STUDIES IN SCIENCE EDUCATION
https://doi.org/10.1080/03057267.2025.2563946

Context-based science education to promote diversity-equity -inclusion – a systematic literature review on the understanding of *context* in science education

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ABSTRACT
Context-based science education (CBSE) has played a central role in re-orienting scientific literacy for all students. However, the notion of addressing 'all students' has not yet been explicitly related to the demands of diversity-equity-inclusion (DEI). This study aims to deduce the potential of context-based teaching and learning for DEI with the goal of making science education more accessible for everybody. To this end, a systematic literature review was conducted to investigate which different functions are attributed to *contexts* in primary and secondary science education and what different understandings of *context* can be delineated. Categories were inductively derived from the analysis of 101 peer-reviewed journal papers. Seven functions and eight understandings of *context* were identified, and their interrelations are shown. We discuss, with regard to different visions of scientific literacy, how different understandings and functions of contexts can promote DEI. Our discussion implies that the greatest potential lies in the combination of different understandings and functions of *context*. Rather than striving for one precise definition, teachers and teacher educators should be aware of the variety of access points that CBSE can offer for a wider variety of students.

KEYWORDS
Context-oriented teaching and learning; DEI; scientific literacy; systematic literature review; inclusive education

Introduction

Equal opportunities and access to resources for learning and participation are fundamental requirements in a fair education system that welcomes everyone with their diverse identities, backgrounds and perspectives (Bianchini, 2017; Ryu et al., 2021). To enable the process of appreciating equity and diversity, an inclusive education system is needed in which every person has the right to engage in the best possible education (Booth &

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/03057267.2025.2563946

Ainscow, 2016; UNESCO, 2018). Teachers should provide a variety of access options that are 'available to everybody in the class rather than a set of differentiated options only for some' (Florian & Spratt, 2013, p. 122).

To promote diversity, equity and inclusion (DEI, Kayumova et al., 2019; Ramachandran et al., 2023; Rodriguez & Morrison, 2019; Ryu et al., 2021), science teachers must take on their responsibilities as key drivers to facilitate scientific literacy for all learners (Bybee, 1997; Erduran & Wong, 2013; Stinken-Rösner et al., 2020). The goals of science education and the concept of scientific literacy, including who it addresses, are dependent on the social, cultural, and political environment (Guerrero & Torres-Olave, 2022) and have – since the term 'Scientific Literacy' was first mentioned in 1945 – intensively evolved over recent decades (Liu, 2013; Roberts, 2007; Sjöström & Eilks, 2018; Valladares, 2021). Regarding DEI, 'Scientific literacy for all learners' can be interpreted differently. This becomes clear when considering the different visions of scientific literacy and its development over time in European and Anglo-American democracies, i.e. in regard to Western science. Here, science teaching and learning has undergone at least two paradigm shifts (Figure 1): From (I) a pure scientific content perspective through (II) a contextualisation of that content – making those contexts successively available and meaningful for all – and finally (III) towards science engagement for socio-political engagement and transformation delineating from a Western mainstream understanding (Liu, 2013; Sjöström, 2024; Sjöström & Eilks, 2018).

The idea of contextualising science content to make it more meaningful has played a crucial role in advancing especially paradigm shift 1 (Broman et al., 2015; Nentwig et al., 2007; Roberts, 2007; Sjöström & Eilks, 2018), successively inviting more students with their different experiences and knowledge to participate in science, not only those intending to become scientists.

We refer to *context-based science education* (CBSE) as an approach or framework (Bulte et al., 2006) that uses contexts for pedagogical purposes, aiming at e.g. improved motivation and learning (Bennett & Lubben, 2006) for all students by raising a 'need to know' and give meaning to the learning of scientific content (Bulte et al., 2006). While the term *CBSE* lacks a mutual definition, some research has been conducted on its outcomes (e.g. Fayzullina et al., 2023; Sevian et al., 2018), or related ideas like 'science-in-context' (Bencze et al., 2020).

In general, it must be noted, that the definition of the terms *context* and *context-based science education* (CBSE) is often broad or not explicit and varies from paper to paper (Bennett et al., 2005; Broman et al., 2022). Despite this fuzziness, the discourse about CBSE has been a very powerful one in terms of shifting the goals of science education.

Figure 1. Paradigm shifts in science education (cf. Liu, 2013; Sjöström & Eilks, 2018; Valladares, 2021).

From our perspective as part of a German network for inclusive science education, which works on connecting inclusive pedagogy with science education in primary and secondary schools (Stinken-Rösner et al., 2020), the following is important: CBSE, an established approach in our country to reach all students in terms of Vision II, must also be DEI-sensitive to strive for more equitable science education.

Within our network of inclusive science educators exists a broad consensus driven from practical experiences that CBSE has strong potential for advancing science education for everybody, but until now the shift from scientific literacy Vision I to Vision II did not explicitly address DEI. Therefore, we wonder if a systematic analysis of the use of the term *context* in the science education literature could help to identify aspects that make CBSE a suitable instructional approach for every learner. The even further shift to Vision III is more oriented on emancipation, participation, and empowerment and has the potential to address aspects of DEI like social justice explicitly. At the same time, there is a risk that especially learners from educationally disadvantaged homes cannot act as honest science brokers as they show lower levels of scientific literacy (OECD, 2023).

To discuss whether or in what way CBSE is suitable for promoting DEI, it is first necessary to systematically analyse the literature regarding the functions that contexts in CBSE serve, i.e. which goals and pedagogic intentions are associated with the use of *contexts*. Doing so, we had to acknowledge that the term *context* is not only associated with vastly different pedagogic functions, but that the understanding of the concept *context* itself differs significantly among authors, indicating that authors were operating with divergent definitions of *contexts*. The second goal of our analysis therefore was to systematically analyse which understandings in terms of definitions or explanations of the term *context* are found in the literature. The two research questions of the systematic literature review (SLR) therefore were:

- Q1: Which different functions are attributed to *contexts* in science education literature?
- Q2: What different understandings of *context* in science education literature can be delineated?

Based on the SLR's results, we will discuss the potential impact of functions and understandings of *contexts* in regard to CBSE as an approach to promote DEI and scientific literacy *for everybody* (in the sense of Florian & Spratt, 2013, see above).

Goals and target groups of science education – two paradigm shifts

The first paradigm shift: from science to prepare future scientists to science for all

Triggered by the modest achievements of many learners in the natural sciences, as revealed by the Third International Mathematics and Science Studies in 1995 (Beaton et al., 1996), a first paradigm shift in science education occurred (Liu, 2013; Roberts, 2007). Before this shift, the curricula of school subjects were mainly guided by contents and structures of the respective academic science disciplines from the Global North and aimed at promoting students' pure science understanding to prepare them to become scientists (Millar, 2006; Roberts, 2007; Valladares, 2021). After the paradigm shift, content selection was more strongly based on educational theory (*Bildung*, Sjöström, 2013). The central aim of this re-orientation was 'scientific literacy for all learners' (Vision II, Aikenhead, 2006; Bybee, 1997; Erduran & Wong, 2013; Millar, 2006), also causing a refocusing of the PISA tasks in the following years (Erduran & Wong, 2013; Liu, 2013; OECD, 1999). Accordingly, science education should not only be science-propagating and prepare students to be future scientists but should also make the natural sciences exciting and attractive for all learners and provide insights that enable orientation in everyday life *and* the professional world (Roberts, 2007). Consequently, science education had to take into account what the public (and not only scientists) found worth knowing (Liu, 2013). Addressing the large group of students ('all learners') who did not strive for an academic occupation in the natural sciences made it necessary to include their conceptions in and about science (Liu, 2013; Valladares, 2021).

From the very beginning, the idea of CBSE played a crucial role in this re-orientation enhancing scientific literacy (Eilks et al., 2013; Habig et al., 2018; Parchmann et al., 2006). The general idea of contextualisation is widely accepted (Fayzullina et al., 2023) and valued as a 'big idea' for education in the scientific community (Sevian et al., 2018). Scientific literacy for all was to be achieved by applying scientific knowledge to phenomena, technological and societal issues, also discussed in the media, or students' everyday experiences (Bennett & Lubben, 2006; Eilks et al., 2013; Habig et al., 2018; Roberts, 2007). Thus, the relevance of the content was made apparent and anchors in prior knowledge and interest were provided (Cognition and Technology Group at Vanderbilt, 1992). Students were expected to apply scientific knowledge in real-life and societal contexts (Liu, 2013; Valladares, 2021), with socio-scientific issues serving as effective vehicles to achieve this goal (Eilks et al., 2018; Owens & Sadler, 2024). Contexts should help students to make sense of science, thus motivating them to engage with the plain scientific content more eagerly. Subsequently, teaching concepts such as the public programmes by *Salters' Institute* in England (Burton et al., 1995), *Chemie im Kontext* in Germany (Parchmann et al., 2006) or *Chemistry in Context* in the United States (Hill & Holman, 2000) were developed and tested (cf. also Eilks et al., 2018). They called for a change of perspective in curriculum design, demanding strict contextualisation of all curriculum content and a renunciation of historically grown canonical teaching of science subjects (Bennett & Lubben, 2006; Demuth et al., 2008; Hodson, 2003). Educational strategies following the idea of contextualisation (i.e. CBSE) in the sense of Vision II of scientific literacy 'emphasise the discussion and application of science in context, problem solving, and, with this, the pragmatic dimension of science is promoted' (Valladares, 2021, p. 570).

