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Vision III of scientific literacy and science education: an alternative vision for science education emphasising the ethico-socio-political and relational-existential

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Vision III of scientific literacy and science education: an alternative vision for science education emphasising the ethico-socio-political and relational-existential

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ABSTRACT

Publications with Vision III-ideas of scientific literacy and science education are reviewed. Since its inception in 2007, the same year as Vision I and II were first formulated by Roberts, there have been at least eight mainly independent proposals for Vision III. The ideas encapsulated in Vision III – understood as alternative views to Western mainstream understandings – have been in existence for an even longer period. Different interpretations of Vision III are reviewed. Common interpretations and emphases are (environmental) engagement, pluralism, realising complexity, the political, and responsible knowing-in-action. The article explores how the three visions relate to each other and their different curriculum emphases. Six new curriculum emphases are suggested for Vision III: STS-perspectives (science and technology studies), ethico-socio-political perspectives, agency, philosophical values, cultural-existential perspectives, and embodied knowledge. The article culminates with a suggestion of an integrated conceptualisation of Vision III. Scientific literacy from Vision III-perspectives can be characterised as: based on broad scientific knowings, fundamental and digital literacy, and an understanding of our complex world from pluralistic perspectives (cross-disciplinary, critical, history-philosophy-sociology, intersectionality, indigenous worldviews, relationalism), being engaged and prepared for 'glocal' action. In essence, Vision III can be seen as synonymous with critical-eco-reflexive *Bildung*-oriented scientific literacy and science education.

KEYWORDS

Vision III; scientific literacy; science curriculum; curriculum emphases; environmental education

Introduction

Since 1945, when the term was first used by the American physicist Gaylord Harnwell[1] (Rudolph, 2024), many different definitions of *scientific literacy* (SL) have been put forward (e.g. Costa et al., 2021; Holbrook & Rannikmae, 2009; Osborne & Pimentel, 2023; Rudolph, 2024). It is often seen as based on a blend of three knowledge dimensions: (a) important scientific terms and concepts, (b) nature of science (NOS) aspects, and (c) interaction of science-technology-society-environment (STSE) aspects. According to Jarman and McClune (2007), scientific literacy involves an 'understanding of scientific terminology and concepts, scientific

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enquiry and practice, and the interactions of science, technology, and society' (Jarman & McClune, 2007, p. 3). These three dimensions are intertwined (Murcia, 2009).

The following components are typically suggested to be included in a broad conceptualisation of scientific literacy (see e.g. Holbrook & Rannikmae, 2009):

- understanding science and its applications
- understanding Nature of Science (NOS), including its relationship with culture
- knowledge of the benefits and risks of science
- ability to distinguish science from non-science
- ability to think scientifically and critically about science
- ability to use scientific knowledge in problem solving and responsible decision-making

Since its first appearance in the mid-1940s, the following four meanings of scientific literacy have been the most prominent, according to Rudolph (2024): (1) scientific literacy to maintain the scientific elite in a democratic political system, (2) scientific literacy for a critical understanding of science and society, (3) scientific literacy for economic development, and (4) scientific literacy as a basic content knowledge. Rudolph (2024) contends that 'Scientific literacy [...] has never been a specific thing at all. Its meaning has continually shifted depending on the demands of historical moments in time, who is doing the defining, and for what purpose' (Rudolph, 2024, p. 528). However, Shen in 1975 identified three basic forms of scientific literacy that remain applicable today (Rudolph, 2024) in a broad sense, although the details in their original formulation were described in a quite modernistic way. The three basic forms are as follows: practical scientific literacy (science knowledge for solving everyday problems), civic scientific literacy (knowledge in and about science to engage with science-related social issues), and cultural scientific literacy (Shen, 1975). Sometimes it is instead formulated as five arguments for scientific literacy for all: the economic argument, the utility argument, the democratic argument, the social argument, and the cultural argument (Ryder, 2001, referring to; Millar, 1996).

Recently, Almeida et al. (2023), based on several references, claimed that scientific literacy consists of at least the following five components:

> (i) the understanding of science and its applications, (ii) the understanding of nature of science (NOS) and its relationship with culture, (iii) the ability to identify what may (and what may not) be considered as science, (iv) the ability to think scientifically, and (v) the ability to produce arguments using scientific data and reasoning to engage in meaningful conversations about scientific issues. (p. 568)

In 2007, Roberts suggested his two well-known visions of scientific literacy: Vision I and Vision II. Simplified, Vision I can be described as science without society (internal view), whereas Vision II is about contextual application of scientific knowledge in life and society (external view) (see further, Table 1). Fensham (2012) summarised the two visions as:

> Vision I SL derives its meaning and content for learning by looking inward at the canons of the natural sciences, particularly biology, chemistry, earth sciences and physics. Vision II derives its meaning from real world situations students are likely to encounter in their lives that have a scientific component (p. 9).

In relation to Shen's (1975) three basic forms of scientific literacy, Vision I is closest to practical scientific literacy, while Vision II is closest to civic scientific literacy and cultural

Table 1. Notions of three different visions of scientific literacy (according to Siarova et al., 2019, p. 15; based on, Liu, 2013, p. 29).

Vision	Emphasis	Content	Orientation
Vision I	Scientific content	Knowledge, skills, habit of mind, and disposition	Within science
Vision II	Science-technology societal issues	Knowledge in action, practical problem-solving, attitude, and professionalism	Science in relation to society
Vision III	Scientific engagement – social, cultural, political, and environmental issues	Critical thinking, communication, consensus building	Science within society

scientific literacy. In relation to the four meanings identified by Rudolph (2024), aspect (2) – scientific literacy for a critical understanding of science and society – is closest to Vision II, whereas the other three are closer to Vision I. However, at the same time, and according to Ibrahim et al. (2022), there are 'tendencies of most mainstream science education to fall under Vision-I/II's umbrella' (Ibrahim et al., 2022, p. 41), where Vision I from critical perspectives can be seen as a positivist approach and Vision II as based on individualistic and utilitarian perspectives (Gandolfi, 2024). The development of an alternative vision, Vision III, has largely been driven by a perceived lack of emphasis on civic and cultural scientific literacy, including a critical understanding of the interaction between science, technology, society, and environment.

As will be shown in this article, the majority of papers that conceptualise, utilise, or refer to Vision III, position it as a critical alternative to the other vision(s). However, interpretations of its critical nature vary. Some see Vision III as merely 'a more critically oriented form of Vision II' (Cetinkaya & Saribas, 2023, p. 1175), while others, like Ibrahim et al. (2022), perceive a clear divide with Visions I and II, on one side (rooted in a neoliberal worldview), and Vision III, on the other.

In fact, a 'Vision IV for scientific literacy, one that is concerned with education as socio-eco-activism' (Jones, 2017, p. 520) has also been proposed. Jones suggested this fourth vision as a further development of Aikenhead's (2007) Vision III. Similarly, in a recently published paper, Jones et al. (2024) instead suggested a Vision IV for socio-political activism built on Sjöström and Eilks' (2018) Vision III. However, in this article I argue that socio-eco-activism and socio-political activism can be incorporated as one facet of a broad Vision III-conceptualisation.

Already in 2003, Carter and Smith argued for a re-visioning of the traditional view of science education. Their argument was grounded in futures perspectives and the field of science [and technology] studies (STS).[2] They maintained:

> It seems to us that an approach to the science education which is based upon insights from science studies and critical ecology firmly embedded in futures perspectives is essential for a more relevant, critical and just science education. (p. 49)

This can be seen as the initial formulation of a Vision III, although the term was not coined at that time. Carter and Smith (2003) suggested six guiding principles for science education: (1) being framed in a futures perspective, (2) being socially critical, (3) including the history and philosophy of science, (4) focusing on what it takes to create a sustainable future, (5) including postcolonial perspectives, and (6) invoking a sense of wonder and transcendence (Carter &

Smith 2003, p. 50). As I will demonstrate in this article, these principles align well with a comprehensive understanding of Vision III.

Eight years after Carter and Smith's publication, Choi et al. (2011) discussed scientific literacy for the 21st century. They highlighted the following five dimensions in a global context: content knowledge (including big ideas), science as a human endeavour (including characteristics of scientific knowledge, science and society, and the spirit of science), metacognition and self-direction, habits of mind (including systemic thinking), and character and values (including ecological worldview). In their theoretical framework, they suggested the following three key elements for a global citizen within the dimension of character and values: ecological worldview, socio-scientific accountability, and social and moral compassion. As I will demonstrate in this article, these ideas align closely with a Vision III-view of scientific literacy. Choi et al.'s paper was followed up by a paper by Mun et al. (2015), which emphasised the importance of 'global scientific literacy'.

The three visions can be succinctly described as follows: Vision I concerns the learning of scientific content and processes for future application; Vision II focuses on understanding the utilisation of scientific knowledge in everyday life and social contexts; while Vision III emphasises philosophical values, transdisciplinarity and critical thinking (e.g. Sjöström & Eilks, 2018). Several different ideas (or maybe better facets) of a Vision III have been suggested, all of which share a (post)humanistic view of science and science education.

Since the publication by Roberts (2007), there have been at least eight mainly independent propositions of a Vision III (Aikenhead, 2007; Hadzigeorgiou & Stamatis, 2017; Liu, 2013; Murray, 2015; Schulz, 2009; Sjöström & Eilks, 2018; Tan, 2016; Yore, 2012). All these eight publications, barring Murray's (2015), refer to Roberts (2007) paper that introduced Vision I and II. However, Murray (2014) did reference it in his PhD thesis. The term 'mainly independent' is used because at least Tan (2016) and Sjöström and Eilks (2018) acknowledge some previous Vision III-suggestions. Several recent reviews addressing Vision III (Hernández-Ramos et al., 2021; Holbrook et al., 2022; Siarova et al., 2019; Tippett et al., 2019; Valladares, 2021) often cite the same papers, including those by Yore (2012), Liu (2013), and Sjöström and Eilks (2018). Therefore, these three papers are primarily associated with the concept of a Vision III of scientific literacy in research literature. Yore (2012) emphasised the fusion of fundamental and derived senses of scientific literacy, Liu (2013) focused on scientific engagement and participation, while Sjöström and Eilks (2018) discussed individual and societal transformations and socio-political actions.

