly scientifically literate tending to gravitate towards the more comprehensive scientific content in English, and thus their second language skills in English develops more. Or, they may have attended a third variable institution, which has fortified both their English skills and scientific literacy. Or, as prior research has suggested, science and English learning as a second language may work synergistically: as one increases, so does the other (Carrejo & Reinhartz, 2012).

As not all native English speakers are highly scientifically literate (obviously), it seems likely that scientific literacy is also supported, in part, by *media literacy* and *science curiosity* (or scientific curiosity or interest), which all three together with English proficiency can further be fostered by proper *education* (see, e.g., Bybee & McCrae, 2011; Chevrier et al., 2019; Fandakova & Gruber, 2021; Gruber & Fandakova, 2021; Kahan, 2018; Kahan et al., 2017a; J. D. Miller et al., 2021a–b; Takahashi & Tandoc, 2016; Vogl et al., 2020). Media literacy can support navigation skills online, and science curiosity can function as a motivator to navigate towards better science contents, thus both together supporting scientific literacy. At least in Finland, media literacy is often co-developed in contexts where English as a second language is learned (e.g., in Finnish general upper secondary education, *lukio*) – as opposed to merely contexts where English is learned as a native language (e.g., at a native home). Notably, EU has paid a lot of attention to media literacy (in Finnish: medialukutaito) in educational development in recent years, and this has been quite visible also in the Finnish national Core Curriculum for General Upper Secondary Education (European Commission, 2021; Opetushallitus, 2019). In any case, it also seems to be beneficial for scientific literacy to be better able to navigate the more plentiful and up-to-date science communication available in the English language, on the Internet and other media, as compared to merely being able to navigate the more limited science contents available in languages of smaller language areas.

Overall, the connection between English language and scientific literacy can be seen relevant for the objective of this study, in finding out what kind of habits of media consumption may support scientific literacy. According to the results, scientifically literate people tend to understand English material better and thus are likely to spend more time with English media sources, including more plentiful and up-to-date scientific sources. Also, higher level of education appears to encourage people to better keep up with science, even though education was only relatively weakly linked with English proficiency ($p < .05$; indicating that both education and English proficiency are not required to sufficiently keep up with science in Finland, although their combination is likely to help). Based on prior research and current educational planning in Finland, it seems that scientific literacy is also supported by media literacy and science curiosity, which may in part be co-developed in educational contexts where also English is learned (see European Commission, 2021; Opetushallitus, 2019; Takahashi & Tandoc, 2016). Of course, education also supports scientific literacy itself ($p < .001$) that can help better navigate information online. English proficiency further negatively correlated with TV consumption ($p < .001$), suggesting that other forms of media better support English proficiency (even in a country like Finland where subtitles, as opposed to dubbing, are the norm for all foreign language programs targeted for adults).

5.1.2 Scientific literacy and religiosity

In line with prior research (e.g., A1; J. D. Miller, 2010b, 2021b; Sherkat, 2011), scientific literacy was also found to negatively correlate with belonging to a church, religious community, or religious group ($p < .05$); and with the participants' view of God(s) ($p < .05$), with atheism being especially prominent in the top quartile of scientific literacy (see sect. 4.1.1, Figure 4). Education moderated the correlation with view of God(s), but not the correlation with belonging to a religious community.

One way of approaching an explanation for this might be through a third variable of *critical thinking*, which has even been suggested to be one part of scientific literacy itself (Fasce & Picó, 2019; Siarova et al., 2019, pp. 17–18). This may then manifest in two relevant ways. *Firstly*, a person well-adapted in critical thinking might be more likely well-adapted in scientific thinking as well, or better acquainted with current science, due to her being more skeptical of everyday claims, followed by a tendency to look up possible confirming or disconfirming sources for those claims. *Secondly*, a critical thinker is more likely to take a critical stance on religions, due to them making various epistemic, metaphysical, and normative claims that might appear flimsy and unwarrantedly dogmatic. Conversely, a person upholding an institution of organized religion may more likely be (socially) invested in ideas and beliefs, which are dogmatically taken to be true while them also going against some scientific evidence (or lack thereof). A clear example of this is the creationism versus evolution debate in the US (see, e.g., Berkman & Plutzer, 2011; Ruse, 2013; Shermer, 2013; see also J. D. Miller et al., 2021b; Weisberg et al., 2018). Relatedly, a religious person may be more inclined to think she has all the answers already, as a holy book, like the Bible or Quran, may be viewed as an inerrant message from either God(s) or prophets, and thus she does not need to look for answers any further – whereas the critical thinker does not think she necessarily has the answers, and is thus inclined to keep searching for evidence, which often means keeping up with the latest science (that remains fallible; see sect. 2.1.1).

Sherkat (2011, p. 1146) has further hypothesized that the connection between scientific literacy and religiosity might be explained by limited scientific offerings in Catholic colleges and high schools, and other faith schools. However, since Finland does not have colleges nor high schools upheld by religious institutions, the religious communities people report belonging to in the present survey likely refer to settings outside of formal education. Thus, a more universal explanation, in line with Sherkat's other suggestion, appears to be that religious communities – in whatever form – are more likely to de-emphasize scientific knowledge, potentially due to conflicting epistemologies (and/or metaphysics; see also Corriveau et al., 2014; Miller et al., 2021b; Rutjens et al., 2018). At the same time, atheists and agnostics tend to know more about religions than most religious people, at least in the US (Pew Research Center, 2019b).

Religious communities may also more likely de-emphasize Internet usage, as indicated by the further negative correlations between quality of Internet connection and the participants' view of God(s) ($p < .001$) as well as belonging to a church or religious community ($p < .05$). View of God(s) was also negatively correlated with Internet consumption ($p < .05$) and mentions of SLIPs ($p < .05$), both moderated by education. This too is compatible with prior research: more frequent Internet use, or more frequent access to broad networks of heterogenous communities through the Internet, may be pushing people away from traditional religions and religious beliefs, perhaps resulting in more encouraged caution towards Internet connection and/or use in such communities, or among religious individuals (Downey, 2014; McClure, 2016, 2020; see also Pew Research Center, 2019d). A recent longitudinal survey gives further reason to think this potential caution might not be misguided: the percentage of US adults belonging to a church in 2020 had dropped more than 20 percentage points from the turn of the century – going from an average of 69 % to 47 % – and this is primarily due to rise in Americans with no religious preference (Gallup, 2021). A similar decline has happened in Finland, with the percentage of people belonging to the national Evangelical Lutheran Church dropping from around 85 % in 2000 to 68 % in 2020, largely due to rise in the number of unaffiliated Finns (Statistics Finland, 2021b).[51] Of course, during this time, Internet use has massively grown, along with the emergence and risen use of smartphones and social media (sect. 2.2.5). At the same time, television consumption (here including Netflix and streaming services), which is not similarly social activity, does not appear to have this association with declining religiosity (McClure, 2020).

Overall, these findings concerning the negative connection of scientific literacy with religiosity are not the primary focus of this study, but they are still interesting and noteworthy, supporting the sufficient robustness of the sample as they are in line with prior research. Being aware of this may also be fruitful in planning efforts of targeted science communication, especially when noting that the religious, on average, appear to practice more caution towards the Internet. Consequently, they would be less likely to find and/or regularly follow the curious, scientifically skeptical epistemic communities and other SLIPs found online.

[51] There are notable differences between the US and Finnish statistics, making them not directly comparable. The Finnish statistics include many newborns and children growing up, as they are recorded in the Digital and Population Data Services Agency's *Population Information System* with the religious denomination their parents report at the same time as they report the child's name (Statistics Finland, 2021a, pp. 10–11). In the current system, it is only once the child turns 18 when they can change the status without official consent from their parents (or other legal guardians). The US data, on the other hand, is based on a nationwide random sample phone survey of adults (Gallup, 2021).

5.1.3 The benefits of SLIPs: Different affordances of television versus Internet

The main finding of the study was support for Miller's findings: overall television consumption negatively correlated with scientific literacy ($p < .01$), while print media and Internet consumption did not. However, specific type of Internet consumption was found to be particularly predictive of scientific literacy. Despite the challenge of vagueness of many of the answers given to the qualitative questions (see sect. 5.2.5), the analysis indicated that people with higher scientific literacy are more likely to use more and/or more unique *social learning-related Internet platforms, channels, and forums* (SLIPs). This initially inductive observation was confirmed by a quantitative analysis of the qualitative questions, via classification of the answers revealing a significant positive correlation between scientific literacy and SLIPs mentioned ($p < .001$). Especially participants with top scores in scientific literacy were likely to mention high quality unique SLIPs for the sample or report using more SLIPs. The top scorers were also characterized by consistently high English proficiency, education (in minimum matriculation examination), and quite Internet-focused and television-dismissive media preferences in learning new knowledge, with non-fiction books being also mentioned quite often. The bottom quartile had the opposite characteristics.

These observations raise the question of what differences are there between television and Internet, particularly SLIPs, that may explain why television consumption seems to hinder scientific literacy while SLIPs seem to support it. Some initial suggestions were presented already in the inductive analysis of the answers given to the qualitative questions (sect. 4.2.1), but generally the differences may be classified into those concerning [a] the amount, variety, and accessibility of content, and [b] sociality; that both result in different affordances for supporting and inducing science curiosity and related exploration, as well as other positive epistemic emotions (e.g., surprise).

5.1.3.1 Amount, variety, and accessibility of content

As the people in the top quartile of scientific literacy were prone to use SLIPs while having consistently high English proficiency and education, in the inductive analysis (sect. 4.2.1) it was deduced to be likely that Internet provides unique affordances for supporting scientific literacy via providing constant access to many kinds of social platforms, channels, and forums for that purpose, *insofar* as one is sufficiently proficient in *media literacy* and *English language* to find those affordances. Moreover, it was reasoned that *science curiosity* may motivate one to search and find the learning-related spaces on the Internet, consequently cyclically feeding that curiosity and English skills to be able to find even more content to spark science curiosity and support scientific literacy (see also Takahashi & Tandoc, 2016). Media literacy, English language proficiency, and science curiosity may all be supported by *education*, while it also supporting scientific literacy itself. Television, of course, cannot provide similar constantly available and voluntarily navigable amount and variety of high-quality content (given that one is able to find them online): unlike content on the Internet with multitude of platforms and choices at any one time, the content on TV is controlled by a relatively few broadcasting companies with set programming schedules (see also sect. 2.2.5.1).

Thus, it may be that the comparably negative relationship between TV consumption and scientific literacy is chiefly explained by the medium not providing as much (or as high quality) content as the vastness of the Internet where users can more voluntarily, speedily, and conveniently themselves choose what and when to consume, so long as they have sufficient media literacy and English language proficiency (and corresponding navigation skills online). Consequently, the causality may cyclically work both ways: as compared to TV, people already curious about science may more actively search for content to feed their curiosity on the Internet, and people who can well navigate Internet (via proficiency in English and media literacy) may more likely bump into content – particularly SLIPs – that spark their science curiosity (and other positive epistemic emotions). This interpretation is in line with prior research (J. D. Miller et al., 2021a; Takahashi & Tandoc, 2016).

To add, it has been suggested that general distrust of traditional media (also incl. newspapers) and less favorable perception of scientists, that have been found to be more common among those who are scientifically curious and/or literate, may play a part in them more likely turning away from traditional media as a source for science information. Specifically, as traditional media does not regularly report on science news (e.g., Baker et al., 2012), those interested in science go to Internet for information, and this process can in turn lead to lower confidence in the mainstream press and a less favorable perception of scientists, which criticality can finally lead to higher knowledge about science via the variety of information on the Internet. Though not mentioned in prior research, media literacy and English proficiency – that facilitate epistemically skillful navigation online (e.g., in finding proper sources) – seem likely to play a part here as well. Conversely, those who trust the press and the few scientists quoted or simplified there, may use that trust as a heuristic to believe the information – thus, skipping deeper information processing that the scientifically curious develop via their habits of exploring the Internet. For example, traditional media may have the tendency to sensationalize singular scientific articles, which may give a misleading representation of science, whereas those embedded in proper SLIPs more likely realize that what matters more is the state of the overall body of scientific evidence and the gradual process of science. (Takahashi & Tandoc, 2016; see also Brewer & Ley, 2013; Kahan, 2018; Kahan et al., 2017a; further, see Novella, 2021.)