To sum up, the advancement to 'scientific literacy for all learners' meant a departure from an elitist science-discipline and job-related understanding of science education. However, contextualisation can also make content learning more complex (Aikenhead, 2006; Broman et al., 2015) and 'science for all' was originally not related to ideas of DEI, at least not explicitly in terms of an everybody approach (cf. Erduran & Wong, 2013; Florian & Spratt, 2013; Liu, 2013).

The second paradigm shift: from science for all to science engagement

The idea of science engagement is to seek 'informed/best possible solutions to complex social, cultural, political, and environmental issues' in the role of an 'honest broker of policy options' (Liu, 2013, p. 29). Every learner needs to be skilled in 'critical thinking, science communication, and consensus building' to work on socio-scientific issues like globalisation, health issues, climate crisis etc. and beyond (e.g. cultural, religious or political aspects) using a value-laden, interdisciplinary approach (Liu, 2013, p. 28) 'to prepare for and take responsible action' (Hodson, 2003, p. 656). Guerrero and Sjöström (2025) have positioned the concept of critical scientific literacy at the centre of their deliberations and argue that, in light of global ecological crises and the rapid transgression of planetary boundaries, ecological questions and environmental literacies must be addressed. Their goal is to examine 'opportunities to substantiate and foster awareness toward a process of "conscientization" in science education' with regard to ecological literacy. The term *critical scientific literacy* was formerly introduced in the discourse by Hodson (2011), emphasising the integration of the ethical and political dimensions in science teaching by addressing socio-scientific issues and decision-making from a social justice perspective. Students should be empowered to critique how scientific knowledge is produced and used in society, particularly concerning environmental sustainability, social equity, and global justice concerns. The knowledge and skills expected are, for example, 'draw and access conclusions, Make and assess judgements, (...) Argue, Communicate, Assess courses of action' (Vieira & Tenreiro-Vieira, 2016, p. 667).

In Osborne's framework, however, Vision III appears as an understanding of the interplay of different types of expertise, i.e. knowing that 'we are collectively dependent on the knowledge of others and a network of differing expertise' (Osborne, 2023, p. 785). Scientific literacy thereby becomes a communal good, a property of a community, which is scientifically literate when (correct) expertise is believed and consulted. What other authors (see above) defined as Vision III is, in Osborne's view, a more radical variant of Vision II (namely to empower students to take action in the face of major crises).

These and other propositions of Vision III are presented in Sjöström's (2024) review on Vision III. In a provided overview (Table 3 in Sjöström, 2024), Sjöström lists Vision-III ideas. Some of them can be associated with a promotion of DEI aspects like 'Socio-political embeddedness and emancipation' (Sjöström & Eilks, 2018), 'Plural-science-perspectives, including alternative indigenous worldviews' (Murray, 2015; Tan, 2020), 'NOS for social justice' (Dagher, 2020), 'Justice-oriented scientific literacy' (Birdsall, 2022), or 'Value-based agency-oriented scientific literacy' (Rasa et al., 2022, 2024). Especially highlighted is the transformative view of Valladares (2021), who explicitly included equity and social justice (Sjöström, 2024).

With regard to science education that focuses on subject-specific content or conceptual understanding, the question of '*is Vision III still science*' may arise. In Vision III, science is politicised and thus a relation to science concepts may not be that obvious. For Sjöström and Eilks (2018), however, only this kind of socio-political connotation makes science education relevant. This means the idea of science engagement (Vision III) is to make science perceived as relevant to students (Liu, 2013) by *'Engaging in Sociopolitical Actions*' (Hodson, 2003, p. 658, original emphasis) or *'Addressing socio-scientific issues*' (Hodson, 2014, original emphasis; also cf., p. 2537; dos Santos, 2009) 'being engaged and prepared for "glocal" action' (Sjöström, 2024, p. 25). Educational strategies of science engagement are, for example, "SSI collective discussion, Open questions of local/global relevance, Inclusion of risk and uncertainty, Socio-scientific reasoning, Science engagement for context-transforming actions, Authentical evaluations" (Valladares, 2021, p. 569). Participation and active involvement are fostered accompanied by the aim to change one's actions (Liu, 2013). Science education in the sense of Vision III should address

> students' cultural context through socially relevant themes that incorporate issues of oppressive context in society, and that ought to be developed through a dialogical process in classrooms, engage students in sociopolitical action and thus make it possible to look forward to bringing equity and social justice into our world. (dos Santos, 2009, p. 377)

Thereby, aspects of DEI like equity and social justice are promoted while scientific concepts are not neglected. dos Santos (2009) points out the importance of introducing them in relation to a socio-scientific issue. For Sjöström and Eilks (2018), ethical and transformative learning as well as critical sustainability are at the core of science engagement (Vision III), 'not only aiming on content learning via context, but from the beginning aiming at general educational skill development and transformative education via making authentic and controversial issues from everyday life and society the drivers for science education' (p. 79). While in this regard the contents and contexts addressed in Vision I and II are questioned, Vision III science is more in line with demands of DEI like equity, justice, emancipation, and participation as key indicators of science engagement (Valladares, 2021):

> With students living in unequal conditions of oppression, science education demands a real belief in the relevance of creating new and differentiated scientific literacy opportunities that truly guarantee that science participation and emancipation derived from school science effectively takes place for all students, whose relations with science will be always situated at some point within this diverse and conflicted society. (Valladares, 2021, p. 571)

In a BANI (Brittle, Anxious, Non-Linear, Incomprehensible) world, informed and critical thinking in terms of 'science engagement in a social context' can help to address the challenges of the 21st century (Valladares, 2021, p. 566). However, it is also challenging to integrate the ideas of science engagement in current educational politics, administration and teaching (cf. also Hoeg et al., 2017), as teachers are bound to current curricula and assessments that, at least in our country rather strive for Vision I and II. Additionally, especially in Germany, there is a huge gap between the competency level of privileged and underprivileged students (OECD, 2023), so that 'science participation and emancipation derived from school science' does not effectively take place 'for all students' (cf. Valladares, 2021, p. 571).

Additionally, the three visions of scientific literacy overlap and it 'is unrealistic to expect that an equal emphasis is placed on all three visions of SL [scientific literacy] for all science education settings' (Liu, 2013, p. 36). Perhaps, at the moment, it is even unrealistic to expect Vision III at all from most teachers.

However, we think of the integration of DEI into science education as an obligation. A way to achieve this is to check current and established educational approaches like CBSE for their potential to address ideas of DEI inherently. Thus, at the moment, we see it as more realistic to integrate DEI aspects into established Vision II-approaches than demanding a comprehensive DEI-sensitive implementation of Vision III.

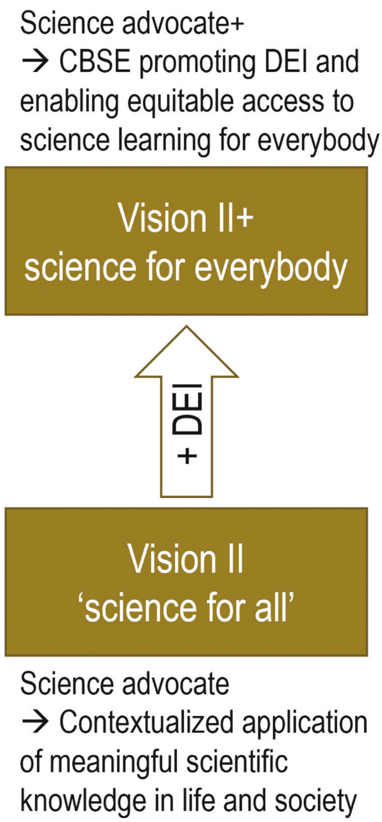

Figure 2. From science for all to science for everybody – Vision II integrating DEI.