Aikenhead's initial suggestion of a Vision III was formulated concurrently with Roberts (2007) initial publication about Vision I and II. Holbrook et al. (2022), drawing their description of Vision III on Aikenhead (2007), Yore (2012), Sjöström and Eilks (2018), and Valladares (2021), describe it as an approach that 'seeks to expand the scope of scientific literacy in promoting, both individually and collectively, as active societal engagement in resolving societal concerns' (Holbrook et al., 2022, p. 3). Similarly, Birdsall (2022) suggests that from a Vision III perspective, the purpose of scientific literacy 'is that of developing students' understanding of science, its practices, and the way it is embedded in society, reflecting that society's culture and norms' (Birdsall, 2022, p. 240). Furthermore, it needs to 'develop students' critical thinking so that they can discuss and consider the ethics, values, and risks involved in societal issues [. . . and use . . .] knowledge to make decisions and take action, both personally and collectively'. Rasa et al. (2024) elaborate, 'The Vision

III approach augments SL with a proactive component, the capacities required to shape the world in socioscientific contexts in accordance with one's values, in line with the personal, cultural and democratic purposes of science education' (Rasa et al., 2024, p. 1147). As early as 2009, Murcia, without referring to the three visions, underlined that 'Scientific literacy is clearly about KNOWING but it is also about a way of THINKING and ACTING'. (Murcia, 2009, p. 219).

The following two questions guide this review article:

- How has Vision III developed, and how is it portrayed in the literature compared to Vision I and II, particularly in terms of different interpretations and curriculum emphases?
- What could characterise a multifaceted and integrated Vision III of scientific literacy and science education?

The subsequent elaboration on these two questions will be divided into the following seven sections: The upcoming section presents the literature search that forms the basis of the review and some statistically interesting findings. The following section delves into a discussion of the three different visions, obviously with a special focus on Vision III. It outlines the main elements of Vision III conceptualisations and their connection to environmental literacy. The section thereafter explores the path dependence of various Vision III conceptualisations. The following section examines three different interpretations of how the three visions relate to each other: (a) as complementary visions; (b) as levelled visions, with increased sophistication; and (c) as Vision III bridging Vision I and II from critical perspectives. The next section focuses on the relationship between the three visions and different curriculum emphases. A model with eight curriculum emphases of Vision III is presented. Two of these, 'Self as explainer' and 'Science and decisions', are derived from Roberts (1982, 2011) classical seven curriculum emphases. These two are complemented with six new curriculum emphases: STS-perspectives (perspectives from science and technology studies), ethico-socio-political perspectives, agency, philosophical values, cultural-existential perspectives, and embodied knowledge. The section also introduces A and B versions for all three visions: structure of science-emphasis (Vision IA), scientific skills-emphasis (Vision IB), everyday life-emphasis (Vision IIA), decision making-emphasis (Vision IIB), ethico-socio-political-emphasis (Vision IIIA), and relational-existential-emphasis (Vision IIIB). Vision III (both A- and B-versions together) has an ethico-socio-political-relational-existential-emphasis and can be seen as synonymous with critical-eco-reflexive *Bildung*[3]oriented scientific literacy and science education. The subsequent section touches upon the connection to worldview perspectives and *Bildung*. The final section presents a multifaceted and integrated conceptualisation of Vision III, based on the results of the review.

About the literature search

A search was conducted on Google Scholar using the terms 'Vision III' AND 'scientific literacy' on the 1st of February 2024. This resulted in 227 hits[4] initially (similar searches with 'Vision I' (883 hits) or 'Vision II' (831 hits) gave about four times more hits). However, the real number of hits transpired to be somewhat lower, 210 hits. After removing duplicates, 197 hits remained. Of these, 85 are referred to in this article and marked with a star ('*') in the reference list. Among the 197 hits, 180 were in English. The remaining 17 hits were in various languages: German (6), Danish (3), Swedish (3), Arabian (1), Finish (1), French (1), Korean (1), and Portuguese (1). The distribution of hits based on years and sources will be described shortly.

When 'Vision III' was paired with a different search term other than 'scientific literacy', the following number of hits were obtained (for comparison, 'scientific literacy' as a search term resulted in 227 hits): 'science education' (274 hits), 'science knowledge' (84 hits), 'physics education' (35 hits), 'chemistry education' (82 hits), 'biology education' (24 hits), 'environmental education' (103 hits), 'environmental literacy' (32 hits), 'critical scientific literacy' (73 hits), and 'action competence' (36 hits). These hits were typically the same and included in the group of hits when searching for 'Vision III' AND 'scientific literacy'. Therefore, the ensuing analysis is mainly based on the aforementioned literature search. Some additional articles of relevance (Marušić Jablanović, 2020; Murray, 2014; Rudolph, 2024) were discovered when the search terms 'third vision' and 'scientific literacy' were used, yielding a total of 47 hits, the majority of which were part of the initial 227 hits.

Figure 1 shows the distribution of hits for the terms 'Vision III' AND 'scientific literacy' over various years. It clearly indicates that Vision III has become much more common in the science education literature in recent years.

Of the 180 English hits, 84 were publications in scientific journals. The number of hits for journals with more than one hit is detailed in Table 2. Among the other hits, 21 were Springer chapters and 6 Routledge chapters, three of which were chapters in the latest *Handbook of Research on Science Education* (Dillon & Herman, 2023; Osborne, 2023; Zeidler & Sadler, 2023). The 180 hits also included 27 other scientific publications, 12 conference abstracts, and 30 academic theses. Of the latter, 24 were PhD theses from: the USA (6), Canada (4), New Zeeland (4), Finland (2), Germany (2), Iceland (1), India (1), Ireland (1), Spain (1), Sweden (1), and the UK (1).

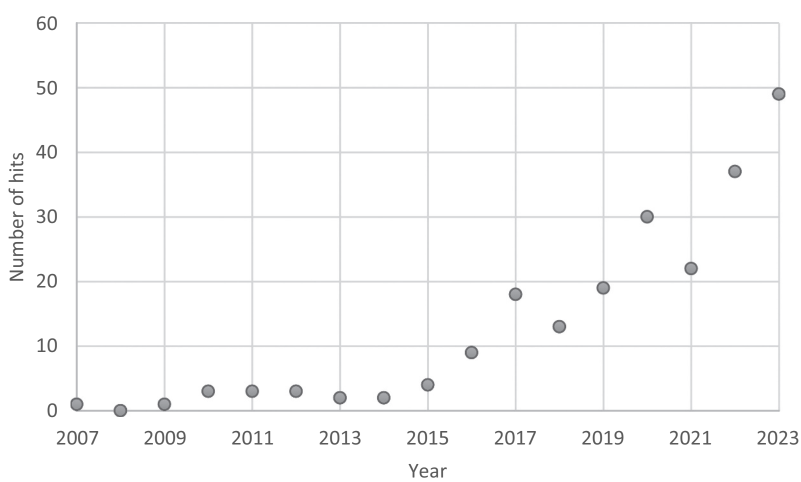

Figure 1. Distribution of hits for 'Vision III' and 'scientific literacy' in a Google scholar search made 1st of February 2024. The three hits found for January 2024 are not included in the diagram.

Table 2. Journals with more than one hit when the 1st of February 2024 searching for 'Vision III' and 'scientific literacy' on Google Scholar.

Journal	Hits
Science & Education	11
Asia-Pacific Science Education	8
International Journal of Science and Mathematics Education	8
Cultural Studies of Science Education	7
International Journal of Science Education	5
Journal for Activist Science and Technology Education	5
Journal of Chemical Education	4
Frontiers in Education	3
International Journal of Science Education, Part B	3
SFU [Simon Fraser University] Educational Review	3
Canadian Journal of Science, Mathematics and Technology Education	2
Chemistry Education Research and Practice	2
Educational Sciences	2
Sustainability	2
The Curriculum Journal	2
TOTAL	*67*
17 journals with one hit each	17
TOTAL (including those with one hit)	*84*

Except for one (Murray, 2015) (see further below), all eight publications that mainly independently suggested a Vision III were among the 180 English hits from the Google Scholar search for 'Vision III' AND 'scientific literacy' conducted on 1st of February 2024. The first suggestion of a Vision III was published in a chapter in a book entitled *Promoting Scientific Literacy: Science Education Research in Transaction* (Aikenhead, 2007). The other Vision III-suggestions were published in Springer chapters (Liu, 2013; Sjöström & Eilks, 2018; Yore, 2012) or in articles published in the journals *Science & Education* (Schulz, 2009), *Interchange* (Hadzigeorgiou & Stamatis, 2017), and *SFU Educational Review* (Tan, 2016; Tan, 2020), respectively. The article by Murray (2015), which was published in the magazine *Education Canada*, was not among the publications found in the Google Scholar search. However, two of the hits found were other texts by Murray, both referencing Aikenhead's (2007) first Vision III-publication. When the search terms 'third vision' and 'scientific literacy' were used, Murray's (2014) PhD thesis was found.