5.1.3.2 Affordances for social learning

It may further be that there are important differences between the two media themselves – not only between the amount, variety, and accessibility of content within – that explain their different relationship with scientific literacy, to some degree. Specifically, it may be that the gatekeeping unidirectional nature of the medium of television, as compared with the actively multidirectional *social* network of the Internet, hinders active thinking, deliberation, and exploration, thus hindering developing critical understanding of scientific topics. Conversely, the interactive, time-independent, and socially exploratory nature of the Internet – and particularly of SLIPs – may provide more organic affordances for *interleaving*, *spacing* and socially supported *scaffolding* that can facilitate learning[52], as well as for *positive epistemic emotions* like curiosity and surprise (Chevrier et al., 2019; Fandakova & Gruber, 2021; Gruber & Fandakova, 2021; Vogl et al., 2020; see also sect. 2.1.4n22, 5.2.5n55).

As hinted by the unique SLIPs mentioned by the most scientifically literate participants (sect. 4.2), there is a distinct quality of *sociality* within a community with mutual interest in science that is unique to the science channels on the Internet, as compared to even the best of science content on television. These *epistemic communities* (or *learning networks*) can then support scientific literacy of all members (even conversationally passive ones), via mutually shared links, conversations, and likes, for example, organically inducing positive epistemic emotions along with opportunities for interleaved and spaced learning as well as social scaffolding. Notably, in well-controlled studies, medium itself does not seem to determine learning outcomes so long as the content is otherwise equivalent (Clark, 1994; Muller, 2008, sect. 1.2.2, 1.3). But, unlike television, the Internet may provide more plentiful and fruitfully *social* affordances for those who can find them, effectively providing the ability to partake in communities and networks where educative peer interaction and sharing of scientific curiosity-inducing multimodal content can regularly take place (Muller, 2008,

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[52] *Interleaving* refers to a learning process whereby the learner mixes – i.e., interleaves – multiple subjects or topics to improve learning via not forcibly focusing on any one topic for too long continuously. This is opposite to blocked learning, wherein one topic is focused on thoroughly before moving onto another. In studies it has been found that interleaving may benefit learning as it can facilitate one to form more creative and diverse connections between the various learned materials that are then better retained (e.g., Brunmair & Richter, 2019; Taylor & Rohrer, 2009; Yan & Sana, 2021).

Spacing refers to a learning process whereby the learner spaces out the time used for learning and retrieval on a long period timeframe. That is, everything is not chunked into memory and retrieved in a short time frame when spacing, but rather the learning happens in smaller chunks spaced throughout a longer period. The material that is being learned is then come back to in regular longer intervals. This has been found to benefit learning as the learned material is then able to better consolidate into long-term memory and form creative connections with other learned ideas and concepts (e.g., Carpenter et al., 2012; Latimier et al., 2020).

Scaffolding refers to breaking up learning into smaller chunks that, in a sense, form an organic ladder of simple steps that are climbed to learn a complex idea. This is often done in interaction with a teacher, instructor, or a social learning community that breaks down the material in a way conducive to scaffolding. Often, scaffolding a topic builds on prior knowledge, and encouraging repetition is utilized as needed. (e.g., Jumaat & Tasir, 2014; Mamun et al., 2020.)

sect. 7.3 & pp. 211–212). This would be well in line with the finding that those with higher scientific literacy are more likely to report learning most amount of new knowledge from SLIPs.

However, this last suggestion remains a bit more provisional, due to the deficiencies in the qualitative data in the sample. There are also most definitely some hindering affordances in contemporary social media that should be noted, like its potential to decrease our attention spans (cf. Lorenz-Spreen et al., 2019), biased information processing in echo chambers (cf. Bright et al., 2020; Nguyen, 2018, 2020b), and mis-/disinformation (cf. G. Miller, 2021); that all need to be prevented, filtered out, or otherwise dealt with for a truth-valuing epistemic community to be optimally effective (see also Kangassalo, 2019, sect. 1.1–1.2; 2021a–b; sect. 2.2.5, 5.2.3, 5.2.4.4). In the end, it might just be a matter of managing to find the hidden gems – i.e., to distinguish the right kind of communities or networks (SLIPs) from the overall noise – where, again, media literacy, English proficiency, and motivating factors like science curiosity can all help.

5.1.3.3 Summary and the importance of promoting SLIPs

Overall, the negative relationship between TV consumption and scientific literacy, and the positive relationship between certain kind of Internet consumption and scientific literacy, may be explained by a combination of the following overlapping factors: differences between TV and Internet in [1] the amount, variety, and accessibility of content on offer; [2] social affordances, e.g. in the ability to partake in epistemic communities of shared learning on the Internet but not on television; and, relating to both, [3] affordances for supporting and inducing science curiosity (and other positive epistemic emotions). Further, media literacy and English proficiency, and often related education, seem important in properly finding and navigating these affordances (e.g., in finding SLIPs). Moreover, it might be that once proper Internet consumption habits have been formed, they can in turn lower trust in traditional press on science-related topics via the press presenting science in a very confined format as compared to what is on offer online (Takahashi & Tandoc, 2016), especially on the best SLIPs.

Even though science curiosity – combined with sufficient English proficiency and media literacy skills – may drive people to find platforms and virtual communities to learn about science, it is likely that many people who could be interested in science are not aware of these kinds of sites and communities. Hence, their curiosity may not have been as sparked as it could otherwise have been, hindering scientific literacy. Thus, promoting awareness of the right kinds of platforms, contents and communities may be beneficial in both promoting interest in science, and in helping those already interested in science to form media consumption environments and habits for themselves that best support scientific literacy. At the same time, science educators should, of course, continue to go where people are: to television, for creating more affordances for science curiosity there (though, this is contingent on producers and executives); and, more easily, to social media, where they can utilize and facilitate the affordances for social learning (Saurabh & Sairam, 2013; Stokel-Walker, 2019; see also sect. 5.2.5n55). (see also the *epistemic bystander effect* that these measures can counteract: Kangassalo, 2019, sect. 6.4.2.1, 6.4.2.1n163, n165.)

In addition to steering people to find contents and communities like the ones on SLIPs, within those contents and communities it seems useful to explicitly focus on motivational influences. And not only by trying to increase people's intrinsic incentives (e.g., by aiming to spark science curiosity), but also by creating better structures for extrinsic incentives (e.g., material, or social incentives, like educational conventions and rewards). These would encourage participation in the social learning-related epistemic communities online. See, for example, how *delta* characters (Δ) are used on the Reddit board *Change My View* to reward effective communication (Basu, 2020; C. Tan et al., 2016). The *open science movement* would be beneficial here as well, as making scientific data and papers accessible to all may increase trust in science and incentives to investigate it (Pew Research Center, 2020a, item 8), which could also support science curiosity and literacy, not least on SLIPs. Similarly, promotion of *citizen science projects* could be beneficial, as they can help the public become familiar with science via concrete participation (López-Iñesta et al., 2021; Queiruga-Dios et al., 2020). (ibid.)

5.2 Limitations of the Study and Guidelines for Future Research

The limitations in this study can be divided into five categories: limitations related to (1) sample and conducting the survey, (2) language proficiency of participants, (3) developments since 2014, (4) the quantitative part of the survey, and (5) the qualitative part of the survey. Below, I go through limitations in each of these categories and suggest related guidelines for potential future research.

5.2.1 Sample and conducting the survey

The sample size of the survey was relatively low (n = 138), even though it was robust enough to fit with a lot of prior research. In part, this was due to the survey being conducted in a live paper format that is comparatively demanding to gather and analyze – as compared to online survey – though it can better reach people from varying media consumption habits outside of the Internet and prevent cheating in the scientific literacy items. For the same reason, the sample was also not as diverse in, for example, educational background as would be ideal, and not representative of the general Finnish population. The study prioritized reaching people from various media consumption backgrounds yet is still relying on a relative convenience sample. Future studies, with actual funding, should perhaps consider phone survey as a method, which could be made representative of a larger population with varied media consumption backgrounds (see Daikeler et al., 2020; Woo et al., 2015).

5.2.2 Language proficiency of participants

From the original sample of 139, one answer was excluded due to them reporting their language skills in the Finnish language, that they used to fill out the survey, as "below average" (see sect. 3.2n42). The final sample of 138 still included 15 non-native Finnish speaking participants who reported as their Finnish proficiency "good" or better. Specifically, of the included non-native Finnish speakers, four reported their understanding of the Finnish language as "good", six as "excellent", and five as "outstanding". The forms were also available in English, but majority of these participants had lower English understanding still, and thus filled out the survey in Finnish. The only exception was one native English speaker whose Finnish was "outstanding", and who also used the Finnish form.

Considering that lower language skills may decrease data quality (Wenz et al., 2021), it might be that including non-native speakers in a sample – at all – could distort some of the results. Even though it did seem that the 15 with "good" or better Finnish proficiency provided answers that were understanding, this cannot be fully confirmed for each participant and question.

To ease these concerns, an analysis of the main results of the study was additionally performed to the sample after all non-native Finnish speakers were excluded. This resulting sample of 123 yielded the following results: Scientific literacy still significantly correlated with education ($r = .366$, $p < .001$); understanding of the English language ($r(122) = .321, p < .001$), but no longer with Swedish language (nor Finnish, of course); and religiosity (on the part of belonging to a religious community, $r = -.181, p = .045$; while on the part of view of God(s) there was no longer a significant correlation, $r = -.132, p = .146$). Scientific literacy also still negatively correlated with TV consumption ($r = -.262, p = .003$), while not significantly correlating with neither general Internet nor print media consumption. Likewise, written non-fiction consumption still positively correlated with scientific literacy ($r = .179, p = .047$), as did organization of life via Internet ($r = .242, p = .007$) and relative preference of non-fiction books in learning new knowledge ($r = .239, p = .008$). Finally, the more scientifically literate were also still more likely to report learning most amount of new knowledge via SLIPs ($r = .324, p < .001$). No new significant correlations emerged.

Thus, except for the relationship between scientific literacy and view of God(s), inclusion of non-native Finnish speakers who had "good" or better Finnish proficiency did not significantly affect the main results of the study. The key findings remained after excluding all non-native Finnish speakers from the sample. That said, future studies should be aware of potential language effects in multilingual samples, and appropriately control for language skills (Wenz et al., 2021).

5.2.3 Developments since 2014: Potential change in the average effects of Internet use

The survey was conducted during the year 2014. Thus, in 2021, some developments may have already happened that might encourage further studies to examine whether there are any possible ongoing trends. For example, since 2014, political and affective polarization or 'political sectarianism' among many English-understanding Western nations seems to have increased (e.g., Boxell et al., 2020; Harteveld, 2021; Iyengar & Krupenkin, 2018; Norris & Inglehart, 2019; Pew Research Center, 2017c; Reiljan, 2019; see also Finkel et al., 2020; Urman, 2020). And this appears to have been facilitated by related negative phenomena on the Internet gathering momentum, like intergroup moral outrage, questionable design choices, and false news in circulation (Brady et al., 2020, 2021; Carpenter et al., 2021; Iyengar & Massey, 2019; Van Bavel et al., 2021; Vosoughi et al., 2018). (see also sect. 2.2.5.)