Vision II+: from science for all to science for everybody

To promote a DEI-sensitive science education, we propose a Vision II+ (Figure 2), that reinterprets 'for all' in the sense of DEI. The authors of 'Scientific literacy for all' (Vision II) did not explicitly call for a specific adaptation of instruction towards *all learners* in the sense of acknowledging the diversity of everybody with an idea of equitable science education (Bianchini, 2017; Erduran & Wong, 2013; Liu, 2013). Rather the curriculum emphases of Vision II are on everyday life and decision making expanding the Vision I-emphases of correct explanations and scientific skill development (Sjöström, 2024), thus making science more accessible for more students than just pure science learners. The slogan 'science for all' certainly might encompass an understanding of DEI – but only if *for all* is understood in terms of an *everybody approach* (Florian & Spratt, 2013) that engages 'students from a range of dispositions, viewpoints and characteristics' (Erduran & Wong, 2013, p. 199). Thus, we suggest a new Vision II+ called *science for everybody* following the ideas of Florian and Spratt (2013) regarding DEI (Figure 2) to explicitly demand and make the promotion of equitable science education visible.

Science teaching and learning and the educational strategies of Vision II – and thus CBSE – need to take into account potentials, barriers, and challenges they pose for *everybody*. For a DEI-promoting science education, the potential of CBSE is assumed through the following: a) more students find (individually different) access to the scientific content, b) students contribute more different aspects from their prior experiences so that diversity within the class becomes an asset, and c) there are more diverse ways how to connect new knowledge with individual prior concepts (Weirauch & Schenk, 2022; Weirauch et al., 2021). From our viewpoint, contexts promise to be more subjectively meaningful than contents and allow diverse access to the learning object (Hüfner & Abels, 2024; Stinken-Rösner et al., 2020). Accordingly, existing CBSE approaches need to be checked for their understanding of contexts and if they promote DEI, i.e. if they enable access to scientific literacy for everybody.

As well as for Vision II, the idea of promoting DEI is conceivable for the other two Visions (Figure 3). While the pure science learners targeted by Vision I could also be thought of as a diverse group of learners, including underprivileged learners who should be encouraged to pursue a career in science (Vision I+), the original Vision I described above only addresses a narrow group of people and therefore precludes coexistence with the other visions in practice. For example, a Vision I+ would need diverse scientists as role models. Regarding Vision III, aspects of DEI are considered to be inherent (see above). However, those students who may become honest science brokers are more likely to come from privileged homes as PISA data shows them to be in higher competency levels (OECD, 2023). '[T]hose who know how to play the existing political game get their voices heard, whereas those who are traditionally marginalised and voiceless remain so' (Morgan, 2012, p. 629). However, this is an empirical question to be further investigated. Vision III+ (see Figure 3) needs everybody with diverse backgrounds to take socio-political action so that transformation is really happening.

Several questions arise: How can a context be made relevant for a diverse body of students coming from and living in diverse societal environments? What would such a context for DEI-promoting science teaching and learning be? Does it have to be an everyday phenomenon? Would it rather need to relate to a socio-scientific issue? How can all students get engaged in scientific activities (and socio-political actions)? How can a need-to-know feeling (Pilot & Bulte, 2006a), interest and motivation be achieved for as

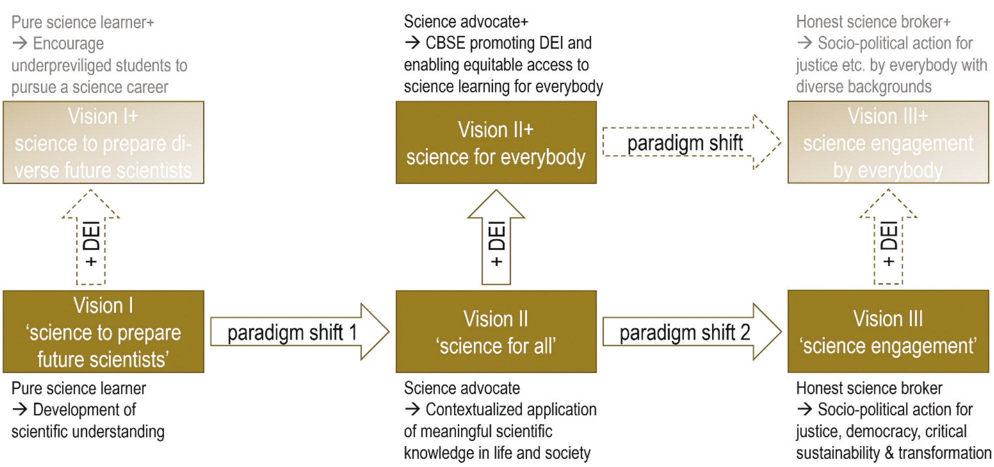

Figure 3. Three visions of scientific literacy integrating DEI.

many students as possible? Moreover, how can contexts provide an equitable variety of different opportunities for everybody to learn science (Windschitl et al., 2018)?

These questions motivated us to perform an SLR to find out more about the functions attributed to contexts and the understandings of contexts in the science education literature to see whether it is possible to associate the results with DEI in science teaching and learning.

Materials and methods

The systematic literature review should answer the following two questions:

- Q1: Which different functions are attributed to *contexts* in science education literature?

- Q2: What different understandings of *context* in science education literature can be delineated?

Our research process was continually documented in a Confluence 7.13.7 workspace (2022 Altassian Corporation Pty Ltd.) switching to the logbook of MAXQDA 2022 at the beginning of the main corpus' data analysis. Following the steps suggested by Fink (2019) after defining the purpose and the research questions of our systematic literature review, the bibliographic databases for the searching process were specified. To include a wide range of international approaches we searched for peer-reviewed papers published in English. For our search, we used the international bibliographic databases Web of Science, Scopus and ERIC. Figure 4 shows the search strings.

Our search strings targeted peer-reviewed papers with hits for the term *context-based* and a term indicating that the papers' focus was on the field of primary and secondary science education, including papers on biology, chemistry, physics and science education, excluding mathematics education. While we worked on the review, the search was renewed three times to include papers published during this period. The last search was conducted on 6 June 2023. The searches produced a total of 326 journal papers (see Figure 5).

The following inclusion and exclusion criteria were applied during the process of building the SLR's corpus: Firstly, only those papers that dealt with contexts in the CBSE sense rather than in the everyday sense, e.g. in phrases as 'in the context of. . .', were analysed and included in the final corpus. Furthermore, the focus on primary and secondary science education excluded those papers that dealt with vocational or higher

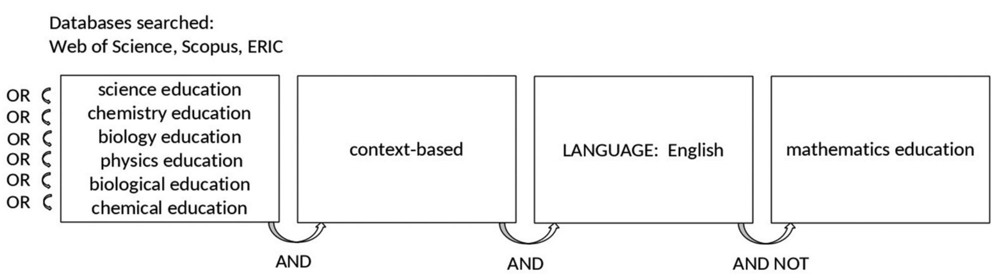

Figure 4. Search strings.