To provide a more detailed overview of the type of common content and perspectives in publications that use both 'Vision III' and 'scientific literacy', a word frequency count was made on the titles of the 85 publications in the reference list marked with '*'. Of these, 'scientific literacy' appears in 25 titles and 'science education' in 27 titles. Additionally, two of the references use 'critical scientific literacy', while one of them mention 'civic scientific literacy'. Some common words in the titles include the following: socioscientific (16 instances, with different spelling including SSI), curriculum/curricula (10), vision (9 instances, with two publications mentioning three visions in the title), critical (7), sustain (-ability/-able; 7), climate (6), citizenship (5), future (5), context (5), transform (-ative/-ation; 5), *Bildung* (5), responsible (4), agency/action (3), citizen science (3), and STEAM (3). Some examples of words, although only used in one title each, show the more specific orientation of those papers: energy, plastics, vaccination, misinformation, and risk.

About the three visions, focusing Vision III

Table 3 presents Vision III-ideas featured in more than 30 publications from the past two decades. It encompasses all eight papers with mainly independent suggestions of a Vision III. Included are also the recent visions-reviews by Valladares (2021) and Osborne (2023), a paper by Zeidler and Sadler (2011) suggesting a *Vision IIB* as a complement to Roberts' two visions (see further below), works focusing on 'critical scientific literacy' (Dos Santos, 2009; Hodson, 2003, 2011), a number addressing social justice and democracy (Birdsall, 2022; Dagher, 2020; Yacoubian, 2018), and publications discussing action/agency/activism (Johansen & Afdal, 2018; Jones, 2017; Rasa et al., 2022).

Publications mentioning 'Vision III' – Jones (2017); Johansen and Afdal (2018); Sjöström (2018); Dagher (2020); Valladares (2021); Lüsse et al. (2022); Kwon et al. (2022); Osborne and Pimentel (2023), among others – are all included among the 180 English hits in the Google Scholar search for 'Vision III' AND 'scientific literacy'. Obviously, those publications *not* mentioning Vision III – Hodson (2003); Dos Santos (2009); Witz and Lee (2009); Yacoubian (2018); Almeida et al. (2023); Zetterqvist and Bach (2023), among others – were *not* found in this literature search.

Table 3, primarily arranged according to publication date, presents several different and complementary interpretations of a Vision III. These interpretations range from fundamental literacy (Yore, 2012), via digital media literacy (Osborne & Pimentel, 2023) and cognitive change (Hadzigeorgiou & Stamatis, 2017), to a deep understanding of science and its processes (Hadzigeorgiou & Stamatis, 2017; Schulz, 2009; Zetterqvist & Bach, 2023). It also includes nature-of-science for social justice (Dagher, 2020), engagement and participation (Liu, 2013), critical thinking in a broad sense (Almeida et al., 2023), citizen science (Kwon et al., 2022; Lüsse et al., 2022), socio-political and critical-emancipatory aspects (Birdsall, 2022; Sjöström & Eilks, 2018), environmental and sustainability literacy (Colucci-Gray et al., 2006; Sjöström & Eilks, 2018; Yavuzkaya et al., 2022), informed action/agency (Johansen & Afdal, 2018; Rasa et al., 2022), and knowing-in-action (Aikenhead, 2007).

Furthermore, Vision III involves evaluating different alternatives in relation to questions of a moral-political nature (Lidar et al., 2018; Romine et al., 2020; Sund, 2016; Yacoubian, 2018; Zeidler & Sadler, 2011), plural-science-perspectives (Aikenhead, 2007), intersectionality perspectives (Valladares, 2021), and/or alternative indigenous worldviews (Murray, 2014, 2015; Tan, 2020). It also encompasses embodied knowledge and relationalism (Sjöström, 2018), including global interdependence (Tan, 2020), as well as emancipation and socio-political actions (Birdsall, 2022; Dos Santos, 2009; Hodson, 2003, 2011; Johansen & Afdal, 2018; Jones, 2017; Rasa et al., 2022; Sjöström & Eilks, 2018).

The first two explicit suggestions of a Vision III were formulated independently by Aikenhead (2007) and Schulz (2009). Around the same time, there were additional suggestions to expand Roberts' Vision II, including the previously mentioned Vision IIB by Zeidler and Sadler (2011). In her PhD thesis, Katarina Ottander (2015) acknowledged Vision I, IIA, and IIB, but she primarily focused on another categorisation. This categorisation comprised three main orientations in the research literature on science teaching:

Table 3. Vision III-ideas in more than 30 publications during two decades.

Paper (parentheses around surname(s) means that the paper does not use Vision III)	Vision III-idea(s) (sometimes among other ideas)
(Carter & Smith, 2003)	Futures perspectives; socio-critical; history and philosophy; sustainability; postcolonial perspectives; sense of wonder
(Roth & Barton, 2004)	New vision of scientific literacy; Science as collective praxis for social justice (see also Fourez, 1997; Roth & Lee, 2002, 2004)
Aikenhead (2007)	Plural-science-perspectives; Knowing-in-action (this was the first paper using Vision III)
(Dos Santos, 2009; Hodson, 2003, 2011)	Critical scientific literacy[12] (however, these publications did not use the term Vision III)
(Colucci-Gray et al., 2006)	Sustainability literacy based on scientific literacy (however, this paper did not use the term Vision III)
Schulz (2009)	Deep understanding of science and its processes; Plural-science-perspectives, including history-philosophy-sociology (HPS)
(Witz & Lee, 2009)	Metaphysical, moral-ethical, spiritual and aesthetic values (this paper presented a humanistic vision, but did not use the term Vision III)
(Zeidler & Sadler, 2011) (Zeidler, 2014)	Moral-political nature of evaluations and decisions (this paper used Vision IIB instead of Vision III). The paper from 2014 established a new understanding of the related concept of 'functional scientific literacy',[13] emphasising moral growth and development of character
(Fensham, 2012)	Complexity; uncertainty; high risk; need for multidisciplinarity (connected teaching about grand environmental challenges to Vision II)
Yore (2012) (Yore first mentioned Vision III in Yore, 2011, p. 27)	Emphasised not to forget fundamental literacy (first highlighted by Norris & Phillips, 2003)
Liu (2013)	Engagement and participation
Murray (2015) (Murray first mentioned a 'third vision of science education' in Murray, 2014, p. iii)	Plural-science-perspectives, including alternative indigenous worldviews
Sjöström and Eilks (2018); Sjöström (2018) *(both accepted in 2016)*	Socio-political embeddedness and emancipation Embodied knowledge and relationalism Connected Vision III to the European *Bildung* tradition Science education for sustainability (Sjöström, 2015)
(Jones, 2017)	Socio-eco-activism (this paper used Vision IV instead of Vision III)
Hadzigeorgiou and Stamatis (2017)	Cognitive change; Deep understanding of science and its processes
Johansen and Afdal (2018)	Connected Vision III to action competence (referring to Mogensen & Schnack, 2010, who did not use the term Vision III)
(Yacoubian, 2018)	Democratic decision-making (this paper did not refer to the three visions, but presented a vision of scientific literacy for democratic decision-making)
Tan (2020); Tan (2016)	Plural-science-perspectives, including alternative indigenous worldviews; embodied and relationalism, including global interdependence; posthumanism; bridging Cartesian divides; melding Science and Art, i.e. emphasising STEAM where A stands for Art
Dagher (2020)	Connected Vision III to NOS for social justice
Romine et al. (2020)	Connected Vision III to socioscientific reasoning (SSR),[14] including complexity, multiple perspective-taking, scepticism, and inquiry (Bennett, 2020, related Vision III to 'socioscientific literacy as a cross disciplinary educational goal')
Valladares (2021)	Emphasised addition of intersectionality perspectives
(Almeida et al., 2023)	Critical thinking about/with NOS as part of scientific literacy and connected to self-awareness-raising, critical positioning and decision-making (this paper did not refer to the three visions, but mentioned 'vision of NOS')
Lüsse et al. (2022); Kwon et al. (2022)	Connected Vision III to citizen science

(*Continued*)

Table 3. (Continued).

Paper (parentheses around surname(s) means that the paper does not use Vision III)	Vision III-idea(s) (sometimes among other ideas)
Birdsall (2022)	Justice-oriented scientific literacy; socially and culturally relevant socioscientific issues involving ethics and risk are being negotiated and deliberatively discussed as a basis for socio-political action
Rasa et al. (2022, 2024)	Value-based agency-oriented scientific literacy; connected Vision III to futures literacy och technology; addressed complexity, uncertainty and alternative futures; emphasised finding meaningful agency within personal and global futures
Yavuzkaya et al. (2022, p. 5)	Connected Vision III to Anthropocene awareness
Salinas et al. (2022); Fuchs (2023a)	Connected Vision III to climate change education and activism
(Zetterqvist & Bach, 2023)	Emphasised the importance of 'epistemic knowledge' in decision-making in society (however, this paper did only refer to Vision I and II)
Osborne (2023)	Vision III of scientific literacy as a collective property in a complex knowledge society (referring to Roth & Lee, 2002; who did not use the term Vision III; see also Roth & Lee, 2004)
Osborne and Pimentel (2023)	Connected Vision III to digital media literacy and to STS[15] competences of 'outsiders to science' (referring to Feinstein, 2011, who did not use the term Vision III).

evidence-based, values-including, and socio-political/activism. Typically, the evidence-based orientation is aligned with Vision I, whereas the values-including and socio-political/activism orientations are more aligned with Visions II and III. As mentioned above, some authors do not distinguish significantly between Vision II and III, both of which are socio-oriented (e.g. Broderick, 2023). However, others – mainly those highlighting socio-critical perspectives in a broad sense – see a dividing line between Vision I and II on one side, and Vision III on the other (e.g. Gandolfi, 2024; Ibrahim et al., 2022).