If the average affordances of the Internet (vs. television) for scientific literacy are connected to these kinds of social phenomena, or some other changes since 2014, the correlations might change or disappear in time. For example, insofar as widespread partisan thinking raises people's epistemic biases (e.g., confirmation bias, negativity bias, and myside bias) and formulation of corresponding echo chambers and epistemic bubbles online (Bright et al., 2020; Cinelli et al., 2021; Nguyen, 2018, 2020b; Stanovich, 2020, 2021), it might have a negative effect for the relationship between Internet use and scientific literacy, even in some specific kinds of SLIPs that may become epistemically misguided (see Frimer et al., 2017; Washburn & Skitka, 2018). Or many people may be put off by the atmosphere on the most popular social media platforms altogether, potentially driving them to form alternative media consumption habits, with various potential effects to scientific literacy; of theirs and those who remain (see Allcott et al., 2020; Bright, 2018; Garimella et al., 2018; Hawkins et al., 2018; for how a loud minority already rules social media, see also Bor & Petersen, 2021; Cohn & Quealy, 2019; DataReportal, 2021; Kim et al., 2021; Pew Research Center, 2019a). (ibid.; see also Kangassalo, 2019, sect. 1.1–1.2; 2021a–b; further, see the *Early Adopter Hypothesis*: sect. 5.2.4.4.)

More broadly speaking, since 2014, we seem to have moved into a time of a widely acknowledged *epistemological crisis*. There is talk of a "post-truth" era (e.g., Barzilai & Chinn, 2020;

Stanovich, 2020, 2021), where mis-/disinformation, or “fake news”, can rapidly spread online (Vosoughi et al., 2018); pseudoscience and other epistemically unwarranted beliefs get visibly promoted (Lewandowsky et al., 2017); public trust in scientific institutions, albeit generally relatively high, is among some groups trembling (Gauchat, 2012; Pew Research Center, 2017a, 2019c); political and affective polarization are dividing people online (Brady et al., 2020, 2021; Brady & Van Bavel, 2021; Carpenter et al., 2021; Iyengar & Krupenkin, 2018; Pereira et al., 2021; Rathje et al., 2021; Van Bavel et al., 2021); and legitimate epistemic authorities can get bypassed by anecdotal personal experiences and assertions of relativity of all knowledge and evidence (see, e.g., Hansson, 2020; Lewandowsky, 2021; Pluckrose & Lindsay, 2020; Stanovich, 2020, 2021; Wikforss, 2020; Williams, 2017). All these phenomena may produce various and potentially detrimental effects to the epistemic communities online, insofar as they integrate more widely into the structures and contents of contemporary social media. (ibid.; see also Pew Research Center, 2021b; sect. 2.2.3n31.)

Amongst these phenomena, it appears that there are some thresholds to the amount Internet is used, or some specific manners of usage, that can make it a negative influence, which future research should continue to investigate. There are indications of this in the research literature on *Problematic Internet Use* (PIU).[53] For example, increased Internet use – especially of synchronous communication – has been found to reduce study skills in university students (Kubey et al., 2001; Malik et al., 2020; Truzoli et al., 2020). Also, outside of epistemic concerns, it appears that low and excessive social media use is weakly related to decreased well-being while moderate use is related to increased well-being, potentially mediated by differences in user psychology, family background, purpose of use, manner of use, and/or use environment (see, e.g., Appel et al., 2020; Beyens et al., 2021; Dienlin & Johannes, 2020; Meier & Reinecke, 2020; Orben, 2020; Tóth-Király et al., 2021; see also Haidt & Twenge, 2021; Kross et al., 2021).

It might be that the skill in organizing life via the Internet to some degree counteracts PIU, as good organization skills may help in self-regulation towards better contents and consumption habits (noting that in the present study organization of life via Internet was positively correlated with scientific literacy, $p < .01$). It might also be that these organization skills are connected to the Big Five personality trait conscientiousness, that has been found to correlate with PIU. Specifically, conscientiousness has been found to have a direct negative correlation with PIU; while emotional instability (i.e., neuroticism) has been found to have a positive correlation with PIU, potentially

[53] *Problematic Internet Use* (PIU) generally refers to an inability to regulate one’s use of the Internet which leads to negative consequences in daily life, for example creating psychological, social, school, and/or work difficulties. It has also been variously termed as Internet addiction, pathological Internet use, and Internet dependence. (Spada, 2014.)

mediated via depression and obsessive-compulsive symptoms, or overall psychological distress (Dalton & Cassidy, 2020; Koronczai et al., 2019; Przepiorka et al., 2020; Tóth-Király et al., 2021). Currently, results concerning the other Big Five traits (i.e., agreeableness, extraversion, and openness) seem partly mixed: having either no or negative correlation with PIU (Koronczai et al., 2019; cf. Dalton & Cassidy, 2020; Kayiş et al., 2016; Przepiorka et al., 2020). Moreover, for example, loneliness (Dalton & Cassidy, 2020; Tóth-Király et al., 2021), paternal neglect and maternal care (Tóth-Király et al., 2021), evening chronotype (Przepiorka et al., 2020), and being male (Su et al., 2019; Tóth-Király et al., 2021) have been found to predict PIU in various samples. Of course, these may further be connected to various related social and cultural conditions.

All in all, much more research would be needed to examine how contemporary phenomena on the Internet, and variety in Internet use and users, may more precisely relate to scientific literacy and well-being, and if there might be some ongoing trends. Much of the research is in its infancy, albeit the role of social media in human interaction has started to gather wide recognition in recent years (see, e.g., Bak-Coleman et al., 2021; Brady et al., 2020, 2021; Haidt & Twenge, 2021; Kross et al., 2021; see also Kangassalo, 2019, 2021a–b). Suffice it to say that finding the right kinds of epistemic communities on the Internet, that support scientific literacy and well-being, is not a straightforward task – and, since 2014, the difficultness of that task may have increased (see also sect. 2.2.5, 5.2.4.4).

5.2.4 The quantitative part of the survey, and Early Adopter Hypothesis

5.2.4.1 Measuring media consumption habits

The limitations concerning the quantitative part of the survey are notable especially in the media consumption habits -section (A3, sect. 2), as the section was specifically formulated as a prototype for the study. The main question is how reliable and valid the questions and their formulations are.

In terms of reliability, test-retest reliability was not tested. However, many of the items were based on a regularly utilized prior survey – the triennial Finnish Science barometer – that seems to have produced reliable measurements (Kiljunen, 2019; Tieteen tiedotus, 2019). Still, self-report measures of media use can be questioned both in terms of reliability of measurement per participant at different times (i.e., do the participants give relatively similar answers between sessions), and reliability between participants (i.e., do the participants give answers that are comparable to each other). Considering that the results did fit with a lot of prior research concerning media consumption and its relationship with both background information and scientific literacy (sect. 4.3), it does seem that the media consumption items produced reasonably reliable and robust results, even with the relatively small sample size. In this regard, the reliability garners more support, as the survey was not solely examining people's media consumption habits but comparing them to other well-established items (in background information and scientific literacy) that have previously documented correlations with specific media consumption habits. Of course, as the media section was a prototype, replications – with tweaks and bigger samples – should be encouraged to further test its reliability.

In terms of validity, the media section of the survey was planned to measure the (self-reported) frequency of various media consumption habits for various purposes. At face value it seems that the items are valid for the purpose (indicating high *face validity*), especially as no participant feedback indicated that the questions would have been unclear in some manner. Still, to hone *content validity*, it could be considered whether some questions should be divided more, and if some further questions should be added, and perhaps some eliminated (see below). A confident statement on *construct validity* would theoretically require direct observation and measurement of people's media consumption habits, but insofar as this remains practically impossible, the media section seems sufficiently valid as all the answers were gathered in 2014, with similarly instructed groups, with the same instruments, no interaction between the participants, and without connection to the Internet. To test for *criterion validity*, comparisons to other similar more established questionnaires could be made in the future (giving both tests to a group). In terms of *external validity* – i.e., generalizability – the sample is of course not ideal, but does fit with a lot of prior research, and is in this study intended to make relative not absolute measures (to test for the null hypothesis based on Miller's studies), which factors give more external confidence in the findings. Due to the correlational nature of the study, no strong causal inferences could be drawn, albeit a cyclical relationship between high scientific literacy and best consumption habits was theorized.

That said, there was one notable discrepancy in the answers in terms of *convergent validity*: the singular 5-point Likert scale question about frequency of TV use (A3, sect. 2, item 1) did not significantly correlate with scientific literacy, but only the overall sum of all TV consumption did (see sect. 3.3.1n45). The relationship with the singular question was still negative, however, just not statistically significant ($r = -.126$, $p = .141$). Yet, this discrepancy does not seem very meaningful, as more instruments measuring a construct seem likely to be more valid than only one instrument measuring the same construct. That is, many questions measuring different aspects of self-reported frequency in TV use seem likely to produce more discernable and valid overall picture than a single 5-point Likert scale question. In another aspect, convergent validity was clearly supported: as should be expected, the SLIPs reported in the qualitative answers negatively correlated with quantitatively reported overall TV consumption ($p < .001$) and positively with Internet consumption ($p < .001$).

In future studies, it would be prudent to also measure podcast consumption for various purposes, with their user profile being potentially rather unique due to the relatively long attention span required to listen to them – all the while attention spans in general seem to have shortened (see Lorenz-Spreen et al., 2019; see also Bratcher, 2020; MacKenzie, 2019; Samuel-Azran et al., 2019). Likewise, virtual reality (VR) device use for different purposes could be added, which was not yet considered in 2014 as VR started to become available only around 2015 (and is still quite niche). Also, separate more specific studies should be encouraged to investigate specific habits of media consumption within specific social media platforms (e.g., Facebook, Twitter, YouTube, etc.) or within different SLIPs, rather than focusing only on the still relatively general categories. Characteristics of different epistemic communities, like their group size, content modalities, membership criteria, moderating styles, and fit with user personality might also be factors to investigate.

In the future, specific newspapers could also be distinguished, though this could be challenging insofar as people tend to use diverse online newspapers from around the world. Non-fiction books, science magazines, and scientific journals should perhaps also be distinguished, as opposed to including them all under the same category as was done here (A3, sect. 2, item 16; cf. Tieteen tiedotus, 2019, pp. 12–13). Similarly, news, documentaries, and science programs on TV could be distinguished (A3, sect. 2, item 3), especially as the aggregate question used in this study correlated negatively with scientific literacy in the sample ($r(138) = -.175$; $p = .037$) while some prior studies have linked TV science program consumption to retaining of corresponding scientific knowledge (J. D. Miller et al., 2006; Nisbet et al., 2002). Finally, studies that reach a larger number of diverse people who play digital games would be needed to properly test the hinted but inconclusive negative connection between general digital games consumption and scientific literacy (see sect. 4.1.3).

5.2.4.2 Background information

Regarding background information, in hindsight it would have been prudent if a measure of self-reported political affiliation had been added (cf. A3, sect. 1). Especially considering the seemingly increased polarization on social media since 2014, it would have been useful to have some data on potential differences of scientific literacy between different affiliations. Recent research in the US suggest that partisan differences in scientific literacy are topic specific, guided by politically motivated reasoning and selective exposure, but counteracted by science curiosity (see Frimer et al., 2017; Kahan et al., 2017a; Washburn & Skitka, 2018; see also Kahan, 2018). There are also considerable differences between liberals and conservatives in the US in media trust and loyalty (Pew Research Center, 2014, 2018). (see also Kangassalo, 2019, sect. 1.2n20; sect. 2.2.5.2, 5.2.3.)

Furthermore, the specific number of college/university courses studied could have been asked and controlled for when examining education background (cf. Miller, 2004). For future studies, there might also be interesting data to be gathered on differences between university majors, which could be useful in spotting areas in need of development in different education programs, so that they could better support scientific literacy and multidisciplinarity. For example, though not hypothesized in this study, the data did show a difference in average scientific literacy between students on a basic course on psychology versus students on an advanced course on pedagogy, with the *latter* having lower scientific literacy but without statistical power (the psychology students' scientific literacy (n = 38): Mdn = 24; Mo = 24, M = 23.13; and the pedagogy students' (n = 10): Mdn = 20; Mo = 18, M = 20.10).