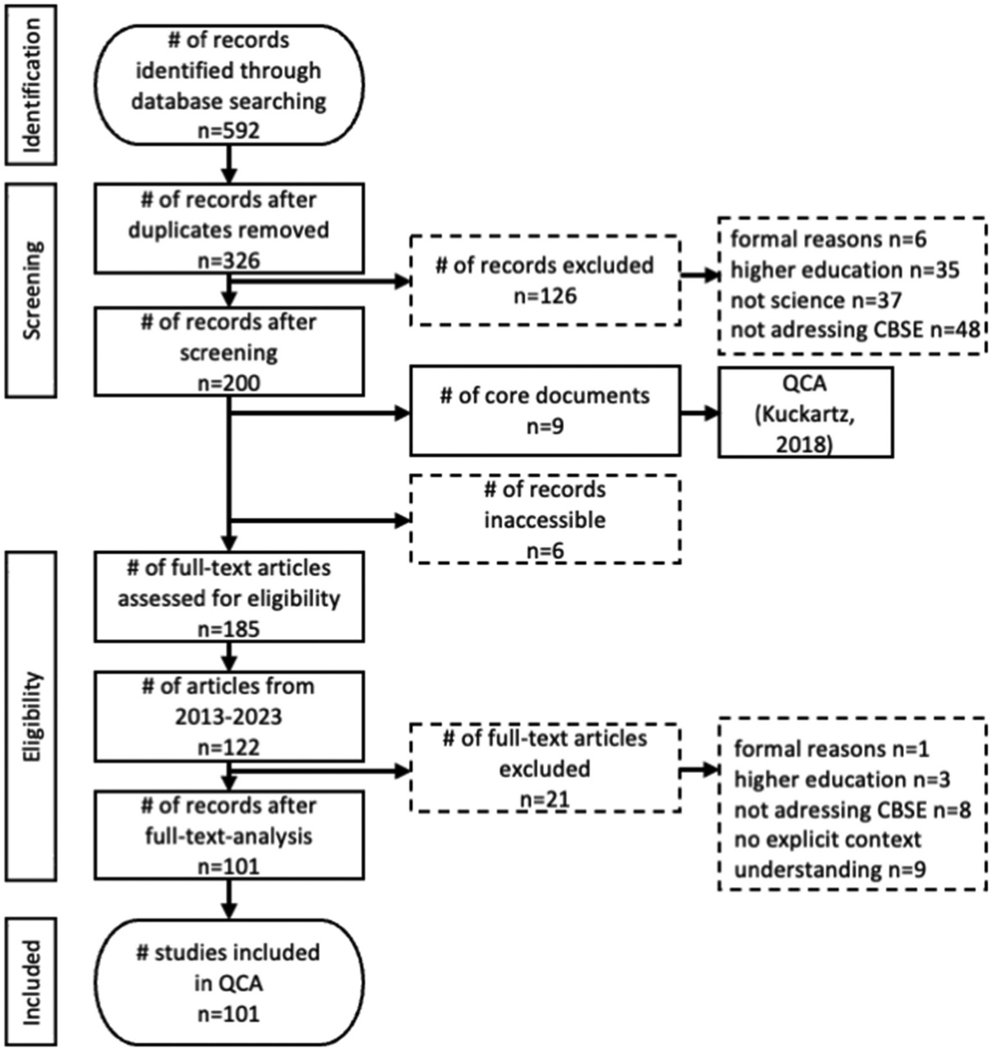

Figure 5. Process of selecting the papers (figure based on Moher et al., 2009, QCA = qualitative content analysis).

education. This decision also led to a focus on natural science subjects, specially chemistry, biology and physics and, in the sense of disciplinary culture, to the exclusion of papers on, for example, computer science or health sciences. A further strict exclusion criterion was whether the papers contained a clear positioning with regard to the underlying understanding of context. Only those papers that explicitly stated which understanding of context they were following were included. A rarely used exclusion criterion (n = 7) concerned formal requirements, for example if the text was incomprehensible or gave the impression of being of poor scientific quality.

In the first round of title-abstract screening via AbstracR (Wallace et al., 2012), we identified key phrases indicating that some papers were unsuitable for our search target. The phrases *computer science*, *programming*, *information technology*, *health* *science*, and *medical* indicated that those papers might not target science education. The phrases *undergraduate* and *majors* suggested that the focus of the papers might be on science education in higher education, a level we were not investigating. Furthermore, the phrase *in the context of* in the title indicated that those papers might use the word *context* in a meaning other than CBSE. During the screening with AbstracR (Wallace et al., 2012), however, we recognised that these papers could not always be excluded. Therefore, we conducted a search for the key phrases within the citation program Mendeley (Mendeley Ltd., 2008–2020) and screened the corresponding abstracts in a first step. With the remaining papers, we conducted a title-abstract screening beginning with the newest articles in alphabetical order within the year of publication (Fink, 2019). Apart from the language of the papers and the field of science education, our guiding questions for screening abstracts were whether the papers focused on CBSE at the level of primary and secondary education or science teacher professionalisation, and whether the term context was used in reference to science education. Of the 126 papers excluded during the screening process, six were excluded for formal reasons, 35 papers for addressing higher education, 37 because they related to other subjects than science and 48 because they did not target CBSE. As a result of the screening, 200 papers were obtained. Due to availability issues, six could not be used for the main corpus's data analysis.

Since recent papers kept referring to a relatively small number of earlier publications when it came to definitions, we focused on those key papers which dealt with the conceptual meaning of context and covered the internationally established context-based approaches. This procedure led to a total of nine core documents published between 2006 and 2018, which were analysed by an inductive approach via qualitative content analysis (Kuckartz, 2014) with MAXQDA 2022.

As our purpose was to achieve a systematic review of the current understanding of *context* and its functions attributed in the science education literature, we decided to narrow the analysis of the remaining papers to those published from 2013 onwards. This reduced the number of papers to 122, which formed the main corpus for analysis. During the analysis, 21 more papers were excluded (for formal reasons: 1, for addressing higher education: 3, for not addressing CBSE: 8, for not explicating the authors' understanding of context: 9; see Figure 5), so that our results are based on analysing a total of 101 papers.

The categories determined inductively from the analysis of the nine core documents on the different functions (Q1) and understandings (Q2) of *contexts* were then deductively applied in the qualitative content analysis of the main corpus's data analysis, starting with the newest papers. In a reciprocal process, new categories were added inductively, if necessary, until theoretical saturation was reached (Kuckartz, 2014).

In order to enhance the rigour of the analysis, a minimum of two individuals were consistently engaged in the data processing. Title-abstract screening was carried out by the lead author and the second author, with partial assistance from a student assistant. The core documents were coded by the lead author and the second author. The resulting inductive category system was discussed with all authors and also presented at national science education conferences. The system was continuously further developed throughout this process. The coding of the full texts was conducted by the lead author and the third author. Peer debriefing (Lincoln & Guba, 1985) was carried out regularly between the lead author and the third author to extensively discuss all categories and text passages that were challenging to code. In certain cases, the other authors were also involved in this process.

In the papers reviewed, the extent to which the authors present their understanding of *context* differs significantly. As only the respective contextual understanding was of interest in this study, the following results do not take into account how often a certain code was assigned within a paper, but only count the papers in which a category was coded at least once.

Results

Description of the corpus underlying the systematic literature review

Table 1 displays the global distribution of the 101 papers included in the final corpus. One paper is excluded from this list because it refers to several countries: Kang et al. (2019) analyses data on lower secondary students from Estonia, Finland and the United Kingdom. A detailed table that assigns all references to the respective countries where the research was conducted or, if not clearly stated, to the authors affiliations can be found in the supplementary material.

Description of the categories addressing the functions attributed to contexts (contexts for . . .)

From the systematic literature review of 101 papers, we retrieved seven categories that describe the functions attributed to *contexts* in CBSE approaches (Table 2). The categories are displayed in descending order according to the number of documents in which 561 codings in the categories Cf1-Cf7 were attributed.

The category *contexts for influencing affections* (Cf1) was coded the most (86 of 101 papers). The codings relate to contexts assuming positive effects on various kinds of science-related affections. Firstly, contexts should make the lesson, unit, or subject more meaningful from the students' perspective or – in other words – facilitate a feeling of relevance (e.g. van Dinther et al., 2023; Eugenio-Gozalbo, Ramos-Truchero, et al., 2022; Karakaya et al., 2022). Some of the authors (e.g. Tolppanen et al., 2019) refer to Stuckey et al. (2013) model for three different dimensions of relevance: individual, societal, and vocational relevance. Engendering and maintaining (situational) interest is another positive influence contexts should have according to the literature (e.g. Habig et al., 2018; Löffler et al., 2018). Additionally, contexts should motivate students to engage in learning science and in conducting scientific practices (e.g. Peretz et al., 2023; Ummels et al., 2015a,

Table 1. Global distribution of the analysed papers.

# of papers	country in which the research was conducted
21	The Netherlands
19	Türkiye
8	Sweden
6	Spain; Israel
4	Germany; Indonesia; South Africa
3	Australia; Finland; The United States of America
2	Argentina; China; Ireland; The Philippines
1	Bangladesh; Bulgaria; Brasil; Chile; Estonia; Georgia; Greece; Italy; Malaysia; Portugal; Switzerland