As previously noted, some authors argue that Vision III is merely a more extreme version of Vision II. However, others suggest that Vision II can be divided into two subcategories Vision IIA and Vision IIB (e.g. Lidar et al., 2018; Sund, 2016; Zeidler & Sadler, 2011). Vision IIA includes knowledge used to solve everyday problems, while Vision IIB involves knowledge needed to address issues requiring the evaluation of different alternatives in relation to moral-political questions (see further below). In a chapter written in Swedish, Lundqvist et al. (2013) connected Vision I to Aristotle's Theoria (knowledge), Vision IIA to Techne (applying knowledge), and Vision IIB to Praxis/Phronesis (awareness of ethical and political values when using knowledge in decision-making). This can be compared to how Sjöström and Eilks (2018) described the three visions in a table, where Vision II was connected to Techne and Vision III to Praxis/Phronesis (see Table 4). Based on this, we can conclude that the dividing line between Vision IIB and Vision III is not always clear; it can indeed be a grey area at times. Nonetheless, I believe it is reasonable to establish a fairly distinct dividing line been Vision II and Vision III. Vision III is a much more complex and *Bildung*-oriented vision than Vision II (see e.g. Sjöström & Eilks, 2018; Sjöblom et al., 2024 and further below).

In her paper 'Scientific literacy and social transformation: critical perspectives about science participation and emancipation', Valladares (2021) explored different interpretations of scientific literacy, including Vision III. She began her discussion with the fundamental and derived senses of scientific literacy (part 2 of her paper), as well as Vision I and

Table 4. Connection between the three visions of scientific literacy, different knowledge types/ideal, aims with scientific research and emphasis in science education (from table 4.1 in Sjöström & Eilks, 2018, p. 78; see also table 1 in Valladares, 2021, p. 569).

Vision	Knowledge types/ ideals	Aims with scientific research (Sjöström, 2013)	Emphasis in science education
I: Pipe-line science	*Theoria/episteme* Intellectual Disciplinary rationality	Development of scientific understanding (mode 1)	Epistemological
II: Science for all	*Techne* Pragmatic Technical rationality	Growth and wealth, including sustainable development (mode 2)	Everyday life and usefulness
III: Science for transformation	*Praxis/phronesis* Emancipatory Critical rationality	Democracy and justice; critical sustainability (mode 3)	Ethics and transformation

Vision II (part 3). Subsequently, she delved into Vision III, under the heading 'A Transformative Vision of Scientific Literacy' (part 4). She states (2021):

> This new vision integrates three innovative aspects: 4.1: a fusion of the fundamental and derived senses of scientific literacy (Yore, 2012); 4.2: an introduction of the notions of science engagement and participation (Liu, 2013); and 4.3: the inclusion of a political and emancipatory agenda aligned with values such as equity and social justice (Dos Santos, 2009, p. 565)

Further in her paper, Valladares (2021) incorporated intersectionality perspectives as a new facet of a broad Vision III-conceptualisation. This point will be revisited later. The following two subsections will somewhat extend what Valladares outlined as characteristic of Vision III. The first subsection discusses the fusion of fundamental and derived senses of scientific literacy, while the second pertains to participation and socio-political actions. These two subsections are followed by one final subsection about the connection between Vision III and environmental literacy.

Fusion of fundamental and derived senses of scientific literacy as an aspect of Vision III

As previously stated, Yore (2012) in his Vision III-conceptualisation emphasised a fusion of fundamental and derived senses of scientific literacy. As early as 2003, Norris and Phillips suggested that scientific literacy can be understood in two ways: in a fundamental sense – which involves being able to read, write, and talk science – or in a derived sense. While all the three visions mainly understand scientific literacy in a derived sense, they do so in different ways. At the same time, scientific literacy in a fundamental sense can also be important in all the three visions. Siarova et al. (2019) presented the following five aspects in their basic framework for scientific literacy: fundamental [and digital] literacy, scientific knowledge and competences, contextual understanding, critical thinking, and agency/engagement. Lefkos and Mitsiaki (2021) added 'digital literacy' to the first aspect. They combined scientific literacy with a 'multiliteracy approach', including, for instance, basic reading and writing skills, digital skills, 'hands-on skills', media literacy skills, and civic literacy skills.

Instead of these five aspects, Tippett et al. (2019) suggested the following three dimensions in their '3-dimensional model of scientific literacy' (Tippett et al., 2019, p. 325):

- fundamental dimension (this includes metacognition, critical thinking, language and literacy, digital literacies)
- disciplinary dimension (this includes big ideas, nature of science, habits of mind and practices, scientific inquiry, engineering design)
- applied dimension (this includes participation in individual and public decision making about SSI and/or STSE issues)

Participation and socio-political actions as central in Vision III

As already mentioned, Liu (2013) in his Vision III-conceptualisation emphasised scientific engagement and participation. In relation to socio-political aspects, Siarova et al. (2019), with reference to Liu (2013), described Vision III as 'Scientific engagement – social, cultural, political, and environmental issues' (as already shown in Table 1). According to Tan (2016), Yore interpreted a Vision III-scientific literate person as one who: 1) understands core ideas through scientific inquiry, 2) has fundamental scientific principles rooted by *critical thinking skills*, and 3) participates from a scientific perspective in socioscientific issues (Tan, 2016, p. 6). Siarova et al. (2019) regard Vision III as 'the broadest interpretation of scientific literacy' (Siarova et al., 2019, p. 15). They explained it as follows: science embedded in society and societal issues; action in the form of scientific engagement in various social, cultural, political, and environmental issues and contexts; and a means to prepare students to become informed, responsible and active citizens and therefore needed by all students. It involves key elements such as critical thinking.

In their paper 'Reconsidering different visions of scientific literacy and science education based on the concept of *Bildung*', Sjöström and Eilks (2018) expanded upon previous Vision III-conceptualisations by incorporating stronger political and emancipatory aspects. They considered both individual and societal transformations, as well as socio-political actions. Their approach can be labelled 'critical scientific literacy'. Recently, Kruse et al. (2024) argued that this Vision III-approach 'is needed as post-truthism infiltrates our scientific and cultural discourses' (p. 2 a.o.p.).

Sjöström and Eilks (2018) referred to both Dos Santos (2009) and Hodson (2011), who had previously elaborated on 'critical scientific literacy',[5] albeit without using the term 'Vision III'. Hodson (2011) explicitly used 'critical scientific literacy' as a shorthand for 'critical scientific, technological, and environmental literacy'. Sjöström and Eilks (2018) connected this broad understanding of critical scientific literacy to Vision III, thereby also connecting science education to environmental education (see further below and e.g. Dillon & Herman, 2023).

In his recent PhD thesis, Fuchs (2023b) presented a conceptual tool to visualise possible Vision III goals: 'a tool to think about Vision III enactments'. The vertical axis represents possible orientations: self, other, community, and environments. The horizontal axis represents possible goals: recognise harm (identify SSI), evaluate harm, evaluate mitigation strategies, take a stance, mitigate harm (take action), and reflect on mitigation

Table 5. Detailed descriptions of the three visions.

Vision	Description
I	focus on content (Roberts, 2007) 'Learning about scientific content and scientific processes for later application' (Kubisch et al., 2022) no external contextual factors; prepare for a career in science; later application (Siarova et al., 2019, p. 15) obtaining basic science knowledge and inquiry skills (Lee, 2022) 'seeing and interpreting the world as a scientist does' (Murray, 2015) 'Focuses on acquiring scientific knowledge and relevant processes for understanding science and its further applications. This vision focuses mainly on learning about scientific content. However, learning and knowledge do not incorporate links to social, political, or environmental dimensions' (Salinas et al., 2022, p. 8).
II	problem-solving (Liu, 2013, p. 29) pragmatic and procedural (Valladares, 2021) focus on individual and societal contexts (Roberts, 2007) 'understanding the usefulness of scientific knowledge in life and society by starting science learning from meaningful contexts' (Kubisch et al., 2022) considering non-scientific factors; social contexts; science for all; developing responsible citizens (Siarova et al., 2019, p. 15) utilitarian perspectives; decision-making on everyday SSIs (Lee, 2022) Vision II view a scientifically literate person as someone who 'reflects critically on information and appreciates and understands the impact of science on everyday life' (Roberts & Bybee, 2014, p. 547) 'Focuses on understanding the usefulness of scientific knowledge in life and society. This vision exposes applications of science in the daily lives of students by contextualizing scientific knowledge. This vision promotes science for all and typically gives more relevance to science in action or in contexts, aiming to understand the practicality of scientific knowledge in life and society' (Salinas et al., 2022, p. 8).
III	science for transformation (Sjöström & Eilks, 2018) holistic; critical perspectives; socio-political actions (Lee, 2022) embedded science; engagement; action; critical thinking; science for all; developing responsible and active citizens (Siarova et al., 2019, p. 15) relationality and connectivity (Tan, 2020) justice-oriented scientific literacy (Birdsall, 2022) engagement in socio-political action for socio-ecojustice, democracy and eco-reflexivity (Sjöström & Eilks, 2018) knowing-in-action (Aikenhead, 2007, p. 68), critical scientific literacy (Guerrero & Sjöström, 2024; Hodson, 2003; Sjöström & Eilks, 2018) 'Implies a politicized and action-based (e.g. climate change activism) knowledge aiming at promoting the development of critical thinking for dialogic emancipation and socio-eco justice. This vision emphasizes transdisciplinarity and sustainability; is oriented towards praxis and action; aims at articulating scientific literacies with socio-political, economic, and environmental dimensions; and makes references to experiences, reflections, and collective actions. This vision investigates relations of power and justice and incorporates elements of transformation of social reality' (Salinas et al., 2022, p. 9).

(evaluate consequences) (Fuchs, 2023b, p. 54). These possible goals are a simplified version of Hodson's (2011, p. xi) eight steps for socio-political action.

All the three visions are described in more detail in Table 5, with illustrative quotations especially taken from Salinas et al. (2022). Regarding Vision III, the authors particularly emphasised its socio-political orientation, which is in line with the Vision III-interpretation by Sjöström and Eilks (2018).