5.2.4.3 Measuring scientific literacy

Regarding the scientific literacy section of the survey, it should be underlined that the percentage of right answers in this study are not directly comparable to the measure of civic scientific literacy that Miller has used in his studies, utilizing Item-Response-Theory (IRT; see sect. 3.3.1, Table 3; cf. J. D. Miller, 2006, pp. 3–6; 2010a, 2016). *Firstly*, although the questions are mostly the same as Miller's questions, he has frequently used some open-ended qualitative questions, that can better reflect people's knowledge of the constructs (cf., e.g., Miller, 2010a, p. 246). Conversely, all the questions in this study were (re)formulated into a quantitative format, due to its demanding length. This quantitative focus likely raised the percentage of correct answers to the questions that Miller has surveyed in a qualitative manner (A3, sect. 3, q25–q27; cf. Miller, 2010a, p. 246). *Secondly*, the sample is much more limited in size than in Miller's studies, with university students being also comparatively over-represented, and particularly those in psychology and pedagogy. *Thirdly*, the added possibility in the present study to give an uncertain answer "I'm not sure", instead of just "true" or "false", likely contributed to the number of correct answers given in the sample (the participants did regularly utilize the "I'm not sure" option, when not forced to choose either "true" or "false"). Overall, therefore, no conclusions should be made on the part of how many people from the sample – let alone from the general population of Finland – would qualify as civic scientifically literate by Miller's criteria. Still, the quartile frequency analysis along with the fully quantitative approach of this study (on the part of measuring scientific literacy), even with the limited sample, seems representative in terms of how its results fit with prior research in other dimensions than the percentage of correct answers. Again, the study intended to make relative not absolute measures.

Another aspect in the present study that was not ideal in terms of comparability had to do with the participants' age. Namely, it was unfortunate that [a] older cohorts were underrepresented, and/or

[b] many chose not to provide their age ($n = 21$; sect. 3.2, Table 1). This weakens any conclusions that can be made from the sample in terms of the effects of age cohort. Still, insofar as conclusions can be made, it seems that albeit the comparatively underrepresented older cohorts had more TV-focused habits of media consumption ($p < .001$), they did not have lower scientific literacy, and controlling for age did not moderate the negative correlation between scientific literacy and TV consumption ($p < .01$). Thus, one plausible interpretation seems to be that scientific literacy is negatively affected by TV consumption also in older cohorts, but that the negative effects of them consuming more TV is statistically counterbalanced via the older cohorts' (at least in this sample) being more likely to be better educated ($p < .001$), consume more news items overall ($p < .05$), and perhaps consume better *kinds* of TV news/documentaries more ($p < .001$) even though overall TV news/documentary consumption was also negatively correlated with scientific literacy (A3, sect. 2, item 3; across the whole sample: $r(138) = -.178$, $p = .037$; across those who reported their age: $r(115) = -.197$, $p = .034$; controlling for age: $r(114) = -.202$, $p = .03$). Future studies should more carefully study the effects of different habits of media consumption between different age cohorts, and how they relate to scientific literacy. Also, it should be noted that older cohorts may be more unwilling to provide their age in a survey by default, so it should explicitly be encouraged in briefing.

The added questions to the traditional ones were quite useful: revealing, especially, the relatively high prevalence of unawareness of the unscientific status of homeopathy, even among many university students (A3, sect. 3, item 19; sect. 3.3.1, Table 3). Still, more questions about well-established psychological/social science might be useful to add in future studies, and open-ended questions could provide more insight into civic competence, especially together with more advanced statistical methods like IRT, as they are encouraged to be utilized in Miller's studies (J. D. Miller, 1998, 2006, 2010a, 2016; cf. sect. 3.1). At the same time, however, the questions utilized in this kind of survey primarily measure scientific *content knowledge* needed for *civic scientific literacy*. Thus, future studies should be encouraged to pay more attention also to other aspects of scientific literacy, like procedural and epistemic knowledge, and consumer, cultural, and aesthetic scientific literacy, and how they relate to various media consumption habits (see sect. 2.1.3–2.1.4, incl. 2.1.4n23). It would also be useful to add simple Likert scale questions about curiosity and interest about science, or – better yet – a Science Curiosity Scale (SCS; Kahan et al., 2017a). This way, the likely connection with science curiosity might more clearly be established from a sample, rather than relying on past research and induction (e.g., Kahan, 2018; J. D. Miller et al., 2021a–b; Takahashi & Tandoc, 2016).

Relating to procedural knowledge, as an example, in his interview studies Miller has utilized a two-stage approach to asking about understanding of scientific inquiry. After first establishing a participant's self-perceived level of understanding of what it means to study something scientifically, those who claim clear understanding are then asked an open-ended question: "From your point of view, what does it mean to study something scientifically? (Just in your own word)" (J. D. Miller, 2004). In 2018, as reported in the 2020 Science and Engineering Indicators, 24 % of people in the US could provide a minimally acceptable explanation (Besley & Hill, 2020; see also J. D. Miller, 2004).

The formulation of the questions as true/false according to current scientific knowledge (+ the added "I'm not sure") was based on a commonly used formulation (see, e.g., Besley & Hill, 2020; Kahan et al., 2012; J. D. Miller, 1998). However, an alternative formulation could frame the briefing in terms of "agree/disagree with the following science-related statements". This might be something to consider in future studies, as the "true/false according to current science" framing does not rule out the possibility that a participant merely knows what science thinks but does not think so themselves. For the general purpose of measuring knowledge of science, the true/false formulation seems fine. One would also think the answers would significantly correlate with what people themselves think, but this could be of some interest for future studies. For example, it could theoretically be that a 'Flat Earther' is well-aware of what science thinks of the shape of the Earth (i.e., of it being considered an oblate spheroid), yet believe themselves (falsely) that it is flat. This general note was raised by one of the participants in the present survey (106).

5.2.4.4 Early Adopter Hypothesis: Decline in correlation between scientific literacy and Internet consumption?

As a final note, concerning the finding that general Internet consumption did not correlate with scientific literacy in the sample – unlike in prior research (cf. A1; J. D. Miller, 2010b–c; Takahashi & Tandoc, 2016) – a possible influence of early versus late adoption could be posited but would need further research and longitudinal data to test. Specifically, as Miller's finding was based on data from 2007, and Takahashi & Tandoc's (2016) newer sample was from 2012, it might be that a third variable of relative distribution of early adopters (e.g., of the Internet, smartphones, and SLIPs) could explain the statistically higher scientific literacy among those actively using the Internet in the earlier studies. This is assuming that early adopters might also be more interested in science, as they like to keep ahead of the curve and curiously follow the latest information technologies (see also A1; sect. 2.2.5).

Then again, it might just be a deficiency in the current sample from 2014, but if this Early Adopter Hypothesis (or Early Adoption Hypothesis) was to be supported, then we *should* see decrease in the correlation between general Internet use and scientific literacy as more and more people adopt Internet and smartphone use (see sect. 2.2.5, 5.2.3). This is assuming that there would not emerge a sudden solution to how, for example, social media platforms or cross-national educational work could start supporting scientific literacy for everyone. At the same time, TV use, consisting more and more of laggards (i.e., late adopters), might see a more negative correlation with scientific literacy as well (assuming TV content would stay relatively the same).[54]

Still, partaking in the epistemic communities on SLIPs (of certain kind) might remain predictive of scientific literacy, and the early adopters would likely keep migrating to the ones that best support them keeping up to date. At some point, it may even be that a wholly new media would emerge to replace contemporary social media, for example in virtual or mixed reality (VR, MR), at which point the early adopters may start to migrate there. (see also *diffusion of innovations*: Rogers, 2003.)

5.2.5 The qualitative part of the survey

People were prone to provide rather vague answers to the qualitative questions. That is, they were prone to list only some general social networking sites (e.g., “Facebook”, “YouTube”, “Reddit”) rather than any specific channels or communities within those sites (e.g., no one answered “science-related subreddits on Reddit, *like ‘Ask a scientist’*”). This was despite being encouraged to list specific channels on the question instruction (A3, sect. 2). Likewise, people were not prone to list any specific television, radio, or podcast programs. Hence, the formulation of the questions should be considered further (e.g., even specifically and shortly asking people to list some “channels/groups/forums within site A”, “…within site B”, etc.). Or, perhaps, quantitative closed questions could be considered (e.g., listing some site-specific channels and measuring how familiar people are with them). Interview studies and studies that monitor – i.e., concretely measure – what channels people use might also be fruitful endeavors for the future (though, proper tools for the latter kinds of studies are likely available only to specific platform providers, like Facebook).

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[54] Two preliminary observations that lend additional support for the Early Adopter Hypothesis:

(1) A *clear* downward trend of interest in “science” is revealed on Google Trends in web search, going from its inception (January 2004) to this day (September 2021): in the US, UK, Australia, Canada, New Zealand, Nigeria, South Africa, France, and worldwide; and locally roughly the same with, for example, Finnish “tiede”, German “Wissenschaft”, Italian “scienza”, Japanese “科学” (kagaku), Portuguese “ciência”, Russian “наука” (nauka), Spanish “ciencia”, and Swedish “vetenskap” (see, e.g., https://trends.google.com/trends/explore?date=all&geo=US&q=science). A notable exception, showing a nascent opposite trend, is India with the Hindi “विज्ञान” (vigyaan). Access to Internet has increased in India only in recent years (Hootsuite & We Are Social, 2021), thus perhaps still showing more effect of the local early adopters, lest there might also be some other significant cultural or contextual differences at play.

(2) Unique SLIPs were found *solely* among the most scientifically literate in the current sample (see sect. 4.2.2), thus them likely being comparative early adopters of various SLIPs (and potentially of other things before them). At the same time, however, non-fiction books retain popularity among the most scientifically literate, especially compared to the more confined medium of television that they tend to avoid. This is perhaps telling of the continuing informational value of non-fiction books alongside SLIPs.

Nevertheless, as the vague answers did reveal the interesting correlation between scientific literacy and mentions of using *social learning-related Internet platforms, channels, and forums* (SLIPs) in learning new knowledge ($p < .001$), it would deserve more focus in future studies (assuming the finding is replicable with enhanced instruments and larger samples). For example, a study focusing on categorizing SLIPs more carefully, and seeing if any specific characteristics are best predictive of scientific literacy could be useful. And as Wikipedia was mentioned by also several others than the top quartile (sect. 4.2.2, Figure 7), it could be useful to ask and control for use frequency as well as for language used. Theoretically, one can answer learning most amount of knowledge from someplace they do not frequently use, and consequently do not learn that much from. Language may also play a role as the information on Wikipedia is likely to be more up-to-date and exhaustive in English than in smaller language areas or language areas that are not considered the current universal language of science. This, again, emphasizes the important role of English proficiency in most effectively navigating the parts of the Internet that might best feed and spark science curiosity.

A further related question for future studies could be how to best spark positive epistemic emotions, like science curiosity, for intrinsic incentives. One avenue to explore this might be to study the communication methods of people with high cultural and aesthetic scientific literacy (see sect. 2.1.4n22).[55] It might also be that some SLIPs are better at sparking different forms of intrinsic and extrinsic incentives, the nuances of which would be useful to find out.

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[55] Relevant to cultivation of scientific literacy via sparking science curiosity, science can be a profound learning experience not only about the cosmos in general but our place in it: while we – the sentient creatures of the universe – are a way for the cosmos to know itself, science is a facilitator. Arguably, these kinds of poetic facts, that can induce science curiosity via awe and wonder, are ignored in science education only for its own detriment. (see Chevrier et al., 2019; Gruber & Fandakova, 2021; Fandakova & Gruber, 2021; Kahan et al., 2017a; Kahan, 2018; Rutherford, 2005, pp. 370–372; see also sect. 2.1.4n22.)

Fortunately, some parts of popular culture have started to answer the lament made by the late physicist Richard Feynman (1918–1988) in one of his short works, reflecting on the value of science. He lamented how there is no music composed about science, no songs sung, nor poetry written, but only evening lectures offered, even though the natural world is filled with marvelous beauty (Feynman & Robbins, 1999, pp. 144–145). For how things may be changing, the album *Endless Forms Most Beautiful* (2015) by the symphonic metal band *Nightwish* could be considered an example of aesthetic scientific literacy popularized via music and lyrics. The album was inspired, in part, by the work of the naturalist Charles Darwin (1809–1882), as well as the ethologist and evolutionary biologist Richard Dawkins' & Yun Wong's book *The Ancestor's Tale: A Pilgrimage to the Dawn of Life* (2004), Dawkins' *The Greatest Show on Earth: The Evidence for Evolution* (2009), and, by and large, "the beauty of life, the beauty of existence, [the beauty of] nature," while being a "tribute to science and the power of reason" (EMP Rockinvasion, 2015; SpazioRock, 2015).