Table 2. Category system summarising functions attributed to *contexts.*

No.	Category Contexts for ...	Definition	Exemplary Codings
Cf1	... influencing affections (234 codings in 86 papers)	Contexts are used to positively influence the students' affections towards engaging in science learning in the specific learning situation and in general. This could be achieved through the contexts making science learning more relevant in the perspective of the students, provoking situational interest, motivate students and/or improve their general attitude towards science, scientific careers, and scientific applications in real-life.	One of the fundamental ideas with context-based learning (CBL) approaches is to use a contextual setting for the content with an aim to increase students' perceived interest and relevance to the subject, in this case chemistry (Broman et al., 2022, p. 479).
Cf2	... developing scientific competencies (146 codings in 72 papers)	Contexts should enable the development of scientific competencies such as skills and abilities, coherent knowledge, technical language, and transfer of knowledge.	First, context-based approaches intend to promote students' cognitive development and increase their achievement by connecting a recognizable real-life issue to chemistry concepts (Vogelzang et al., 2021, p. 721).
Cf3	... promoting scientific literacy (40 codings in 25 papers)	Contexts and CBSE are attributed the function to foster scientific literacy, e.g. understanding more about the nature of science, understanding the meaning of science and its connections to the society now and in the future, the preparation of students for the future and of them becoming critical citizens.	In the best-case scenario, through context-based teaching on ionic liquids, it is possible to support relevance both in the individual and societal dimensions, and to increase understanding of the meaning of chemistry and its connection to society now and in the future (Pernaa et al., 2022, p. 6220).
Cf4	... providing accessibility (18 codings in 14 papers)	The context should provide gateways to learning for the students, e.g. through making it easier to visualise, choosing different contexts for individual needs or making tasks interesting.	The overarching driving question or problem should contextualise the big idea of the lesson, which might otherwise be inaccessible to EBLs, given the abstract nature of many secondary science concepts and technical terms (Cummins 1991; Stoddart et al. 2002; Tolbert et al., 2019, p. 1072).
Cf5	... self-regulated learning (13 codings in 11 papers)	Context should enable students to become autonomous, self-regulated learners, that direct their own learning and feel a sense of ownership.	Context-based approaches invite students to direct, monitor and reflect on their learning so that they become self-regulated learners (Vogelzang et al., 2019, p. 2).
Cf6	... learning on sustainable development (7 codings in 7 papers)	The context facilitates learning on sustainable development and promotes knowledge and competencies that promote the sustainable development of the society.	CBL facilitates learning on sustainable development, and it is most readily implemented in applied aspects of chemistry, where the real-life contexts are easily identified (Tal et al., 2021, p. 1004).
Cf7	... authentic learning (7 codings in 7 papers)	Contexts are used/implemented to facilitate authentic learning instead of learning in 'simulations'.	Using a garden as a real context to pose the core question ("If we cultivate our own vegetable garden, will we eat better?") and real-life activities proved both to be useful [39,47] to promote an authentic science learning experience and, in turn, to prepare students for real-life decisions and life-long learning, which constitute the main objectives of science education [42,56]. (Eugenio-Gozalbo, Ramos-Truchero, et al., 2022, p. 12)

Table 3. Category system summarising understandings of *context.*

No.	Category Context as ...	Definition	Exemplary Codings
C1	... topic (186 codings in 76 papers)	The context as a topic a content is embedded in. Within this category the kind of the relation between topic and content can vary. On one side of the spectrum the context/topic can be the basis for selecting and organising content and activities. On the other side the topic may be chosen because of the content it is able to represent. Another variation might be whether there is only included content needed to understand the context or whether the content exceeds the necessary amount of information.	In other words, a context can be seen as a topic (or frame of reference) a content (or concept) is embedded in (Podschuweit & Bernholt, 2018, p. 724). The design of teaching units must connect relevant contexts, from which questions are derived, and the basic concepts that can be applied to answer such questions (Parchmann et al., 2006, p. 1046).
C2	... situation (68 codings in 49 papers)	A context as a situation, in which a focal event occurs in a specific setting, meaning at a certain time in a certain place in a certain social surrounding with its own behavioural environment, i.e. specific activities and actions.	Reflecting Duranti and Goodwin (1992), we agree on the broad characterisation of context as an individually constructed focal event embedded in and interconnected with a field of action (Podschuweit & Bernholt, 2018, p. 724).
C3	... educational form (86 codings in 48 papers)	A context is presented as an educational form, that serves the purpose. This form serves as the context, e.g. a question, a problem/issue, a task.	The overarching driving question or problem should contextualise the big idea of the lesson, which might otherwise be inaccessible to EBLs, given the abstract nature of many secondary science concepts and technical terms (Cummins 1991; Stoddart et al. 2002; Tolbert et al., 2019, p. 1072).
C4	... structuring element for teaching and learning (57 codings in 39 papers)	A context as the structuring element for lesson planning or for structuring the teaching and learning process.	As Nentwig and his colleagues (Nentwig et al., 2007) proposed, a context is "the red thread along which the investigation of the issue in question develops" (Chi et al., 2023, p. 1441).
C5	... practice (41 codings in 23 papers)	The context is or includes a practical activity that is typical for science or real-life.	We redefined "context" as "practice", since it not only defines the specific situation, but also the type of actions together with the necessary knowledge to be able to perform these actions (Bulte et al., 2006, p. 1074).
C6	... socio-scientific issue (14 codings in 11 papers)	The context as a socio-scientific issue, which usually has a connection to science, is significant to society and has a controversial character.	Socio-scientific issue as a controversial issue can be used as a context of chemistry learning (Wiyarsi et al., 2021, p. 3).
C7	... starting point for curriculum design (6 codings in 6 papers)	Contexts are used to design the curriculum and/or curricular units to address problems like curriculum overload and lacking relevance.	We found that the choice of contexts as a starting point for the design of curricula and units within those curricula offers fruitful opportunities to avoid overload and to provide a representative curriculum (Pilot & Bulte, 2006a, p. 954).
C8	... starting point for assessment (9 codings in 3 papers)	A context is used for assessment, e. g. assessment questions.	Firstly, in keeping with the context-based approach, the external assessment questions (either in the form of module assessment or examinations) use contexts as starting points (Bennett & Lubben, 2006, p. 1006).

b). In a more permanent and internalised way, the positive influences of contexts should lead to improving students' attitudes towards science (e.g. Bennett et al., 2007; Gilbert, 2006; Vogelzang et al., 2021).

The category containing the second most codings is *contexts for developing scientific competencies* (Cf2), occurring in 72 papers. This category contains a very broad range of codings that refer to the learners' learning performance, whether it is building scientific skills and abilities (e.g. Schwartz, 2006), a coherent mental structure of the topic (e.g. Vogelzang & Admiraal, 2017), scientific language (e.g. van Dulmen et al., 2023) or the transfer of knowledge (e.g. Broman et al., 2015). As for skills and abilities connected to science, these include: procedural and epistemic aspects of scientific competencies such as locating information, addressing specific issues, developing analytical skills and critical judgement (Schwartz, 2006) or recognising important and answerable questions, using scientific methods in experimental investigations, interpreting data, discussing and presenting results, and developing critical judgement (Parchmann et al., 2006). Cf2 also contains codings that focus on knowledge-related aspects like gaining scientific knowledge and developing coherent mental maps of scientific concepts that tie the context to prior knowledge and enable students to make connections to and between the same and other contexts (Pilot & Bulte, 2006b). Further important aspects of Cf2 are the development and use of specific scientific language (Gilbert, 2006) and arrangements for the transfer of knowledge. For instance, Herranen et al. (2019, 1978) state, 'contexts from "everyday life" are expected to [. . .] possibly promote knowledge transfer between the science classroom and life outside formal education (Gilbert et al., 2011)'.

Category Cf3, coded in 25 papers, contains codings that refer to *promoting scientific literacy* as a function of contexts. There is a wide range within the codings' precision. In most of the codings, the term 'scientific literacy' is merely mentioned without further elaboration, e.g. Lupión-Cobos et al. (2017, pp. 940–941) state that 'the main goal of this approach [CBSE] is to foster scientific literacy'. Other papers address specific values and competencies and relate to certain visions of scientific literacy. For example, Nida et al. (2021, p. 2) refer to a 'recently suggested critical vision of scientific literacy' and cite Sjöström and Eilks (2018, p. 66) for this Vision III 'which aimed at preparing students for responsible citizenry in their society'.

The category *contexts for providing accessibility* (Cf4, coded in 14 papers) contains codings which explicitly describe the functions of contexts in a way that they offer 'gateways to learning science' (van Vorst & Aydogmus, 2021, p. 1254). In some of the codings, it is not described which kind of access the context offers. The specific paths that are presented vary from support for the students to 'visualize it better in their minds' (Karsli Baydere, 2021, p. 644) to motivational factors that 'help students engage with new content' (Habig et al., 2018, p. 1156) or help them bridge rather abstract scientific concepts with their everyday life (e.g. Swirski et al., 2018; Tolbert et al., 2019).

Contexts for self-regulated learning (Cf5) was coded in 11 papers. It addresses a different field of pedagogical intentions. This category stresses the students' responsibility for their own learning processes, including the idea that contexts provide an opportunity to develop a sense of ownership in the learners (e.g. Dolfing et al., 2021).

Another function of contexts that could be derived from seven papers is *contexts for learning on sustainable development* (Cf6). For example, Chowdhury et al. (2022), Pernaa et al. (2022) and Tal et al. (2021) see the potential CBSE has for sustainable development without further elaboration of this term.

Another category with few codings in seven papers is *contexts for authentic learning* (Cf7), stating that contexts make science education more authentic in contrast to an artificial learning setting, which means giving students 'opportunities to study science in their real-world rather than through a "simulation"' (King & Henderson, 2018, p. 1222).