Vision III and environmental literacy

The environmental education aspect of the field Environmental and Sustainability Education (ESE) can be seen as part of the Science Education field (e.g. Dillon, 2014; Dillon & Herman, 2023; Wals et al., 2014). Thus, a connection between Vision III and environmental issues is expected. A search for 'Vision III' and 'environmental literacy' resulted in 32 hits, including the following references, among others: Fuchs & Tan (2022);

Salinas et al. (2022); Sjöström et al. (2017); and Dillon & Herman (2023). A reference by Marušić Jablanović (2020) was found when searching for 'third vision' and 'environmental literacy'.

Regarding environmental literacy (EL), Hunter and Jordan (2022) have proposed three levels that correspond with increasing participation in a community of practice. Their framework bears similarities to the three visions of scientific literacy and science education (e.g. Sjöström & Eilks, 2018). The three levels, as defined by Hunter and Jordan (2022), are functional EL, cultural EL, and critical EL (see also, Dillon & Herman, 2023, p. 735). Critical EL is described as the ability to 'grapple with social-ecological entanglement and identify human behavior and systems as root of environmental issues and questions how to change them. Engages in greater system-level political and legal behaviors' (Hunter & Jordan, 2022, p. 770). Functional EL includes conceptual knowledge; cultural EL also extends to include knowledge of issues and systems thinking; and critical EL also integrates socio-political knowledge and environmental justice. The subdivision into functional, cultural, and critical literacy can be paralleled with Fuchs' (2023a) subdivision of the three SL visions in relation to climate change education: conceptual – contextual – critical literacy (see also, Sjöström et al., 2017, p. 182).

Both environmental literacy and scientific literacy are viewed as important components of 'sustainability competences' (e.g. Bianchi, 2020; Redman & Wiek, 2021). The latter includes both planning competences, such as systems thinking and futures thinking, as well as disciplinary thinking. According to Park et al. (2020), sustainable actions are driven by 'knowledge, skills, values and attitudes', on the one hand, and by 'participation and action experiences', on the other (Park et al., 2020, p. 21). These authors further detailed these different parts in a table (p. 23). For instance, knowledge is sub-divided into scientific, relational, and responsive categories. Skills include, for example, socioscientific reasoning (SSR)[6]; and values/attitudes include, for instance, ecological perspectives and global citizenship.

Recently, Laherto et al. (2023) connected Vision III to 'sustainability values'. They referred to a framework called *GreenComp*, which consists of four competence areas, each containing three competences (p. 86):

- embodying sustainability values (valuing sustainability, supporting fairness, promoting nature)
- embracing complexity in sustainability (systems thinking, critical thinking, problem framing)
- envisioning sustainable futures (futures literacy, adaptability, exploratory thinking)
- acting for sustainability (political agency, collective action, individual initiative)

In recent years, numerous studies in the field of environmentally oriented science education have referred to Vision III as it is conceptualised by Sjöström and Eilks (2018). These studies are characterised by keywords such as the following: responsible global citizenship (e.g. Avsar Erumit et al., 2024; Birdsall, 2022; Georgiou & Kyza, 2023; Hadjichambis et al., 2024), climate change education (e.g. Fuchs, 2023a; Kubisch et al., 2022; Salinas et al., 2022; Sjöblom et al., 2024), socio-ecojustice (e.g. Fuchs & Tan, 2022; Ibrahim et al., 2022), futures thinking (Rasa et al., 2022, 2024), and agency (e.g. Guerrero & Torres-Olave, 2022). Recently, Kang and Tolppanen (2024) connected Vision III to 'cultivating active agents with growth mindsets [...] in the context of the ongoing climate crisis' (Kang & Tolppanen, 2024, p. 12). Vision III has also been referred to in connection with sustainability exhibitions at museums (e.g. Iannini & Pedretti, 2022; Kellberg et al., 2024). Iddy et al. (2024) recently summarised the Vision III-approach by Sjöström and Eilks (2018) in the following way: 'In essence, Vision III of SL should result in a politically motivated science education that strives for emancipation and socio-ecojustice (Iddy et al., 2024, p. 407).

Path dependence of Vision III conceptualisations

This section will look closer at the path dependence of different Vision III conceptualisations. The section will highlight the background, references, and impact of 13 key papers on Vision III (see Table 6). These include the eight Vision III-papers previously discussed, along with five recent papers by Valladares (2021), Holbrook et al. (2022), Birdsall (2022), Kubisch et al. (2022), and Osborne (2023), respectively. All these additional papers were among the 180 English Google Scholar hits. In five or six of the eight core Vision III-papers (the count is somewhat ambiguous due to Murray's work), a Vision III was proposed in relation to Roberts' two visions, but without considering earlier Vision III-suggestions. As shown in Table 6, seven of the total 13 papers in the table refer to between one and five of the previously published Vision III-papers.

Table 6 also includes Google scholar citations for the 13 papers, offering insights into their respective impact. The four papers with highest impact are Sjöström and Eilks (2018), Valladares (2021), Aikenhead (2007), and Yore (2012).

The different conceptualisations of Vision III, ordered by the number of citations as of 1st of February 2024, are as follows: critical scientific literacy (Sjöström & Eilks, 2018), intersectionality-aware scientific literacy (Valladares, 2021), scientific literacy for pluralistic knowing-in-action (Aikenhead, 2007), fundamental literacy- and multimodal-oriented scientific literacy (Yore, 2012), engagement-oriented scientific literacy (Liu, 2013), indigenous worldviews-aware scientific literacy (Murray, 2014, 2015), HPS-aware scientific literacy (Schulz, 2009), cross- and transdisciplinarity-based scientific literacy (Kubisch et al., 2022), scientific literacy for active societal engagement (Holbrook et al., 2022), justice-oriented scientific literacy (Birdsall, 2022), collective scientific literacy (Osborne, 2023), relationalism-aware scientific literacy (Tan, 2016), and cognitive change-based scientific literacy (Hadzigeorgiou & Stamatis, 2017). To these can be added 'global scientific literacy' (e.g. Choi et al., 2011; Georgiou & Kyza, 2023; Mun et al., 2015) and 'socioscientific literacy as a cross disciplinary educational goal' (Bennett, 2020).

Altogether, different facets frame Vision III in the following way: it is based on broad scientific knowings, fundamental and digital literacy, as well as an understanding of our complex world from pluralistic perspectives. These perspectives include cross-disciplinarity, critical history-philosophy-sociology perspectives, intersectionality, indigenous worldviews, and relationalism. All these elements prepare citizens for 'glocal' action, meaning they are engaged and ready to act on both global and local scales.

Furthermore, Table 6 lists examples of articles that reference the 13 different Vision III publications. These articles were mainly found via the 'cited by' function in Google Scholar. Almost all of them were among the 197 hits when searching for 'Vision III' AND 'scientific literacy'. Those not included are italicised in the right column of the table. In some cases – for

Table 6. Path dependence of vision III conceptualisations.

Paper (Google scholar citations February 1, 2024[16]) *Main focus of conceptualization*	New/Refers to	Referred by (and sometimes used by), examples *italic=not among the 197 hits found when searching for Vision III + scientific literacy February 1, 2024*
Aikenhead (2007) (97) *Scientific literacy for pluralistic knowing-in-action*	*New*	Zeidler and Sadler (2011); Németh and Korom (2012); Vieira and Tenreiro-Vieira (2016); Barrett (2017); Haglund and Hultén (2017); Sjöström and Eilks (2018); Johansen and Afdal (2018); Vogelzang et al. (2020); Park et al. (2020); Song et al. (2021); Knekta et al. (2022); Leung (2022); Holbrook et al. (2022); Fuchs and Tan (2022); Dillon and Herman (2023); Fuchs (2023); Owens and Reiss (2023); Avsar Erumit et al. (2024); Wang et al. (2024); Iddy et al. (2024)
Schulz (2009) (15) *HPS-aware scientific literacy*	*New*	Hadzigeorgiou and Schulz (2014)
Yore (2012) (94) *Fundamental literacy- and multimodal-oriented scientific literacy*	*New*	Chin et al. (2016); Vieira and Tenreiro-Vieira (2016); Seah (2016); McDermott and Hand (2016); Guo and Chiu (2016); Sjöström and Eilks (2018); Tippett et al. (2019); Valladares (2021); Leung (2022); Holbrook et al. (2022); Tang et al. (2022); Lüsse et al. (2022); Ağlarcı Özdemir and Önen Öztürk (2023); L. Wang et al. (2024)
Liu (2013) (49) *Engagement-oriented scientific literacy*	*New*	Haglund and Hultén (2017); Sjöström and Eilks (2018); Johansen and Afdal (2018); Tippett et al. (2019); Park et al. (2020); Marušić Jablanović (2020); Valladares (2021); Lefkos and Mitsiaki (2021); Wei and Lin (2022); Kubisch et al. (2022); Ibrahim et al. (2022); Holbrook et al. (2022); Lüsse et al. (2022); Birdsall (2022); van Kampen (2022); Fuchs (2023); Georgiou and Kyza (2023); Sjöblom et al. (2024); L. Wang et al. (2024); Iddy et al. (2024); Liu etal. (2024)
Murray (2015) (17) *Indigenous worldviews-aware scientific literacy*	(Aikenhead)	Zidny et al. (2020); Fazio (2022)
Tan (2016) (5) *Relationalism-aware scientific literacy*	Yore and Murray	Sankaya and Topçu (2022); Mang et al. (2023)
Sjöström and Eilks (2018) (259) *(accepted in 2016)* (parenthesis around the reference in the column 'Referred by (and sometimes used by), examples' means that it contains a reference to another Vision III-publication by Sjöström) *Critical scientific literacy*	Aikenhead, Yore and Liu	Haglund and Hultén (2017); (Levinson, 2018); Tippett et al. (2019); (Y. Wang et al., 2019); (Bencze et al., 2020); (Bencze, 2020); Vogelzang et al. (2020); Hansson and Yacoubian (2020); Dagher (2020); Evagorou and Dillon (2020); Zidny et al. (2020); Romine et al. (2020); Valladares (2021); Moura et al. (2021); Mang et al. (2021); Guerrero and Torres-Olave (2022); Knekta et al. (2022); Leung (2022); Kubisch et al. (2022); Holbrook et al. (2022); Wei and Lin (2022); Lüsse et al. (2022); Salinas et al. (2022); Rasa et al. (2022); Yavuzkaya et al. (2022); Birdsall (2022), (Fuchs & Tan, 2022); (Kwon et al., 2022); (Ibrahim et al., 2022); Iannini and Pedretti (2022); Canlas and Karpudewan (2023); Osborne and Pimentel (2023), (Cetinkaya & Saribas, 2023); Georgiou and Kyza (2023); Osborne (2023); Dillon and Herman (2023); Zeidler and Sadler (2023); Rasa et al. (2024); Fuchs (2023); Owens and Reiss (2023); Jones and Smith (2023); Norambuena-Meléndez et al. (2023); Avsar Erumit et al. (2024); Kutlu-Abu et al. (2024); Garthwaite et al. (2023); Chang Rundgren (2023); (Laherto et al., 2023); Rudolph (2024); Hadjichambis et al. (2024); Li et al. (2024); Sjöblom et al. (2024); Iddy et al. (2024)