Or, on YouTube, one can find the music video series *Symphony of Science* by the user melodysheep (https://youtu.be/tKjbHv_0KKY&list=PLFC4EE4355ADEBDB1), and user acapellascience's a cappella harmonies about science (https://www.youtube.com/user/acapellascience), and much more. Or one can view the playful videos made in the annual *Dance Your Ph.D.* competition (est. 2008) (for links to annual participants, see "Dance Your Ph.D.", 2021). Unappealing evening lectures are no longer all on offer either, thanks to MOOCs via platforms like *Coursera* and *edX* (see also Veritasium, 2014). I would call these examples of some amount of progress within a very short time, by means of aiming to spark science curiosity, in large part via cultural and aesthetic scientific literacy.

6 CONCLUSIONS

6.1 Summary of Key Findings

The present study contributes to the research literature on scientific literacy by providing additional support for and expanding on the findings of J. D. Miller (2010b–c) and others (Nisbet et al., 2002; Takahashi & Tandoc, 2016). Particularly, it supports the finding that – on average – television consumption has a significant negative correlation with scientific literacy, while print media and Internet consumption do not. And it expands on this by noting that, in the sample, scientific literacy had significant positive correlations with the more specific categories of 'organization of life via Internet' and written non-fiction consumption, as well as with giving relatively more value to non-fiction books in learning new knowledge. The additional category of digital games consumption was also hinted to have a significant negative correlation with scientific literacy, potentially moderated by education and age cohort, but this would need further corroboration as the sample reached only relatively few and homogenous gamers.

Moreover, in line with prior research, higher scientific literacy was found to be significantly more prevalent among people who were more educated, had better understanding of the English language as a second language, and who were less religious. Analysis of the answers given to the qualitative questions further revealed that people with higher scientific literacy were more likely to mention learning most amount of new knowledge from *social learning-related Internet platforms, channels, and forums* (SLIPs) that were more plentiful and/or unique compared to the rest of the sample, while also being more prone to mention reading non-fiction books and to not mention television. A quantified analysis of the qualitative answers confirmed a significant positive correlation between scientific literacy and SLIPs mentioned.

It was theorized that particularly SLIPs can provide many benefits for learning, in virtue of them being – at their best – efficient epistemic communities or networks that socially support the process of learning. For example, they can provide organic affordances for interleaving, spacing, and socially supported scaffolding, that can all facilitate learning. However, to find these kinds of *scientific* and ideally civil communities from the multitude of what the Internet offers, and to effectively utilize them, it appears that some level of media literacy and English proficiency are often required. Science curiosity seems to also be needed for motivation, although the best communities – once found – would then systematically feed it further, potentially creating a lifelong socially supported cycle of curiosity and learning, and thus supporting scientific literacy.

6.2 Practical Suggestions

The important project of raising people's scientific literacy, or public understanding of science, is still in its relative infancy, in terms of success. Yet, while measuring scientific literacy can in part reveal this, choosing the best methods to tackle misinformation and facilitate better-informed private and public policy decisions is a different matter. For example, it does not help to merely communicate science to the public, it also matters how that communication is done, where it is done, and who does it to whom and when. In persuasion, facts often do not matter as much as other factors, such as emotions, motivations, prior beliefs, and interpersonal and group dynamics. (see, e.g., McRaney, 2021a–b, 2022; Scheufele & Krause, 2019.) Thus, many factors in addition to scientific literacy need to be considered when designing effective communication strategies.

Next, I conclude by presenting some practical suggestions for various interested parties. Specifically, I illustrate what practical implications the present study seems to have for science communication and self-improvement strategies, insofar as they aim to encourage media consumption that may best support scientific literacy. Further, I end with looking beyond scientific literacy: I note some other factors that should also be paid attention to when wanting to tackle misinformation and facilitate better-informed private and public policy decisions, on SLIPs or elsewhere. In the end, scientific literacy is only one facet of being a democratically informed and well-functioning citizen. Any comprehensive strategy aiming towards a better deliberative space needs to also account for various natural human biases and reasoning errors, lest scientific literacy may even itself turn into a tool for motivated reasoning.

6.2.1 How to encourage better media consumption habits

Considering that social learning-related communities on the Internet appear to support scientific literacy, *teachers* and *science communicators* should be encouraged to [A] form those kinds of communities, actively produce/link and discuss scientific content on them and encourage students and/or the public to partake in them[56]; and [B] guide and inspire students and/or the public to find

[56] Forming social learning-related communities online might include creating, for example, corresponding Facebook groups; forums; Instagram, YouTube, or TikTok channels; Reddit subreddits; Twitter accounts, etc. Of course, a singular teacher or communicator need not necessarily be everywhere. Instead, they can choose what production and interaction format best fits with their desired content production techniques, personality, and preferences of the target group. For example, one might prefer intimate conversations (e.g., podcasts), photo or picture editing (Facebook, Instagram), text-based communication (short length: Twitter; medium: Facebook groups; long: blogs), video production (short: Instagram, TikTok; medium or long: Vimeo, YouTube), or topically categorized text-based discussions (Discord, forums, subreddits).

already existing high-quality learning-related communities on the Internet, as part of media literacy. Also, educators in general should note that the more active science communicators there would be online, the better it would be for public understanding of science (insofar as other factors important for public communication are also noted; cf. sect. 6.2.2). In schools and online learning communities, students/members should further be encouraged to find and read curiosity-inducing non-fiction books (particularly high-quality popular science-books), and socially present and discuss them; alongside more general written non-fiction, and fiction (the latter is arguably overrepresented in contemporary pre-collegiate curricula, or the former underrepresented, not counting textbooks).

Educational and science foundations, *policymakers*, and *philanthropists* should provide opportunities for educators to bring their expertise to social media (e.g., by offering grants for public outreach SLIPs, MOOCs, and their promotion; for all age groups and skill levels, in various topics). Moreover, effort should be put in educating all *academics* in these matters, not only to better support their preparedness to function as efficient science communicators, but also to better support their own ability to function as democratically informed and well-functioning citizens. To this end, it would be fruitful to add relevant basic psychological/social science education to natural science and technical/engineering programs around the world, and vice versa to add basic natural science and technical education to all psychological/social science education programs (see also sect. 2.2.3n31, 6.2.2). Similarly, critical thinking classes could be implemented, not only to universities and SLIPs, but also to art schools and pre-collegiate education (see Dyer & Hall, 2019; Hyytinen et al., 2019).

Social media platform designers, particularly, should take note of the potential learning benefits of SLIPs. Consequently, they should conduct further research on the matter; learn how to identify the most effective, curiosity-inducing, scientific and civil SLIPs, and related social networks; and then actively make them salient to all users via appropriate algorithms. Currently, what often seems to be promoted instead is the lowest common denominator clickbait, aimed merely to maximize advertising revenue and time spent on the platforms, without any notable epistemic nor moral benefits.

Similarly, *television executives and producers* should be encouraged to add more high-quality science-related content on their networks, especially considering the longstanding cross-cultural negative correlation between TV consumption and scientific literacy. Although not specifically measured in the present study, the same might go to streaming services like Netflix. Currently, it appears that that these services provide very low amounts of high-quality, curiosity-inducing science-related content, in contrast to the amount of low-quality traditional entertainment content on offer.

Parents should also be encouraged to function as role models for their children, not only by reading more non-fiction themselves but by reading and discussing age-appropriate non-fiction books as bedtime stories with them. They might also, for example, periodically ask their adolescent children if they might know of any interesting learning-related communities on the Internet, and more generally show interest in science by also searching for and partaking in such communities themselves. Of course, *children* (incl. adolescents and adults) aware of these issues should likewise model interest in science for their parents. In other words: make learning-related communities a fluid area of discussion and form of life also at home and among family, rather than something delegated only to the area of formal education.

Finally, *all media consumers* should want to cultivate more beneficial habits of media consumption to support their own scientific literacy. This would include avoiding excessive television consumption, seeking scientific learning-related, curiosity-inducing communities on the Internet, and consuming more written non-fiction, especially non-fiction books. Moreover, if possible, they could discuss all the above – and whatever they learn along the way – among friends and any possible online audience they might have. This could encourage learning-related communities to also form around them. *High-quality journalism* might provide guidance for people in how to accomplish all these things (via the journalists consulting science communication researchers). Potential conflict of interest arises, of course, insofar as the best habits of media consumption should steer people away from specific places of journalism (e.g., television and newspapers; see sect. 5.1.3.1), in which case the focus should, again, be put on producing better, more engaging, and diverse scientific and scientifically literate content in those places, and not letting low-quality entertainment or tabloid content dominate the supply (e.g., reality TV shows, celebrity gossip, or news that cyclically feed off online moral outrage and partisanship).

In all these endeavors, the communicators and guides should aim at sparking science curiosity in all people, patiently acknowledging and calmly correcting typical misconceptions, and, insofar as possible, avoid politicization/moralization of science (e.g., by striving to unite and not divide people, and by not blaming people for not being familiar with the communicated matters, while also acknowledging their own fallibility and, when needed, that of science). The values of the audience should also be considered via appropriate framing. In other words, care should be put into consistently presenting science – its history of hard-earned triumphs, its philosophical underpinnings, concepts, methods, diverse insights, and ongoing processes – in a positively motivating, humble, and calling light; instead of presenting it in a negatively judgmental, divisive, and aversive shadow. Concurrently, cultivation of fitting virtues is advisable, not only because they can provide communicatory *epistemic* benefits but because they can also provide the *ethical* ingredients for living a flourishing life in our emerging global environment. (see also Kangassalo, 2019, 2021a–b; sect. 2.2.1–2.2.2, 5.1.3.3.)

6.2.2 The limits of scientific literacy: Further directions for public communication

In the end, how far can paying attention to scientific literacy get us? It should yet be underlined that even though higher scientific literacy and related higher education seem connected with having fewer *epistemically unwarranted beliefs* – like paranormal, religious, pseudoscience, and conspiracy beliefs – the relationship is complex and not reliably reproduced. For example, university education does not guarantee protection against them, and especially conspiracy beliefs interact poorly with scientific literacy. (cf. Dyer & Hall, 2019; Fasce & Picó, 2019; Impey et al., 2017; Lindeman et al., 2011; see also Gapminder, 2020; van Prooijen, 2017.) Also, domain-general basic scientific literacy – as measured in the present survey – does not necessarily predict literacy on more domain-specific areas of science, like climate science, that may also be more politicized than science more generally (cf. Guy et al., 2014; Shi et al., 2016). At the same time, only specific components of scientific literacy, not necessarily including the measured content knowledge, may provide help for identifying misinformation in general (cf. Sharon & Baram-Tsabari, 2020; sect. 2.1.3–2.1.4). Furthermore, a complication in the value of scientific literacy and education, on their own, is that people with higher scientific literacy, numeracy or education are more able and often *more likely* to interpret words and data to falsely conform with their political outlook and/or prior factual beliefs; making scientific literacy a potential tool for politically motivated reasoning and/or lazy reasoning (Drummond & Fischhoff, 2017b; Joslyn & Haider-Markel, 2014; Kahan et al., 2012, 2017b; Lewandowsky & Oberauer, 2016; cf. Ballarini & Sloman, 2017; Kahan & Peters, 2017; Tappin et al., 2020, 2021).

Thus, in thinking about solutions to the challenges the literature is generally interested in – i.e., how to combat misinformation and facilitate better-informed private and public policy decisions – a more holistic approach is advisable. That is, to understand how progress can best be made, other factors need to be considered in addition to scientific literacy. Ultimately, scientific literacy – and public understanding of science more generally (Bauer et al., 2007; Bauer, 2008) – is only one facet of being a democratically informed and well-functioning citizen, albeit an important one.