Relations between the different functions attributed to the use of contexts

An analysis of the connections between the different categories was conducted and visualised by an aggregated network diagram (see Figure 6). The thicker the line between two categories, the more papers were coded with both categories. The analysis shows that most papers that draw on affective reasons (Cf1) for context-based approaches also strive for *developing scientific competencies* (Cf2, see Figure 6). These two categories were coded by far the most. Figure 6 also shows that none of the functions attributed to contexts stand alone, independently of their frequency of occurrence, but that some of the functions are never addressed together (e.g. *self-regulated learning and providing accessibility*).

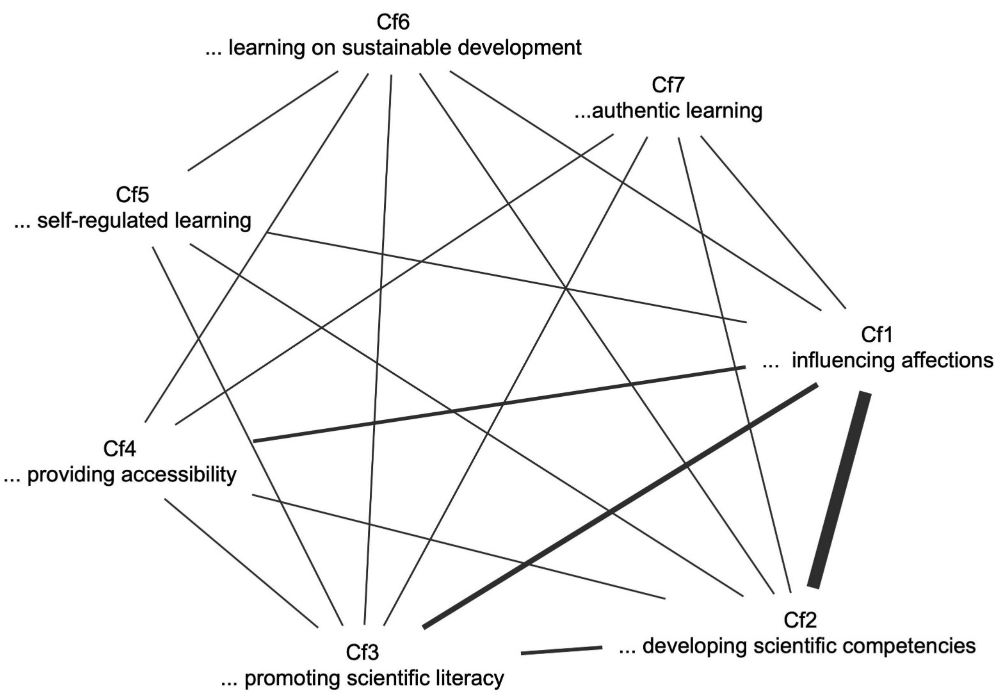

Figure 6. Aggregated network diagram of the functions attributed to *contexts.*

Description of the categories addressing the understanding of the term context (contexts as . . .)

Addressing research question 2 by analysing the corpus of papers, we retrieved 568 codings summarised in eight categories, which address aspects and facets of multiple constructs of *contexts* that can be found in the literature. In Table 3, the categories are displayed in descending order according to the number of papers they were found in.

Codings of the category *context as topic* (C1) were identified in 76 of the 101 papers. This category focuses on the relation between topic and content. The authors mention different areas the topic may come from, such as life, science, society, technology, profession, (socio-)cultural or overlapping areas (e.g. de Putter-Smits et al., 2022; Miller & Roehrig, 2018; Wei & Long, 2021). Some authors (e.g. Pernaa et al., 2022; van Dinther et al., 2023; van Vorst & Aydogmus, 2021) recommend the relation between topic and content to be in a way that emphasises the importance of the topic: The topic is seen as the starting point that determines the context of a unit the content is embedded in (Podschuweit & Bernholt, 2018). In this perspective, the content is introduced on a so-called 'need-to-know' basis (Bulte et al., 2006). Consequently, choosing a context-based approach in the sense of C1 leads to a quantitative reduction of content (Gilbert, 2006). The context becomes an exemplification for meaningful scientific content (Gilbert, 2006). Another perspective on the relation between topic and content with greater emphasis on the science content is seeing the topic of a unit as a context that operates as a vehicle for scientific content (e.g. Barendsen & Henze, 2019; Miller & Roehrig, 2018). The idea behind this emphasis is to start lesson planning beginning with the content and then choosing an appropriate topic as a context for teaching and learning this content. Realistically, these processes are rarely linear and therefore in the analysis of the papers it is not always easy to tell whether the planning process started with the topic or the content. Wei and Long (2021, p. 6) state that a 'context not only precedes concepts but is also followed by (other) concepts, which means that context and concepts are intertwined'. At the end of the spectrum described here, contexts are merely used as an illustration of some content that shall be taught (Barendsen & Henze, 2019; Wei & Long, 2021).

In 49 papers, a *context* is described *as situation* (C2). Many authors (e.g. Barendsen & Henze, 2019; Chi et al., 2023; Güngör et al., 2022; Onwu & Mufundirwa, 2020) in this regard cite or refer to the identified core documents, e.g. Gilbert (2006) respectively Duranti and Goodwin (1992) (also cited by Gilbert, 2006). Consequently, we retrieved category C2 that defines contexts according to Gilbert (2006) as 'focal events', which can be any kind of happening in a setting. The addressed happening necessarily occurs in a specific setting, meaning a certain time in a certain place under certain circumstances including the social surrounding and a behavioural environment (Gilbert, 2006). According to this understanding, a certain phenomenon can become a context if it is embedded in an event and a distinctive setting. For example, Tolbert et al. (2019, p. 1072) refer to 'local phenomena' that can serve as contexts for science education. Chi et al. (2023, p. 298) stress the potential variety of focal events for chemistry education when they state that '[t]hese situations or scenarios contain chemistry-related issues including chemical phenomena, chemistry discoveries, environmental protection, industrial process or applications of chemistry, or recent research and innovations'.

Many codings were sorted into the category *context as educational form* (C3). This category was found in 48 of the papers. Within this category, the context is mentioned to be presented in the form of a question (e.g. Eugenio-Gozalbo, Ramos-Truchero, et al., 2022), a problem (e.g. Chi et al., 2023), an issue (e.g. Broman et al., 2018) or a task (e.g. Habig et al., 2018).

When it comes to lesson planning and lesson design, *context as structuring element of teaching and learning* (C4) plays an important role in 39 of the papers. Here, contexts are seen as a central element used as a starting point, a frame, or a focal point, that is referred to throughout the lesson, building a red thread or storyline (e.g. van Vorst and Aydogmus, 2021; Habig et al., 2018). Another way in which contexts may structure a lesson is by differentiating between a surface structure of the context that refers to real life and is connected to everyday knowledge and experiences, and a scientific deep structure of the context that allows understanding processes and answering questions that cannot be resolved on a macroscopic scale (Löffler et al., 2018).

Context as practice (C5) emphasises an activity that either is typical for science or the environment the students are living in. For example, Herranen et al. (2019) see inquiry as a practice that serves as a context in science education, whereas Eugenio-Gozalbo, Ramos-Truchero, et al. (2022) use the practical activity linked to gardening as an example for a context of science education. In total, 23 papers contained statements that were coded and assigned to this category.

The category *context as socio-scientific issue* (C6), in contrast to the ones derived from coding the core documents inductively, had to be added later to the code system, because it occurred in the other papers. Referring to societal problems with scientific scope and controversial character, quite a few papers (11 in total) such as Wiyarsi et al. (2021), Vogelzang et al. (2020) or Kang et al. (2019) see socio-scientific issues as contexts for science education.

The last two categories, *context as starting point for curriculum design* (C7) and *context as starting point for assessment* (C8), differ from the other six categories, as they can be seen on a meta-level of lesson planning. *Context as starting point for curriculum design* means that the authors of the related six papers in our corpus see contexts as central elements that drive the planning and decisions about how curricula and curricular units shall be constructed (e.g. Dam et al., 2018; Westbroek et al., 2017). Content that is neither relevant nor necessary to understand the context is not included in the planning. This strategy naturally leads to a reduction of scientific content (Pilot & Bulte, 2006a). Within three papers of the main corpus, authors see *contexts as starting point for assessment* (C8) by contextualising tasks that are used for assessments of learners' competencies, e.g. as used in PISA (Bennett & Lubben, 2006).