(*Continued*)

Table 6. (Continued).

Paper (Google scholar citations February 1, 2024[16]) *Main focus of conceptualization*	New/Refers to	Referred by (and sometimes used by), examples *italic=not among the 197 hits found when searching for Vision III + scientific literacy February 1, 2024*
Hadzigeorgiou and Stamatis (2017) (4) *Cognitive change-based scientific literacy*	*New*	
Valladares (2021) (140) *Intersectionality-aware scientific literacy*	Yore, Liu and Sjöström & Eilks	Guerrero & Torres-Olave to (2022); Holbrook et al. (2022); Wei and Lin (2022); Lüsse et al. (2022); Ibrahim et al. (2022); Sankaya and Topçu (2022); Fuchs (2023); Norambuena-Meléndez et al. (2023); Owens and Reiss (2023); Sjöblom et al. (2024); Alcaraz-Dominguez et al. (2024)[17]; Morris et al. (2024)[17]
Holbrook et al. (2022) (8) *Scientific literacy for active societal engagement*	Aikenhead, Yore, Liu, Sjöström & Eilks and Valladares	Sjöblom et al. (2024)
Birdsall (2022) (6) *Justice-oriented scientific literacy*	Liu and Sjöström & Eilks	Georgiou and Kyza (2023); Hadjichambis et al. (2024)
Kubisch et al. (2022) (9) *Cross- and transdisciplinarity-based scientific literacy*	Aikenhead, Liu, Sjöström & Eilks and Valladares	Sjöblom et al. (2024)
Osborne (2023) (5) *Collective scientific literacy*	Sjöström & Eilks	Morris et al. (2024)[17]

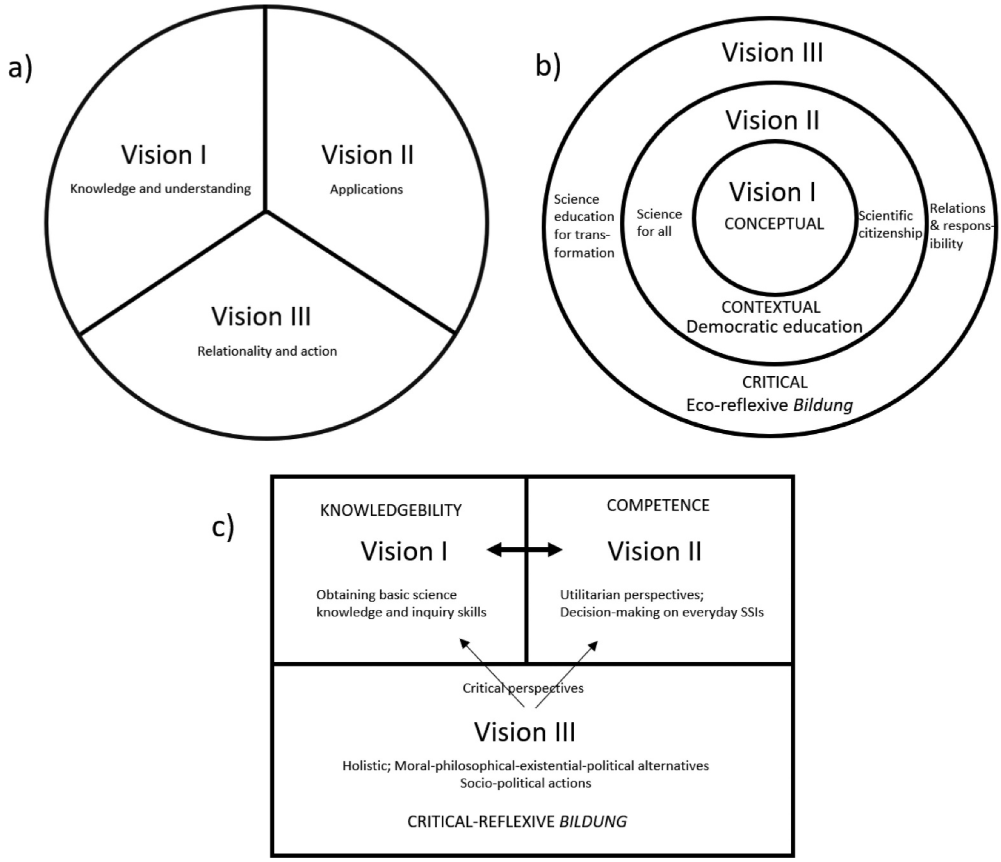

Figure 2. Three different ways to illustrate how the three visions relate to each other: (a) Complementary visions (the idea of this specific model comes from Kutlu-Abu et al., 2024), (b) Leveled visions with increased sophistication (the idea of this specific model comes from Guerrero & Torres-Olave, 2022), and (c) Vision III bridges Vision I and II and adds, for instance, critical perspectives (the idea of this specific model comes from Sjöström, 2022[19]).

instance Vogelzang et al. (2020), Guerrero and Torres-Olave (2022), Wei and Lin (2022), and Kubisch et al. (2022) – the three visions served as the central theoretical bases in the respective study.

How the three visions relate to each other

The three visions can be seen relating to each other in at least three distinctive ways: (a) as complementary visions, (b) as levelled visions – with increased sophistication, and (c) as Vision III bridging Vision I and II from critical perspectives, thereby improving them both.

(a) Complementary visions

The three visions are seen as complementary in this perspective. They have been depicted in various ways, for example, as three pieces of a cake (Kutlu-Abu et al., 2024), parallel visions (Fuchs, 2023a; Kubisch et al., 2022), vertices of a triangle (Murray, 2015; Tan, 2020), and three almost overlapping circles (Eriksson et al., 2023). Sometimes the three visions are perceived as intertwined. Collectively, the visions contribute to 'purposeful, intentional and meaningful science teaching and learning practices' (Tan, 2020, p. 94). Murray (2015) focused on sustainability, while Kubisch et al. (2022) emphasised transformative learning, transdisciplinary education, and transformative engagement for climate action. See further, Figure 2a.

(b) Levelled visions with increased sophistication

In this perspective of how the three visions relate to each other, they are seen as different levels of (post)humanisation – ranging from simple contextualisation to multifaceted problematisation (e.g. Guerrero & Torres-Olave, 2022; Sjöström & Eilks, 2018). Sjöström and Eilks (2018) used a tetrahedron model, and Guerrero and Torres-Olave (2022) explained it as Vision III encompassing Vision II, which in turn encompasses Vision I. See further, Figure 2b.

Sund (2016, p. 400) has previously presented a model that bears similarities to the one shown in Figure 2b. However, instead of using Vision I, II, and III, he utilised the three so-called selective traditions in science teaching: science disciplinary tradition (fact-based), scientific informal application tradition (normative), and scientifically informed societal tradition (pluralistic). These three traditions will be returned to below.

(c) Vision III bridges Vision I and II and improves them both

Roberts (2011) cautioned that a one-sided Vision I risks being interpreted as 'scientism', i.e. an overvaluation of the scientific approach. Conversely, an extreme interpretation of Vision II could diminish the importance of students' understanding of scientific knowledge and activities, thus risking the loss of scientific content among all other aspects. Therefore, Roberts advocated for a balance between the two visions. Similarly, but with addition of critical perspectives, I in a conference presentation in 2017 (Sjöström, 2017; figure first published in Sjöström, 2022) suggested that Vision III could provide a critical dimension to both Vision I and II, thereby enhancing their balance. See further, Figure 2c.

Dagher (2020) pointed out, consistent with Figure 2c, that Vision III serves as a bridge between Vision I and II, and includes 'actions'. As Fuchs (2023b) recently stated, both 'scientific content knowledge (Vision I) and knowledge about the contexts in which science is situated (Vision II) are needed for decision-making and action (Vision III)' (Fuchs, 2023b, p. 52).

Connection to different curriculum emphases

Roberts (2011) connected four of his seven empirically based curriculum emphases (Roberts, 1982) – solid foundation, structure of science, correct explanations, and scientific skills development – to Vision I, and the remaining three – self as explainer, everyday coping, and science, technology, and decisions – to Vision II.