Some other factors and skills worth noting and cultivating seem to include, for example, *media literacy* (European Commission, 2021), *information literacy* (Klucevsek, 2017), *digital literacy*[57] (Valtin et al., 2016), disposition and capacity for *critical thinking* (Hitchcock, 2020), and recognition of the role of *positive epistemic emotions* as motivational facilitators (Chevrier et al., 2019; Vogl et

[57] More specific *algorithmic literacy* or *artificial intelligence literacy*, or broader *data literacy*, could also be emphasized. This would refer, for example, to the awareness of how our choices on social media platforms (what to follow, like, retweet, etc.) are likely to affect what we see on the platforms, and how to best utilize this awareness to shape our online environments in ways that best support our scientific literacy and well-being.

al., 2020). Politically or otherwise biased information processing and partisanship should also be counteracted, where raising the epistemic emotion of *science curiosity* may play a significant part (Kahan et al., 2017a, 2018) along with facilitation of *epistemic rationality* (Ståhl & van Prooijen, 2018), *analytic thinking* (Pennycook et al., 2015; Pennycook & Rand, 2019b, 2019c; see also sect. 2.1.1n6, 2.1.3.2n18), and raising *knowledge about the mechanisms* underlying scientific issues and public policies (Lewandowsky & Oberauer, 2016; Ranney & Clark, 2016; see also Chesterfield & Coombs, 2019; Kahan, 2018; sect. 2.1.4n22, 5.2.5n55).

Cultivating *trust in science* seems especially important to counteract conspiracy theories (Fasce & Picó, 2019; Oreskes, 2019; see also Huber et al., 2019; cf. Nguyen, 2020a; Norris, 2021), as does cultivation of *intergroup trust* to mitigate polarization, political conspiracies, and in-group bias (Nguyen, 2020b; van Prooijen et al., 2015; see also Blöbaum, 2016; Finkel et al., 2020; van Prooijen & Douglas, 2018). Also, *ontological confusions* and *overreliance on intuition* are challenges to be aware of (Fasce & Picó, 2019; Lindeman et al., 2011, 2015). To some degree, these can be counteracted via *specific and direct instruction about how to distinguish scientific claims and reasoning from those of pseudoscience*, and cultivation of corresponding analytic thinking; also including increasing awareness of common *logical fallacies*, *biases*, inappropriate *rhetorical tactics*, misuse of *statistics and probability*, and how to judge *reliability of experts, authorities, and the media* (Dyer & Hall, 2019; Pennycook et al., 2015; Schmaltz & Lilienfeld, 2014; see also Čavojová et al., 2020; Garrett & Weeks, 2017; Gray & Gallo, 2016; Lewandowsky & Cook, 2020; Scopelliti et al., 2015; Stanovich, 2020, 2021; van Prooijen, 2017; further, cf. Boudry, 2017; Boudry et al., 2015).[58]

The value of *intellectual humility* as a virtue should further be recognized (Krumrei-Mancuso et al., 2020; Porter & Schumann, 2018; Porter et al., 2020; Stanley et al., 2020; see also Alfano et al., 2020; Bowes & Tasimi, 2021; Lilienfeld, 2020), along with the importance of *civility* in public communication to optimize the effectiveness of any messages we would like to convey across groups (Popan et al., 2019; Suhay et al., 2018; Tkotz et al., 2021; see also Chesterfield & Coombs, 2019; Druckman et al., 2019; Orosz et al., 2016). Relatedly, simply *shifting attention to accuracy* can reduce misinformation online, as most users do not share it on purpose but "merely" tend to be distracted by other social motives on social media platforms (Epstein et al., 2021; Pennycook et al., 2020, 2021; Sinatra & Lombardi, 2020; Walters et al., 2016; see also Rand & Pennycook, 2021). In a similar vein, algorithmically utilized *crowdsourced news source evaluation* seems to be an effective yet

[58] In terms of formal education, an explicit semester long critical thinking class specifically and directly addressing epistemically unwarranted beliefs has been shown to be beneficial in mitigating them, unlike research methods classes or unrelated general education classes (Dyer & Hall, 2019; see also Hyytinen et al., 2019).

underutilized method to rank source quality online, when it comes to familiar sources (Allen et al., 2021; Epstein et al., 2020; Pennycook & Rand, 2019a). Pre-emptive *inoculation against fallacious reasoning* (i.e., *prebunking*) can also counteract misinformation and epistemically unwarranted beliefs (Cook et al., 2018; Lewandowsky & van der Linden, 2021; Senapathy, 2018), as can considerately done corrective *debunking* (Lewandowsky et al., 2020; Lewandowsky & Cook, 2020), and Socratic questioning or *Street Epistemology* (https://streetepistemology.com/; see also Boghossian, 2013; Boghossian & Lindsay, 2019; McRaney, 2022)[59] (see also van der Linden et al., 2021).

While, ideally, public science communicators, educators, and scientifically literate journalism would play key parts in modeling and cultivating the appropriate thinking and characteristics within the public; at the same time, we can all be each other's environmental influences, especially in the age of social media. Thus, paying attention to the contents and methods of *our own communication* is important, not only in the ways described above but also more broadly in the way of *avoiding feeding into moral outrage* and not prioritizing in-group 'likes' over *prosocial intergroup communication*, including mutual *listening* (Brady et al., 2020, 2021; Brady & Van Bavel, 2021; Carpenter et al., 2021; see also Basu, 2020; Boghossian & Lindsay, 2019; Chesterfield & Coombs, 2019; Christ & Kauff, 2019; Doell et al., 2021; Jamieson, 2021; C. Tan et al., 2016). Relatedly, pre-emptive *prevention of belief polarization* (Nyhan, 2021), and group-specifically *targeted communicators* and *framing* when polarization has already taken place, are useful avenues to explore when more widely developing our science communication strategies (see, e.g., Feinberg & Willer, 2013, 2015; Hornsey & Fielding, 2017; Hurst & Stern, 2020; Täuber et al., 2015; Wolsko et al., 2016; see also Haidt, 2012; Lewandowsky et al., 2020). (see also Kangassalo, 2019, e.g., sect. 1.1–1.2, 6.1.3, 6.4.3.1, 6.6–6.7, 7; 2021a–b; Shigeoka et al., 2020.)

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[59] Street Epistemology (SE) is a conversational method to understand, explore, and politely challenge potential misinformation or false/misguided cognition of an interlocutor, usually in a one-on-one conversation, utilizing *technique rebuttal* (rebuttal via encouraging metacognitive introspection about the argument or thought pattern that has led to the acceptance of the information or cognition) as opposed to *topic rebuttal* (rebuttal with established facts and conclusions). Topic rebuttal is often not an effective way to address misconceptions of an interlocutor, whereas technique rebuttal has been shown to produce good results more consistently. (https://streetepistemology.com; McRaney, 2021a–b, 2022.)

In addition to SE, other similar conversational methods that utilize technique rebuttal, in various contexts, include *deep canvassing*, *motivational interviewing* (MI), *cognitive behavioral therapy* (CBT), *smart politics*, and *the Socratic method*. Roughly speaking, these all follow the same conversational routine of: [1] establishing rapport (no blaming nor shaming), [2] asking for a claim (or belief, attitude, or value), [3] asking for a measure of confidence in the claim, [4] asking what reasoning supports that level of confidence, [5] asking what justifies this reasoning, and [6] exploring if those justifications are strong enough to support the level of confidence (e.g., is the underlying method used to accept claims with high confidence – for instance, faith, personal experience, statistical evidence, etc. – reliable enough to justify the level of confidence in the claim). This kind of routine of technique rebuttal helps the interlocutor to work backwards from their claim to their reasoning and justifications, to spot any potential errors along the way (via aporia); rather than them straight away having to encounter conclusions, as done in topic rebuttal, that they have not themselves arrived at. (ibid.)

Finally, *cultivation and exemplification of fitting virtues* for our emerging global environment – like civility, communicative efficacy, compassion, epistemic rationality, intellectual humility, etc. – seems especially advisable (Kangassalo, 2019; see also Burbules, 2019; Flanagan, 2017; Lapsley & Chaloner, 2020; Sharon & Baram-Tsabari, 2020). Given the fallible and in many ways imperfect character of our default nature (e.g., via our reactivity, biases, reasoning errors, tendency for partisanship, etc.), we need to strive towards something better that would safeguard us from ourselves (see Kangassalo, 2019, sect. 1.1–1.2, 6.1.3). On that path, cultivation of carefully considered *heuristics* may prove beneficial (Kangassalo, 2019, Ch. 7), and some people – who have put extraordinary effort into the project – may function as inspiring *exemplars*; that is, as virtuous role models (Lapsley & Chaloner, 2020; Sharon & Baram-Tsabari, 2020, sect. 4). (ibid.)

In part, *all the above* – and whatever else future research will reveal to be important alongside scientific literacy – could in time be facilitated by building corresponding *lessons*, *boosting*, *technocognition*, and *subtle nudging* into the algorithms and choice architectures of the social media platforms we are situated in. Effectively, this would appear to require a paradigm change in the prevailing conventions of platform design – to in time provide enormous benefits for our public deliberation and decision-making processes. However, care should be put into not politicizing nor moralizing these processes, rather they should follow transparent secular, ethical, and evidence-based scientific principles, striving to unite people rather than divide or blame. (Honkela, 2017; Kangassalo, 2019, 2021a–b; Kozyreva et al., 2020; Lewandowsky et al., 2017; see also Bak-Coleman et al., 2021; Barzilai & Chinn, 2020; Epstein et al., 2021; Fazio, 2020; Marin & Roeser, 2020; Pennycook et al., 2020, 2021; Pennycook & Rand, 2021; further, see Haidt & Rose-Stockwell, 2019.)

Given the widespread prevalence of low level of scientific literacy and the persistence of epistemically unwarranted beliefs, public communication of science is urgently calling for efficacy. And this is only underlined by the recent trends of polarization and salient spread of misinformation, all the while humanity is facing dire global challenges (Kangassalo, 2019, 2021a–b; sect. 2.2.2, 2.2.5, 5.2.3). As the projects that aim at increasing scientific literacy among the public continue – e.g., Project 2061 in the US and the hopefully emerging projects in the EU (sect. 2.2.4) – and as research for the nuances of more efficient science communication accumulate, there remains hope that a more skillful information environment might, in time, emerge. Yet, a lot remains to be done, and scientific literacy is merely one piece of the much bigger puzzle. Hopefully, the present thesis has managed to sketch some road signs for what the solution entails, for the part of cultivating better media consumption habits and public communication of science therein.

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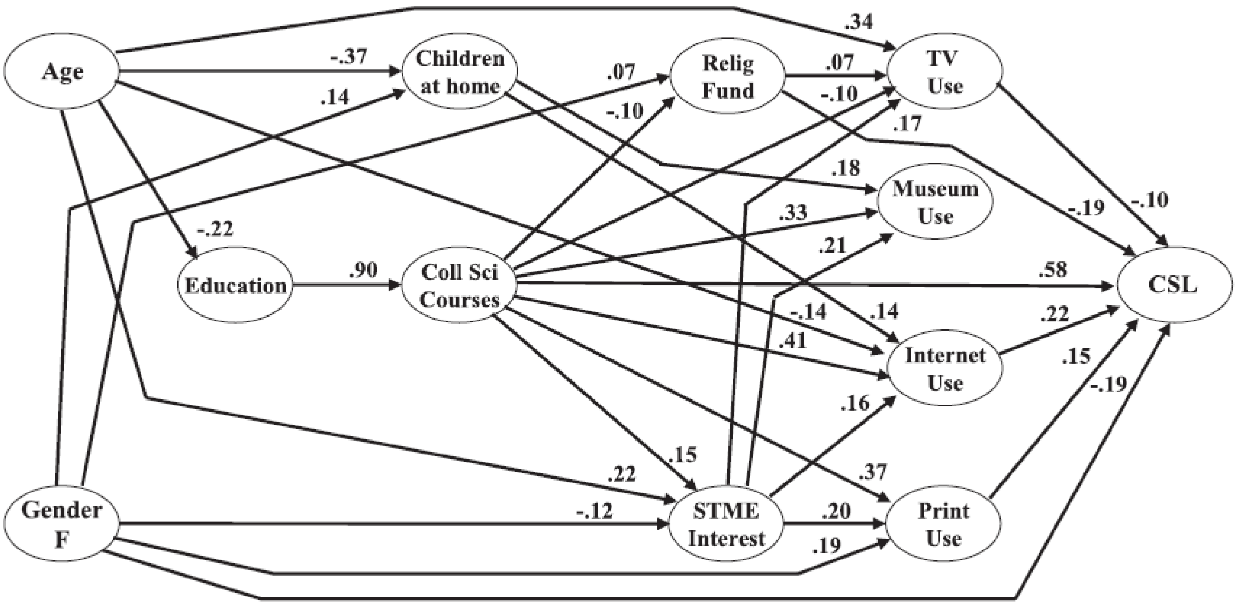
APPENDICES



Appendix 1. Miller's Path Model to Predict Civic Scientific Literacy, 2007 (J. D. Miller, 2010b, p. 198; see also J. D. Miller, 2010c, p. 55; Takahashi & Tandoc, 2016).