Relations between the different understandings of the term context

As can be seen in the description of the categories and the corresponding citations, the understandings of contexts are intertwined. Figure 7 shows the relations between the categories. The thicker the line between two categories, the more papers contain codings of both categories. What is striking is that none of the categories stands alone. How

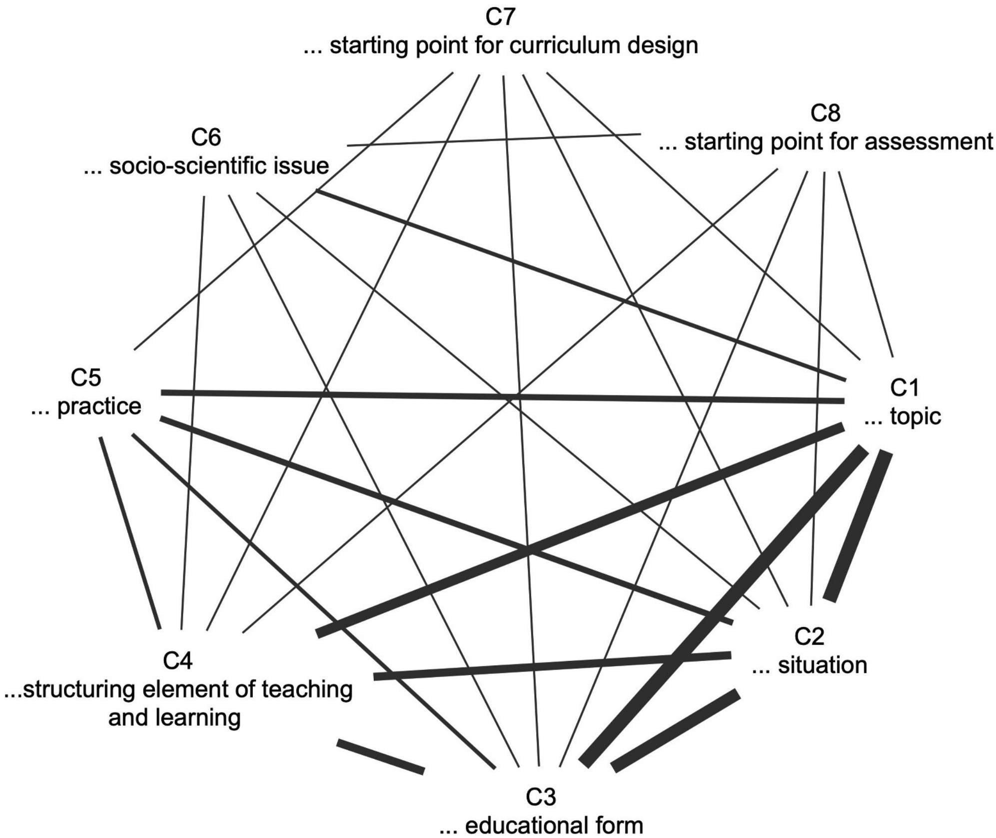

Figure 7. Aggregated network diagram of the understandings of the term *context*.

frequently the categories overlap corresponds, of course, with the frequency of occurrence in papers that contain codings of the respective categories.

Relations between understandings of the term context and functions assigned to contexts

The analysed papers do not only refer to understandings or functions, but they relate aspects of both. Table 4 shows in how many papers they overlap, i.e. in how many papers a certain understanding is coded as well as a certain function. The distance between the frequencies is translated into a colour scheme. Since the table is sorted according to the number of papers the categories occur in (from top to bottom and from left to right), the largest numbers are, in principle, at the top left and the smallest numbers at the bottom right of the table. Logically enough, most overlaps exist between those categories that are coded in most papers, i.e. between papers that contain the contextual understanding *context as topic* (C1) and the function *contexts for influencing affections* (Cf1).

Nevertheless, some numbers in Table 4 do not follow the given logic. For example, the combination Cf4 (*contexts for providing accessibility*) with the context understanding C2 (*context as situation*) occurs in 10 papers in comparison to the combination Cf4 with C1

Table 4. Relations between understandings and functions of *context*.

	Cf1 … influencing affections	Cf2 … developing scientific competencies	Cf3 … promoting scientific literacy	Cf4 … providing accessibility	Cf5 … self-regulated learning	Cf6 … learning on sustainable development	Cf7 … authentic learning	Number of documents with the code
C1… topic	66	52	23	11	9	5	6	76
C2 … a situation	44	35	15	10	6	5	5	49
C3 … educational form	43	34	15	7	6	1	4	48
C4 … structuring element of teaching and learning	34	29	11	4	4	2	3	39
C5 … practice	19	19	5	4	3	1	2	23
C6 … socio-scientific issue	10	7	8	3	0	0	1	11
C7 … a starting point for curriculum design	5	5	1	0	2	0	0	6
C8 … a starting point for assessment	3	1	2	1	0	0	0	3
Number of documents with the code	86	72	25	14	11	7	7	

(*context as topic*), which occurs in 11 papers, although the total number of papers for C1 is much higher than for C2. Another example is that the context understanding *context as practice* (C5) appears likewise in the papers where the two categories *contexts for influencing affections* (Cf1) and *contexts for development of scientific competencies* (Cf2) were coded, although the category Cf1 was found in more papers.

As mentioned before, the function *contexts for promoting scientific literacy* (Cf3) is not explained in further detail in the 25 papers where the category occurs; however, by looking at categories that were mentioned in the same papers, a certain understanding may be deductible, e.g. the category *context as topic* (C1) was also coded in 23 of the 25 papers. The combination *context as socio-scientific issue* (C6) in connection with the category *contexts for promoting scientific literacy* (Cf3) occurred more frequently than the pattern in Table 4 suggests, although only eight of 25 publications, where Cf3 was found, contained both categories. In other words, 17 papers, in which the category *contexts for promoting scientific literacy* (Cf3) was coded, do not link this objective to socio-scientific issues.

The category *contexts for providing accessibility* (Cf4), which is particularly relevant from the perspective of DEI, is assigned in 14 papers in total. It does not appear in connection with the category *context as starting point for curriculum development* (C5) and it appears only once together with the category *context as starting point for assessment* (C8). Cf4 is further mentioned in papers where contexts are understood *as topic* (C1), *situation* (C2), *educational form* (C3), *structuring element* (C4), *practice* (C5) or *socio-scientific issue* (C6). Different understandings of CBSE thus seem to have some potential for making science education accessible in terms of DEI.

Discussion

Which functions assigned to the use of contexts have the potential to promote DEI?

The functions attributed to contexts that were found in the literature were interpreted in terms of promoting Vision II+: One function that is assigned to CBSE is *providing accessibility* (Cf4), which we see as the umbrella category for addressing DEI. However, suggestions from the literature are not very concrete regarding, for example, how a context can be designed to be less/more abstract or methodically more diverse, i.e. more accessible for everybody. In this regard the Universal Design for Learning (CAST, 2012; King-Sears et al., 2015), the NinU Framework (Stinken-Rösner et al., 2020) or the Framework for Inclusive Science Education (Brauns & Abels, 2021) could prove to be helpful, offering specific suggestions such as minimising barriers by using action-oriented scientific methods, digital media, or learning with all senses so that everybody can potentially participate.

The other categories we found mostly do not address DEI explicitly; we see, however, potential also in those:

Self-regulated learning (Cf5) is seen as a way to promote inclusive education and academic achievement, because it offers the opportunity for autonomous learning and for feeling personal relevance (Perry et al., 2017). The idea is to give students a ‘certain autonomy of choice’ (van Dinther et al., 2023, p. 1543) in the ‘sense of ownership of what is to be learned' so that some learners learn independently (Dolfing et al., 2021, p. 131). That would free teachers' resources for those learners in need of more support. This understanding contributes to a perspective of scientific literacy that allows students to take 'responsibility for their own learning processes' (Westbroek et al., 2017, p. 1408). We consider this an opportunity to align with Vision III of scientific literacy, which aims to act as an 'honest broker of policy options' (Liu, 2013, p. 29), encouraging students to take responsibility for their own lives and to contribute to a fairer society. Vision III+ could become a reality if everyone is actively engaged and afforded the chance to contribute. Interestingly, Cf4 and Cf5 have not been addressed together in the same paper, despite the significant potential for enhancing access through self-regulated learning, as outlined above.

Another option to make contexts more accessible is *learning on sustainable development* (Cf6) by using sustainability contexts that students perceive as relevant due to discussions in the (social) media, at home or in school. Therewith, they 'could experience the need for scientific inquiry to investigate ecological causalities and for multi-perspective thinking and responsible decision-making in situations relating to sustainability' (Roesch et al., 2015, p. 587). In comparison with the other functions of contexts in CBSE, this category is rather specific. It is an important component of science engagement in the sense of Vision III that also aims for socio-political outcomes and therefore is in line with future-oriented goals of science education. DEI and education for sustainable development share many norms and strategies (Rieckmann & Vierbuchen, 2020). Therefore, CBSE using sustainability contexts could be a way to integrate both educational goals developing from Vision II to III. Despite there being no direct connection to DEI mentioned in the literature, Cf6 could be used to support DEI if different experiences of students or environmental injustices are included and considered striving for Vision III+. However, there is no context fitting everyone (van Vorst & Aydogmus, 2021): students should be allowed to choose between different contexts according to their interest. Furthermore, teachers need to be aware that students might feel excluded by certain contexts, e.g. due to their low socio-economic background (Calmbach et al., 2020). For example, if they or their families cannot afford an e-bike or organic vegetables, these topics are establishing barriers rather than giving access to science learning.