Vision I can be said to focus on the scientific disciplines, while Vision II emphasises capabilities and societal issues in a broader sense. Both Vision I and II have been subdivided into A and B types (see e.g. Lidar et al., 2018; Sund, 2016). Vision III adds critical perspectives to both Vision I and II (see Figure 2c). In a paper presented at the ESERA-conference in Dublin in 2017, I first suggested an A- and B-subdivision also for Vision III (Sjöström, 2017): a Vision IIIA focusing on moral-political perspectives and a Vision IIIB focusing on philosophical-existential perspectives.

Above, it was described which of Roberts' curriculum emphases that are often connected to Vision I and II, respectively. However, it is interesting that Roberts did not empirically find curriculum emphases clearly emphasising socio-political actions, philosophical values, and/or existential perspectives. Such emphases can all be considered as under the purview of a Vision III. Among Roberts' seven curriculum emphases, 'self as explainer' and 'science and decisions' are to some extent covered by Vision III.

Now I will describe the different A- and B-versions of all the three visions in some more detail:

- Vision IA: knowledge in science, with three emphases: solid foundation, structure of science, and correct explanations (see further, Lidar et al., 2018) – with one label: *structure of science-emphasis*
- Vision IB: knowledge about scientific inquiry, with an emphasis on scientific skills development (see further, Lidar et al., 2018) – with one label: *scientific skills-emphasis*
- Vision IIA: applied science, with an emphasis on everyday coping (see further, e.g. Sund, 2016) – with one label: *everyday life-emphasis*
- Vision IIB: socio-cultural embeddedness and values inclusion, with emphasis on science, technology, and decisions (see further, e.g. Sund, 2016) – with one label: *decision making-emphasis*
- Vision IIIA: moral-political perspectives and socio-political activism, with emphasis on socio-political actions (see further, e.g. Sjöström & Eilks, 2018) – with one label: *ethico-socio-political-emphasis*
- Vision IIIB: philosophical-existential perspectives, with three emphases: self as explainer, philosophical values, and existential perspectives (see further, Sjöström, 2018) – with one label: *relational-existential-emphasis*

In summary, Vision III emphasises moral-philosophical-existential-political alternatives (Gur-ze'ev, 2002), as well as socio-political action competence (Sjöström, 2017).

Table 7 presents the six sub-visions (A- and B-versions of all the three visions) and compares them with different curriculum emphases (e.g. Roberts, 1982) and teaching traditions, here referred to as 'aim-of-teaching orientations'. Vision IA and B can be connected to disciplinary knowledge, Vision IIA and B to competences, and Vision IIIA and B to critical-eco-reflexive *Bildung*. The four first columns (Visions IA-IIB) in the table are mainly derived from Hamza and Lundqvist (2023). For Visions IIIA and B, six additional curriculum emphases[7] (STS[8]-perspectives, ethico-socio-political perspective, agency,[9] philosophical values, cultural-existential perspectives, and embodied knowledge) have been added. Furthermore, the umbrella-terms for the two corresponding aim-of-teaching orientations – socio-political and existential (relational), respectively – are new. As already

Table 7. Connection between different visions, aim-of-teaching orientations, and curriculum emphases. The columns IA-IIB are mainly[18] based on a table in Hamza and Lundqvist, 2023, p. 107, which was adapted from Lidar et al., 2018, p. 757.

Vision→	IA	IB	IIA	IIB	IIIA	IIIB
Aim-of-teaching orientations	Academic (positivist)	Academic (constructivist)	Applied	Moral	Socio-political	Existential (relational)
Curriculum emphases (the first seven from Roberts, 1982)	Correct explanation	(Correct explanation)	(Correct explanation)	(Correct explanation)	(Correct explanation)	(Correct explanation)
	Solid foundation	Solid foundation	Solid foundation	Solid foundation	Solid foundation	Solid foundation
	Structure of science	Structure of science	Structure of science	Structure of science	Structure of science	Structure of science
	Scientific skills development	**Scientific skills development**	Scientific skills development	Scientific skills development	Scientific skills development	Scientific skills development
		Self as explainer	Self as explainer	Self as explainer	Self as explainer	**Self as explainer**
			Everyday coping	Everyday coping	Everyday coping	Everyday coping
				Science and decisions	**Science and decisions**	Science and decisions
					STS-perspectives	*Philosophical values*
					Ethico-socio-political perspectives	*Cultural-existential perspectives*
					Agency	*Embodied knowledge*
Main focus	Disciplinary knowledge		Competences		(Critical-Eco-Reflexive) *Bildung*	

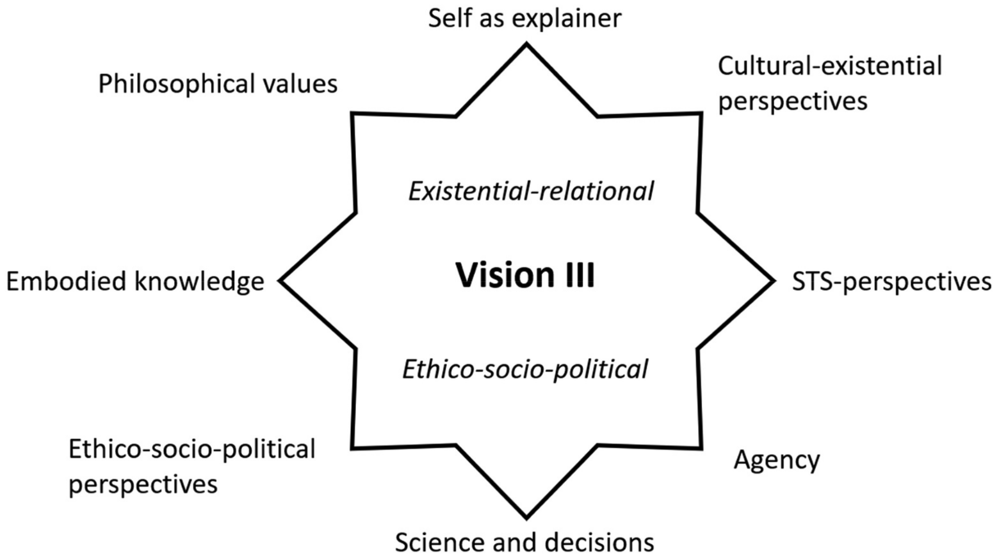

Figure 3. 'Vision III-star'. Model with the eight curriculum emphases of Vision III. Two of these, namely 'self as explainer' and 'science and decisions', are elements that Roberts (2011) connected to Vision II. The model also includes six 'new' curriculum emphases: cultural-existential perspectives, embodied knowledge, philosophical values, ethico-socio-political perspectives, agency, and STS-perspectives.

mentioned above, two of Roberts' seven curriculum emphases, namely 'self as explainer' and 'science and decisions', can also be connected to Vision III. All the eight curriculum emphases of Vision III, including the six new ones, are shown in the model in Figure 3, presenting a holistic view of Vision III.

Revisiting Table 7, Lidar et al. (2018) used the following four umbrella-terms for the teaching traditions related to Visions IA-IIB: academic (positivist), academic (constructivist), applied, and moral. Vision IA sees science as objective and value-free. Furthermore, Vision I can be connected to scientific reasoning, which is dependent on three forms of knowledge: content knowledge, procedural knowledge, and epistemic knowledge (Zetterqvist & Bach, 2023). The latter – epistemic knowledge – is about 'knowledge of epistemic constructs and values and how these are used to justify claims' (p. 486). This kind of meta-knowledge about science, which relates to philosophical values, can also be considered as being part of, or at least tangential to, Vision IIIB.

Dagher (2020) claimed that Vision III combines two of Robert's curriculum emphases that are somewhat connected to Vision I – structure of science and self as explainer – with two of the curriculum emphases connected to Vision II – everyday coping and science and decisions. To these four, she added an 'emphasis on action'. In Table 7, this emphasis is referred to as 'agency' under Vision IIIA. The curriculum emphasis 'self as explainer', although primarily connected to Vision IIIB in Table 7, also appears in other visions, for instance Vision IB.

Connection to worldview perspectives and *Bildung*

The three teaching traditions mentioned above – fact-based, normative, and pluralistic – have been linked to three educational philosophies in the context of Science Education: essentialism, progressivism, and reconstructionism (e.g. Sandell et al., 2005; Sund, 2016). Sjöström (2018) further connected these philosophies to Vision I, II, and III.

The three visions can also be connected to different worldview perspectives. According to Hedlund de Witt and Hedlund de Witt (2013), there are four major worldview perspectives in the West: traditional, modern, postmodern, and integrative. In another manuscript currently under review, I align a traditional worldview with Vision I, a modern worldview with Vision II, and an integrative worldview with Vision III. An integrative worldview brings together rationality and spirituality (including philosophical perspectives); it emphasises critical realism over relativism. Furthermore, emphasis is on embedded relationality (Hedlund de Witt & Hedlund de Witt, 2013). Knowledge is derived from the amalgamation of diverse perspectives. Nature, seen as possessing intrinsic value, is perceived as being oppressed and exploited by modernity (Hedlund de Witt & Hedlund de Witt, 2013).

Visions in relation to worldviews cover epistemology (view of knowledge and research methodology), ontology (view of nature and reality), axiology (morality and identity in relation to society), and societal vision (view of society).[10] The latter two mentioned aspects (axiology and societal vision) can primarily be connected to Vision IIIA, while the first two mentioned (epistemology and ontology) can be connected to Vision IIIB.

In a recent review of 'worldviews beyond sustainability', Fitzpatrick (2023) defined worldviews as 'the overarching philosophies that guide our ideologies, decision-making and actions' (Fitzpatrick, 2023, p. 10). She identified key knowledge themes and concepts related to the overarching theme of human-nature connectedness. These include, for example, systems thinking, relational thinking, spiritual knowledge, place-based knowledge, holism, integration, complexity, plurality, reflective mindsets, and transformative views. As demonstrated above, Vision III (especially Vision IIIB) can be connected to the theme human-nature connectedness and relational-existential perspectives (see also, Sjöström, 2018; Tan, 2020).