Appendix 2. The original Finnish language survey: "Kysely: mediankäyttötavat ja tieteellinen lukutaito" [Survey: habits of media consumption and scientific literacy]. On the next six pages. The one scientific literacy item eliminated from the final analysis has been struck through post-survey (item 20 on the fourth page; see sect. 3.1n41).

Tässä kyselyssä tutkitaan mediankäyttötapojen ja tieteellisen lukutaidon yhteyksiä. Kysely koostuu kolmesta pääosasta (taustatiedot, mediankäyttötavat, tieteellinen lukutaito) sekä vapaavalintaisesta kommenttiosasta. Vastaamiseen kuluu noin 15 minuuttia.

1. Taustatiedot

(*Ympyröi jokaisen monivalintakysymyksen kohdalla yksi vaihtoehto, ellei kysymyksessä toisin mainita.*)

Sukupuoli?

1 Mies
2 Nainen
3 En halua vastata

Syntymävuosi?

____

Mikä on ylin suorittamasi koulutus?

1 Kansakoulu/Peruskoulu
2 Ammattikoulututkinto
3 Ylioppilastutkinto
4 Opintotasoinen ammattikoulutus
5 Ammattikorkeakoulututkinto
6 Alempi yliopisto- tai korkeakoulututkinto
7 Ylempi yliopisto- tai korkeakoulututkinto
8 Jokin muu koulutus, mikä?

____

Millainen nettiyhteys sinulla on käytettävissä kotonasi? (*Ympyröi kaikki vaihtoehdot, jotka pätevät.*)

1 Minulla ei ole kotona nettiyhteyttä käytettävissä
2 Mobiililaajakaista (esim. mokkula, nettitikku, USB-modeemi tai älypuhelimen nettiyhteys)
3 Kiinteä nettiyhteys (esim. ADSL tai kaapelimodeemi)
4 Valokuituyhteys
5 Jokin muu, mikä?

____

Mihin kirkkoon, uskonnolliseen yhdyskuntaan tai uskontoryhmään katsot kuuluvasi?

1 En mihinkään
2 Evankelis-luterilaiseen kirkkoon
3 Ortodoksiseen kirkkoon
4 Muuhun uskonnolliseen yhteisöön, mihin?

____

Mikä seuraavista kuvaa parhaiten näkemystäsi Jumalasta?

1 En usko Jumalaan
2 Uskon Jumalaan ja uskon, että kristillisyys on ainoa oikea tapa tuntea hänet
3 Uskon Jumalaan ja uskon, että kristillisyys on vain yksi tapa tuntea hänet
4 Ajattelen Jumalan olevan se, mikä aiheutti universumin
5 Ajattelen Jumalan olevan luonnonlait ja kaikki universumissa
6 Uskon johonkin polyteistiseen jumalistoon Mihin? ______________________
7 Jokin muu näkemys, mikä?

____

8 En osaa sanoa
9 En halua sanoa

Kuinka hyväksi katsotte seuraavien kielten ymmärtämisenne *puhuttuna ja kirjoitettuna*?
(*Jos et osaa mainittua kieltä, älä ympyröi mitään vaihtoehtoa.*)

	Välttävä	Tyydyttävä	Hyvä	Kiitettävä	Erinomainen	Äidinkieli
A. Suomi	1	2	3	4	5	6
B. Englanti	1	2	3	4	5	6
C. Ruotsi	1	2	3	4	5	6

D. Muu kieliosaaminen? ____

____

2. Mediankäyttötavat

Kuinka usein teet seuraavia asioita?
(*Ympyröi jokaisesta kohdasta yksi vaihtoehto.*)

	Hyvin harvoin tai en ollenkaan	Joskus, mutta ei joka viikko	Ainakin kerran viikossa	Melkein joka päivä	Ainakin kerran päivässä
1. Television katsominen (yleisesti; myös DVD, blu-ray, video yms.)	1	2	3	4	5
2. Maksutelevisiokanavien katsominen	1	2	3	4	5
3. Uutisten, dokumenttien sekä tiede- ja ajankohtaisohjelmien seuraaminen televisiosta (myös DVD-, blu-ray- ja video-dokumentit)	1	2	3	4	5
4. Radion kuuntelu (myös nettiradiot)	1	2	3	4	5
5. Internetin käyttö uutisten lukemiseen tai katsomiseen (esim. netin uutissivustot, sanomalehtien nettisivut; blogit, Ampparit.com, Reddit -uutisosastot yms.)	1	2	3	4	5
6. Internetin käyttö tiedonhakuun tai asioiden oppimiseen (esim. Google, Wikipedia, YouTube-opetussisältö, Khan academy, Coursera yms.)	1	2	3	4	5
7. Internetin käyttö keskusteluun muiden kanssa (esim. chat, Facebook, Twitter, Skype, foorumit, virtuaaliyhteisöt yms.)	1	2	3	4	5
8. Sisällöntuotanto Internetiin (esim. blogi, vlogi, nettisivut, podcast, valokuvien julkaisu yms.)	1	2	3	4	5
9. Internetin käyttäminen viihdesisältöjen katselemiseen tai kuuntelemiseen (esim. YouTuben viihdesisällöt, Netflix, meemit, sarjat, elokuvat, musiikki, Spotify, torrentit yms.)	1	2	3	4	5
10. Internetin käyttö elämän organisoimiseen (esim. kalenterit, sähköposti yms.)	1	2	3	4	5
11. Älylaitteen käyttäminen (esim. älypuhelin, tabletti, älylasit jne.)	1	2	3	4	5
12. Digitaalisten yksinpelien pelaaminen (esim. mobiililaitteella, konsolilla tai PC:llä)	1	2	3	4	5
13. Yhteistoimintaa vaativien digitaalisten online-pelien pelaaminen	1	2	3	4	5
14. Sanomalehden lukeminen (paperimuodossa tai sähköisenä versiona)	1	2	3	4	5
15. Fiktiivisen kirjallisuuden lukeminen (paperisessa tai sähköisessä muodossa)	1	2	3	4	5
16. Tietokirjallisuuden, tiede-lehtien tai tieteellisten journaalien lukeminen (paperisessa tai sähköisessä muodossa)	1	2	3	4	5
17. Aikakauslehtien lukeminen (paperisessa tai sähköisessä muodossa, esim. Aku Ankka, MeNaiset, Tekniikan Maailma, Pelit, Mikrobitti yms.)	1	2	3	4	5

Minkä medialähteen koet olevan itsellesi ensisijainen seuraavien asioiden tekemiseen?
(*Rastita jokaisen asian kohdalla yksi medialähde – se, jonka koet itsellesi ensisijaiseksi.*)

	Televisio	Maksu-televisio	Radio	Internet	Sanoma -lehdet	Aikakaus-lehdet	Tieto-kirjallisuus	Fiktiivinen kirjallisuus	Digitaaliset pelit
1. Uutisten seuraaminen	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Tiedon hakeminen	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Kielten oppiminen	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Uuden tiedon oppiminen	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Yhteiskunnallisen keskustelun seuraaminen	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Yhteiskunnalliseen keskusteluun osallistuminen	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Viihde, seurustelu ja muu ajan kuluttaminen	☐	☐	☐	☐	☐	☐	☐	☐	☐

Kuvaile lyhyesti: millaisia mediasisältöjä käytät mielelläsi?
(*Mediasisältöjä ovat esimerkiksi tietyt tai tietynlaiset televisio-ohjelmat, lehdet, kirjat, pelit tai Internet-sisällöt, kuten YouTube- ja Twitter-kanavat, Facebook-seuraukset, podcastit, Reddit-alueet, TED, Ampparit, Wikipedia yms.*)

Kuvaile lyhyesti: millaisista mediasisällöistä koet oppivasi eniten uutta tietoa?
Mainitse muutama esimerkki.

3. Tieteellinen lukutaito

Ovatko seuraavat väitteet totta vai epätotta nykyaikaisen tieteellisen tiedon mukaan?
(*Rastita jokaisen väitteen kohdalta yksi vastaus.*)

	Totta	En ole varma	Epätotta
1. Valo liikkuu nopeampaa kuin ääni.	☐	☐	☐
2. Kaikilla kasveilla ja eläimillä on DNA.	☐	☐	☐
3. Maapallon keskusta on erittäin kuuma.	☐	☐	☐
4. Mantereet, joilla asumme, ovat liikkuneet miljoonia vuosia ja jatkavat liikkumista tulevaisuudessa.	☐	☐	☐
5. Miljoonien vuosien aikana jotkut kasvi- ja eläinlajit sopeutuvat ja selviävät, samalla kun toiset lajit kuolevat sukupuuttoon.	☐	☐	☐
6. Astrologia ei ole tieteellistä.	☐	☐	☐
7. Antibiootit tappavat sekä bakteereita että viruksia.	☐	☐	☐
8. Elektronit ovat pienempiä kuin atomit.	☐	☐	☐
9. Tavallisissa tomaateissa ei ole geenejä, mutta geenimanipuloiduissa tomaateissa on.	☐	☐	☐
10. Laserit toimivat keskittämällä ääniaaltoja.	☐	☐	☐
11. Varhaisimmat ihmiset elivät samaan aikaan kuin Tyrannosaurus Rex.	☐	☐	☐
12. Ihmiset kehittyivät aiemmista eläinlajeista.	☐	☐	☐
13. Universumi sai alkunsa valtavassa alkuräjähdyksessä.	☐	☐	☐
14. Yli puolet ihmisen geeneistä on identtisiä hiiren geenien kanssa.	☐	☐	☐
15. Kaikki radioaktiivisuus on ihmisen tuottamaa.	☐	☐	☐
16. Radioaktiivinen maito voidaan tehdä turvalliseksi keittämällä.	☐	☐	☐
17. Ydinvoimalat tuhoavat otsonikerrosta.	☐	☐	☐
18. Mikäli fossiilisten polttoaineiden kulutusvauhti pysyy nykyisellään, syntyy vakavia pitkäaikaisia ympäristövaikutuksia.	☐	☐	☐
19. Homeopatia on tehokas tapa hoitaa sairauksia.	☐	☐	☐
~~20. AIDS voi tarttua seksuaalisessa yhdynnässä toiseen ihmiseen.~~	~~☐~~	~~☐~~	~~☐~~

Mikä väite pitää seuraavissa parhaiten paikkansa?
(*Ympäröi jokaisesta kohdasta yksi vaihtoehto.*)

Lääkäri kertoo pariskunnalle, että heidän geneettisen rakenteensa ansiosta heillä on yksi neljästä mahdollisuus saada lapsi, jolla on perinnöllinen sairaus. Mikä seuraavista väitteistä pitää paikkansa?

A. Jos pariskunta hankkii vain kolme lasta, yhdelläkään heistä ei ole perinnöllistä sairautta.
B. Jos pariskunnan ensimmäisellä lapsella on sairaus, kolmella seuraavalla ei ole.
C. Jokaisella pariskunnan lapsella on yhtäläinen riski kärsiä perinnöllisestä sairaudesta.
D. Jos pariskunnan kolme ensimmäistä lasta ovat terveitä, neljännellä on sairaus.

Kumpi seuraavista pitää paikkansa?

A. Aurinko kiertää Maapallon ympäri.
B. Maapallo kiertää Auringon ympäri.

Kuinka kauan edellisessä kysymyksessä esitettyyn yhteen kokonaiseen kiertoon suunnilleen kuluu?

A. Päivä.
B. Kuukausi.
C. Vuosi.

Kun tapahtuu inflaatio, tällöin hinnat…

A. …nousevat.
B. …laskevat.
C. …pysyvät ennallaan.

Miksi kontrolliryhmä on tärkeä testattaessa uusia lääkkeitä?
(*Valitse lähinnä oikeaa oleva vaihtoehto.*)

A. Jotta tulokset saadaan vahvistamaan tutkijoiden hypoteesi.
B. Jotta voidaan kontrolloida kolmansien tekijöiden, kuten plasebon, vaikutus.
C. Näin taataan koehenkilöiden sopeutuminen tutkimukseen.
D. Koska kontrollointi on valtion velvoittamaa toimintaa.

Mikä on DNA?

A. Kaikkein pienin tunnettujen eliöiden sisältämä partikkeli.
B. Kudostyyppi, joka sisältää kaikkien eliöiden toiminnalle välttämätöntä biologista informaatiota.
C. Molekyyli, joka sisältää kaikkien tunnettujen eliöiden kehityksestä ja toiminnasta vastaavat geneettiset ohjeet.

Mikä on kantasolu?
(*Valitse lähinnä oikeaa oleva vaihtoehto.*)

A. Solu, jolla on kyky jakautua muiksi eliön soluiksi.
B. Solu, joista kaikkien eliöiden tukirakenne koostuu.
C. Keinotekoisesti valmistettu solu.
D. Yksinomaan kasveille ominainen solutyyppi.

Mikä on sosialisaatio?

A. Pitkälle edenneen sosialismin tuottama kehityskulku, joka johtaa uuteen yhteiskuntajärjestelmään.
B. Psykologinen tapahtumaketju, jossa yksilöstä muotoutuu ulospäinsuuntautuneempi.
C. Yksilön ja yhteiskunnan välinen vuorovaikutteinen prosessi, jossa yksilö kasvaa yhteiskuntaan.

Mikä on neuroni?

A. Psykiatrinen ahdistuneisuushäiriö.
B. Hermosolu eli hermokudoksen solu, joka välittää hermoimpulsseja.
C. Sähköimpulssi eli eliöissä tapahtuvan sähkökemiallisen toiminnan perusyksikkö.

4. Kommentteja?

Halutessasi voit tässä osiossa esittää palautetta tai kommentteja kyselystä. Myös kaikki mielipiteet tieteestä ja mediasta yhteiskunnassa ovat tervetulleita ja arvokkaita.

SUURET KIITOKSET VAIVANNÄÖSTÄ!

Palauttakaa lomakkeet kyselyn tekijälle.

Appendix 3. Survey: habits of media consumption and scientific literacy. An English language version of the survey. On the next six pages. The one scientific literacy item eliminated from the final analysis has been struck through post-survey (item 20 on the fourth page; see sect. 3.1n41).

This questionnaire studies the connections between habits of media consumption and scientific literacy. It consists of three main parts (background information, habits of media consumption, scientific literacy) as well as an optional comment form. It takes approximately 15 minutes to fill.

1. Background information (*Circle one option on every multiple-choice question unless otherwise specified.*)

Sex[/gender]?
1 Male
2 Female
3 I prefer not to answer

Year of birth?
____

What is your highest degree of education?
1 Primary school
2 Vocational education
3 Matriculation examination
4 Post-secondary education (old)
5 University of applied sciences (polytechnic)
6 Lower university degree
7 Higher university degree
8 Something else, what?
____

What kind of Internet connection do you have access to at home? (*Circle all options that apply.*)
1 I do not have access to an Internet connection at home.
2 A mobile connection (for example a mokkula, nettitikku, USB-modem or a smartphone Internet connection)
3 Solid Internet connection (for example an ADSL or a cable modem)
4 Fiber-optic connection
5 Something else, what?
____

Which church, religious community or religious group do you consider belonging to?
1 None
2 The Evangelical Lutheran Church of Finland
3 Finnish Orthodox Church
4 Other religious community, what?
____

Which of the following best describes your view of God?
1 I do not believe in God.
2 I believe in God, and I believe that Christianity is the only true way of knowing him
3 I believe in God, and I believe that Christianity is just one way of knowing him
4 I think of God as being whatever caused the universe
5 I think of God as the laws of nature and everything in the universe
6 I believe in some polytheistic notion of gods Which? _______________________
7 Something else, what?
____
8 I do not know
9 I prefer not to say

How good would you describe your understanding of the following languages to be, *spoken and written*? (*If you do not understand the mentioned language, do not circle any option.*)

	Below average	Average	Good	Excellent	Outstanding	Native language
A. Finnish	1	2	3	4	5	6
B. English	1	2	3	4	5	6
C. Swedish	1	2	3	4	5	6

D. Other language skills? ____

2. Habits of media consumption

How often do you do the following things?
(*Circle one option per item.*)

	Rarely or never	Sometimes, but not every week	At least once a week	Almost every day	At least once a day
1. Watch television (in general; also DVD, blu-ray, video, etc.)	1	2	3	4	5
2. Watch pay television	1	2	3	4	5
3. Watch news, documentaries, or science and current affairs programs on television (also DVD, blu-ray, and video documentaries)	1	2	3	4	5
4. Listen to radio (also Internet radio)	1	2	3	4	5
5. Use the Internet to read or watch news (for example news pages, newspaper pages; blogs, Ampparit.com, Reddit news sections, etc.)	1	2	3	4	5
6. Use the Internet to search information or to learn things (for example Google, Wikipedia, YouTube educational content, Khan Academy, Coursera, etc.)	1	2	3	4	5
7. Use the Internet to communicate with others (for example chat, Facebook, Twitter, Skype, forums, virtual communities, etc.)	1	2	3	4	5
8. Produce Internet content (for example blog, vlog, web pages, podcast, publishing photos, etc.)	1	2	3	4	5
9. Use the Internet to view or listen to entertainment content (for example YouTube's entertainment content, Netflix, memes, series, movies, music, Spotify, torrents, etc.)	1	2	3	4	5
10. Use the Internet to organize life (for example calendars, e-mail, etc.)	1	2	3	4	5
11. Use a smart device (for example a smartphone, tablet, Google glass, etc.)	1	2	3	4	5
12. Play digital single player games (for example on a mobile device, console, or PC)	1	2	3	4	5
13. Play digital multiplayer online games requiring team coordination	1	2	3	4	5
14. Read a newspaper (either in paper or electronic form)	1	2	3	4	5
15. Read fictional books (either in paper or electronic form)	1	2	3	4	5
16. Read non-fiction books, science magazines, or scientific journals (either in paper or electronic form)	1	2	3	4	5
17. Read magazines (either in paper or electronic form, for example Aku Ankka, MeNaiset, Tekniikan Maailma, Pelit, Mikrobitti, etc.)	1	2	3	4	5

Which media source do you consider your primary source to do the following?
(*Cross one media source per item – the one you consider your primary source.*)

	Television	Pay television	Radio	Internet	Newspapers	Magazines	Non-fiction books	Fictional books	Digital games
1. Following the news	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Searching for information	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Learning a new language	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Learning new knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Following social conversations	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Participating in social conversations	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Entertainment, socializing, and other passing of time	☐	☐	☐	☐	☐	☐	☐	☐	☐

Describe briefly: what kind of media contents do you like to use? (*Media contents can be, for example, certain or certain kinds of television programs, magazines, books, games, or Internet contents, such as YouTube- and Twitter channels, Facebook groups, podcasts, Reddit sections, TED, Ampparit, Wikipedia, etc.*)

____
____
____
____
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Describe briefly: from what kind of media contents do you consider learning the most amount of new knowledge? Mention a few examples.

____
____
____
____
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____
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____

3. Scientific literacy

According to current scientific knowledge, are the following claims true or false?
(*Cross one answer per item.*)

	True	I'm not sure	False
1. Light travels faster than sound.	☐	☐	☐
2. All plants and animals have DNA.	☐	☐	☐
3. The center of the Earth is very hot.	☐	☐	☐
4. The continents on which we live have been moving their location for millions of years and will continue to move in the future.	☐	☐	☐
5. Over periods of millions of years, some species of plants and animals adjust and survive while other species die and become extinct.	☐	☐	☐
6. Astrology is not scientific.	☐	☐	☐
7. Antibiotics kills viruses as well as bacteria	☐	☐	☐
8. Electrons are smaller than atoms.	☐	☐	☐
9. Ordinary tomatoes do not have genes, but genetically modified tomatoes do.	☐	☐	☐
10. Lasers work by focusing sound waves.	☐	☐	☐
11. The earliest humans lived at the same time as Tyrannosaurus Rex.	☐	☐	☐
12. Human beings developed from earlier species of animals.	☐	☐	☐
13. The universe began with a huge explosion.	☐	☐	☐
14. More than half of human genes are identical to those of mice.	☐	☐	☐
15. All radioactivity is manmade.	☐	☐	☐
16. Radioactive milk can be made safe by boiling it.	☐	☐	☐
17. Nuclear power plants destroy the ozone layer.	☐	☐	☐
18. If the present rate of fossil fuel use continues, serious long-term environmental damage will occur.	☐	☐	☐
19. Homeopathy is an effective way of treating diseases.	☐	☐	☐
~~20. AIDS can be transmitted to another person by sexual intercourse.~~	~~☐~~	~~☐~~	~~☐~~

Which of the following claims holds true the best?
(*Circle one answer per item.*)

A doctor tells a couple that they have a one in four chance of having a child with an inherited illness. Which of the following claims is true?

A. If they have only three children, none will have the illness.
B. If their first child has the illness, the next three will not.
C. Each of the couple's children will have the same risk of suffering the illness.
D. If the first three children are healthy, the fourth will have the illness.

Which of the following is true?

A. The Sun circles around the Earth.
B. The Earth circles around the Sun.

How long does one full orbit in the previous question approximately take?

A. One day.
B. One month.
C. One year.

If inflation occurs, prices will…

A. …increase.
B. …decrease.
C. …stay the same.

Why is a control group important when testing a new medicine?
(*Choose the option that is closest to correct.*)

A. So that the results can be made to confirm the researchers' hypothesis.
B. So that the influence of third variables, like placebo, can be controlled.
C. This way the adjustment of the test subjects to the experiment can be ensured.
D. Because controlling is obligated by the government.

What is DNA?

A. The smallest particle in all known organisms.
B. A tissue type, which contains biological information necessary for the functioning of all organisms.
C. A molecule, which contains the genetic instructions used in the development and functioning of all known organisms.

What is a stem cell?
(*Choose the option that is closest to correct.*)

A. A cell that can divide into other cells of an organism.
B. A cell of which the supporting structure of all organisms consist of.
C. An artificially manufactured cell.
D. A cell type found only in plants.

What is socialization?

A. A progression brought on by an advanced form of socialism, which leads to a new social system.
B. A psychological chain of events in which an individual shapes to be more extravert.
C. An interactive process between an individual and society in which the individual grows into the society.

What is a neuron?

A. A psychiatric anxiety disorder.
B. A nerve cell: a cell found in the nervous tissue, and which passes on nerve impulses.
C. An electric impulse: the basic unit of all electrochemical activity in organisms.

4. Comments?

On this section, you can provide feedback or comments about the survey, if you wish. Also, all opinions on science and media in society are welcome and valuable.

MANY THANKS FOR ALL YOUR TROUBLE!

Return the forms to the appointed person.