The three visions can also be compared with Gilbert's (2016) three different future orientations in science teaching/education: (1) business as usual [traditional normal science], (2) science as innovation [STEM-orientation], and (3) 'post-normal' science education in the Anthropocene era. In the context of the latter, i.e. science education in the Anthropocene era, Jeong et al. (2021) discussed scientific literacy as a path to sustainability. With reference to for instance Barad et al. (2000), they used 'posthuman perspectives to consider an alternative onto-epistemological stance that decentres human agency and foregrounds the co-constitutive and intra-active nature of the world' (p. 805). In the same branch of literature, Higgins (2021) discussed, based on posthuman perspectives, alternatives to contemporary science education. The title of one of his chapters is 'Response-ability revisited: towards re(con)figuring scientific literacy'. Some literature explicitly connects such posthuman ideas to Vision III (e.g. Murray, 2015; Tan, 2020; Yavuzkaya et al., 2022).

Vision III emphasises the importance of both deep knowledge and values awareness. In relation to both NOS and SSI, it emphasises a problematising approach. Vision III has a holistic worldview based on both scientific knowledge and socio-historical-cultural-political perspectives. It stresses the importance of both nature experiences and an awareness of global challenges in the Anthropocene era. It articulates the sensations of 'a relational whole' and 'being-in-the-world'. Another word for this is eco-reflexivity (e.g. Sjöström, 2018). Beyond the experience of nature and environmental awareness, it also values wonder, aesthetic experience, and a romantic understanding of the world (see also, Hadzigeorgiou & Schulz, 2014). Furthermore, the concept of 'embodied science' (e.g. Yavuzkaya et al., 2022) is given prominence. Individual decisions are guided by concepts such as phronesis, emancipation, socio-political action competence, and praxis. The latter can be characterised as values-impregnated actions or as a practice based on *Bildung* and practical wisdom. In the societal context, there is a critique of the modern risk society with its inherent injustice and oppression (e.g. Sjöström et al., 2016).

Bildung brings with it a broad view of knowledge and knowing, which, in addition to being disciplinary, is also cultural, practical, tacit, local, experiential, and/or aesthetical (Deng, 2020). Hogstad (2021) asserts 'As an educational concept, Bildung incorporates culture, aesthetics, self-cultivation, political awareness and engagement' (Hogstad, 2021, p. 591). Rømer (2021) connected *Bildung* to the term 'worldification'. It is about the interplay between the self and the world, to both create and leave something of lasting substance. According to Biesta (2012), 'the role of the individual in the process of Bildung, [. . .] has to be understood as a reflexive process' (Biesta, 2012, p. 817), that is, a process in which the individual establishes both a relationship and a critical stance towards the existing culture and society. In an essay, Rowson (2019) discussed *Bildung* in relation to future education and sustainability issues. He portrayed *Bildung* as being a values-driven applied philosophy of education and connected it to, for instance, spirituality, transdisciplinarity, and transformative education. I have together with co-authors connected such a critical-eco-reflexive view of *Bildung* to Vision III (e.g. Sjöström, 2018; Sjöström et al., 2017; Yavuzkaya et al., 2022; Zidny et al., 2020).

A multifaceted and integrated view of Vision III

The article is concluded with a presentation of what a synthesised view of a multifaceted and integrated perspective of Vision III of scientific literacy and science education may include. This synthesis primarily draws on the different facets of Vision III presented and discussed in the article. It is also grounded in scientific literacy frameworks by Hurd (1998), Shamos (1995), Bybee (1997), Gräber (2000), and DeBoer (2000), as referenced in reviews, such as those by Laugksch (2000), Holbrook and Rannikmae (2009), Hodson (2011), Németh and Korom (2012), Siarova et al. (2019), Costa et al. (2021), Almeida et al. (2023), Osborne (2023), and Rudolph (2024). Scientific literacy-dimensions adopted from Hurd (1998) (as cited in Costa et al., 2021, p. 200) were particularly influential when I constructed the Vision III-list below, which is based on the results of the literature review.

A multifaceted and integrated view of Vision III can be connected to critical-eco-reflexive *Bildung* and consists of the following seven components:

- Fascination (and wonder), deep (and spiritual) understanding and aesthetic appreciation of the living world (including understanding the interconnectedness of life on

Earth) and the universe from critical realistic, plural-science, and transdisciplinary perspectives, as well as an integrative worldview, including alternative (e.g. indigenous) worldview perspectives.

- Critical thinking about/with and deep understanding of Nature of Science (NOS), inclusive of its processes from broad socio-cultural perspectives, including intersectionality perspectives and Anthropocene-awareness, and aimed towards socio-ecojustice.
- Understanding of Science and Technology and its interrelationship with Society and Environment ('science-in-context', such as SAQ,[11] SSI and STSE) in the Anthropocene from complexity, uncertainty, and critical perspectives, including the moral-ethical and socio-political nature of evaluations, decisions, and socio-scientific-techno-systems, as well as History-Philosophy-Sociology (HPS) aspects.
- Developing science-related powerful knowings (embodied knowledge and relationalism grounded in a global interdependence view) for responsible knowing-in-action as a reflective global citizen, while also acknowledging the importance of fundamental literacy, including digital literacy.
- Scientific literacy as potential collective praxis in the global risk society for sustainability and for media literacy, including trusting fair scientific processes.
- Using critical science perspectives (emancipatory approach) in everyday living, problem solving, argumentation, democratic decision-making, and futures thinking.
- Social and 'glocal' engagement and participation for transformation, socio-ecojustice, and a better world, for instance through socio-eco-activism.

The condensed version of this is: Based on broad scientific knowings, fundamental and digital literacy, and an understanding of our complex world from pluralistic perspectives (cross-disciplinary, critical, history-philosophy-sociology, intersectionality, indigenous worldviews, relationalism), being engaged and prepared for 'glocal' action.

Notes

1. Often Paul Hurd is wrongly credited for having introduced 'scientific literacy' in 1958, but at that time the term had already been in use for more than a decade (Rudolph, 2024).
2. For more recent articles on STS in science education, see, for instance, Feinstein (2011), El Halwany et al. (2021), and Valladares (2022).
3. The concept of *Bildung* will be described later in the article.
4. In an identical Google Scholar search made seven months later, 1st of September 2024, 273 hits (+20% compared to 1st of February 2024) were found.
5. For a recently published review about critical scientific and environmental literacies, see: Guerrero and Sjöström (2024).
6. Different components of SSR are described and discussed by Kahn and Zeidler (2019).
7. Somewhat similarly, Zeidler (2014) has suggested socioscientific issues as a curriculum emphasis.
8. STS stands for both the scholarly field Science and Technology Studies and Science, Technology, Society, (Environment)-context, which is related to the scholarly field Environmental Humanities (e.g. Castree, 2014).
9. Agency can be defined as the capacity for intentional transformative action (Biesta & Tedder, 2007). It can also be defined as 'purposeful action oriented towards future goals' (Arnold &

Clarke, 2014, p. 739). See also, Rasa et al. (2024), who connected value-based agency to Vision III.

10. According to Hedlund de Witt and Hedlund de Witt (2013), there are five key aspects of *worldviews*: ontology, epistemology, axiology, anthropology, and societal vision. In the context of this article, the aspect of 'anthropology' is seen as being included in 'axiology' and 'societal vision'.
11. SAQ stands for Socially-Acute Questions. See further Bencze et al. (2020).
12. Hodson (2011) used 'critical scientific literacy' as short for 'critical scientific, technological and environmental literacy'.
13. See for instance, Ryder (2001).
14. This term may be seen as relatively closely related to the term 'socioscientific thinking' (used in e.g. Rasa et al., 2024)
15. STS does here stand for the scholarly field Science and Technology Studies.
16. The number of Google Scholar citations seven months later, 1st September 2024, were: Aikenhead 103 (+6% compared to 1st February 2024); Schulz 16 (+7%); Yore 99 (+5%); Liu 63 (+29%); Murray 19 (+12%); Tan 6 (+20%); Sjöström & Eilks 333 (+29%); Hadzigeorgiou & Stamatis 4 (no change); Valladares 229 (+64%); Holbrook et al. 12 (+50%); Birdsall 9 (+50%); Kubisch et al. 17 (+89%); and Osborne 21 (+320%).
17. Published after 1st February 2024, so not included in the 197 hits found when searching for 'Vision III' AND 'scientific literacy' on Google Scholar that date, but found in an identical search being made seven months later, 1st September 2024.
18. In this table 'aim-of-teaching orientations' is used instead on 'teaching tradition' and the parentheses around 'correct explanation' have here been added. The seven first curriculum emphases are based on Roberts (1982). For Vision III six additional emphases have been added here. Bold text symbolises 'main emphases' (see Lidar et al., 2018, p. 757 for Visions IB, IIA, and IIB). The raw ('Main focus') in the bottom of the table has been added compared to the table in Lidar et al. (2018).
19. The model is based on a somewhat similar model that was published in (Christensson and Sjöström 2014, p. 61). An early version of this specific model was first presented at the ESERA-conference in Dublin in 2017 (Sjöström, 2017).

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Notes on contributor

Jesper Sjöström is a professor of science education at Malmö University, Sweden. He has a multifaceted background including being a certified upper-secondary school teacher in chemistry and general science/science studies. His research encompasses three important concepts: Vision III of scientific literacy and science education, eco-reflexive *Bildung*, and European 'didaktik'. Related to this, Sjöström has a keen interest in *Bildung*-oriented didactic models and modelling, as well as the philosophy underpinning science education. His work is framed within the context of the Anthropocene era, addressing pertinent global environmental and socio-political issues. A fundamental question that guides his research is: how may a Vision III-driven eco-reflexive *Bildung*-oriented science education look like?

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