Some papers describe *contexts for authentic learning* (Cf7). Habig et al. (2018) say that students with low interest in science benefit from daily-life, authentic or personal contextualisation, whereas more interested students benefit from unique contexts and unfamiliar topics. Dividing students into those who are more and those who are less interested in science harbours the risk of stigmatisation ('is not interested in science'). Instead of diagnosing individual prerequisites first, we suggest focusing on the accessibility of the learning object (Abels & Witten, 2023). Teachers should start planning with regard to the chosen topic: Is it relevant and motivating? Are the science-related aspects worth learning? Which barriers are inherent to them? (Stinken-Rösner et al., 2020). The chosen topic must take into account the lifeworld of the students – considering which aspects are already part of it and which should be included – while offering various contexts that range from unique experiences to everyday life (cf. Habig et al., 2018). In our review, Cf6 (*contexts for learning on sustainable development*) and Cf7 (*contexts for authentic learning*) were never coded in the same paper. Eventually, disadvantaged students would feel more addressed by sustainability contexts if those were more authentic, i.e. from their daily life (cf. Habig et al., 2018), because more motivated and interested students with a positive attitude and a high sense of relevance learn science better. CBSE can influence these positive affections (Cf1; Broman et al., 2022, p. 479; V. Edelsztein & Vázquez, 2021, p. 781/782). Supporting students to develop positive affects would be more effective than permanently labelling certain students as uninterested. Positive and negative emotions are known to be of importance for learning (e.g. Pekrun, 2006) and, while being individual and diverse, 'emotional experiences are ubiquitous in nature and important and perhaps even critical in academic settings, as emotion modulates virtually every aspect of cognition' (Tyng et al., 2017, n.p.). Thus, they may be seen as a basic way of human access towards the world. In this sense, they offer unique pedagogical opportunities in terms of DEI (Vision II+), for access cannot only be given by action-oriented methods, for example, but also by evoking affects.

Evoking positive affects (Cf1) like interest or motivation promotes the *development of scientific competencies* (Cf2), the central aim of science education, which probably explains why Cf1 and Cf2 are coded together in many papers (65): more interested students understand science better (cf. Höft et al., 2019 for a more complex explanation of this relation). For developing the range of competencies demanded by national standards, teachers need to know what the students are not (yet) able to do and should still acquire. A problem will arise if students are assessed on what they can and cannot do and this leads to a deficit-oriented view on students' learning. To change the perspective here, the teacher should focus on the scientific learning object and what barriers it has, e.g. that it is demanding in terms of language or motor skills or requiring inappropriate levels of abstraction (Abels & Witten, 2023). Teachers need to ask how they can help overcome such barriers, e.g. by offering learning environments that address different competence areas. Emphasising the development of conceptual, procedural, and epistemic competencies rather than just reproducing scientific content supports the idea of empowerment through scientific literacy for everybody (Vision II+). To foster a Vision III(+) of scientific literacy, these competencies must be aligned to socio-political actions (engaging everybody) (Hodson, 2003).

All categories discussed above somehow contribute to the use of *contexts for promoting scientific literacy* (Cf3); however, the papers in our review mostly do not specify the vision they address. At least some of the authors seem to target a Vision II+ of scientific literacy. For example, Çiğdemoğlu and Geban (2015) focus on overcoming gender differences in interest and achievement with CBSE, and Cabello (2022) addresses the diversity of the students regarding their backgrounds that should be met with a CBSE approach. We think that all the Cf-categories from our review are useful to address DEI more explicitly than has been done in most of the analysed papers, thereby enhancing Vision II+ (*science for everybody*).

Which understandings of context have the potential to promote DEI?

In contrast to the different functions attributed to the use of *contexts* in the science education literature, there is no understanding of *context* that is directly and obviously promoting DEI in science teaching. The majority of papers offered an understanding of *context as a topic* (C1), and thus the idea that contexts represent the frame in which scientific content is embedded (Podschuweit & Bernholt, 2018, p. 724). We argue that scientific content generally becomes more accessible for every student in terms of Vision II + when anchor points are offered to the learners, through which a connection with their own life world, experiences and biographies is made easier (Windschitl et al., 2018).

If DEI is understood not only in the sense of empowerment but also in the sense of promoting (educational) justice, the greatest potential is found in contexts that not only are connected to the real world but also open (critical) discussions of relevant societal problems and thereby add a political perspective to science education. This would build a bridge between the understanding of *context as socio-scientific issue* (C6) and an orientation of science education that we presented at the beginning, namely the orientation towards an emancipatory understanding of scientific literacy in the sense of Vision III. Gained knowledge should help to understand the world and solve related problems, enabling every student to participate in controversial societal debates. For example, Wiyarsi et al. (2021) state, 'SSI-based instruction engages students with an interesting scientific problem and trains them in making decisions toward a social problem that has a moral implication on scientific context' (p. 3). In terms of DEI, *socio-scientific issues* (C6) should draw on students' funds of knowledge and their cultural contexts, valuing the diverse backgrounds of the students. It is essential to be aware of and address the different experiences of students when exploring SSI, which may be influenced by factors such as socio-economic status and cultural background. An example from the Philippines is the use of indigenous games as a context for teaching physics (Morales, 2017). In the US, some educators address science-related topics by challenging norms based on structural power relations, such as binarity and heteronormativity, particularly when discussing aspects of gender and sexual orientation (Wright & Delgado, 2023). Another culture-based learning example from the Philippines involves integrating indigenous medicinal plants and practices into 9th grade biology (Bibon, 2022). Onwu and Mufundirwa (2020) from South Africa use storytelling to engage students with a rural community technology – a loading platform made from local wood – to effectively teach the concept of forces. Their aim was to link indigenous knowledge with scientific content.

Regarding DEI, we argued that CBSE is more accessible than content learning. For this to work (and therewith to foster DEI) it is not only necessary to choose contexts that are relevant and meaningful for the students, but to keep the contextual topic present throughout the whole lesson so that it can guide students' learning and enable meaningful engagement (cf. van Vorst & Aydogmus, 2021, p. 1252) throughout the unit. The context should be the *structuring element* (C4) of the unit and not just the hook for science content (Habig et al., 2018). It must serve as a common thread so that the lesson does not tip over into a subject-specific logic that originates in the scientific discipline and thus loses transparency for the learners (example see e.g. Watts & Weirauch, 2022).

The categories *context as a situation* (C2), *context as educational form* (C3) and *context as practice* (C5) all address ways how to design CBSE. We think that these understandings of contexts have large potential to promote DEI in terms of Vision II+: The degree to which a chosen situation (C2) can promote accessibility depends on what kind of focal event and setting is designed. The main driver, again, is the relevance from the students' perspective. One possibility could be to offer various focal events for the students to choose from, within a setting, e.g. a barbecue with focal events or phenomena like burnt wood or coal, grilled food, sauces, etc., or the other way round with the variety in the settings like travelling in space, sailing across the Atlantic or living in a dry area, tied together with the same focal event, in this case the problem that drinkable water is needed to survive. This variability within a shared frame could be an opportunity to provide different and sometimes deeper access for everybody and therefore contribute to a Vision II+ of scientific literacy, e.g. when students are encouraged to find their own examples or analogies drawing on their funds of knowledge (Tolbert et al., 2019).

Since practical activities are concrete, it is easier to design them adaptively to address DEI than more abstract activities such as modelling. Within the category *context as practice* (C5) the potential for DEI lies in the access that practical activities provide as experiences in comparison – and in addition – to written tasks, for example. Practical experimental work enables learning with all channels of perception and thereby provides diverse ways to access the content. Consequently, it increases the likelihood that everybody will find a (scaffolded) access that appeals to them individually (Andersen, 2015; Weirauch et al., 2021).

Regarding *context as an educational form* (C3), offering a higher variety of methods is known to support students' learning in better ways (Tobin & Tippett, 2014). The more educational forms (questions, tasks, problems, etc.) are offered in alternation, the more likely it becomes that every student finds an access to learning science.

In our view, the particular potential to promote DEI in science education lies in the deliberate integration of different understandings of *context* into a single learning environment. The synergy between a relevant topic (C1), embedded within an interactive situation (C2), realised through diverse educational forms (C3), structured coherently around the chosen topic throughout the whole unit (C4), and offering varied practical experiences (C5) creates multiple entry points and engagement opportunities for diverse learners, thereby promoting Vision II+.

The intentional combination of these context dimensions creates an inclusive learning ecosystem where:

- Students with different backgrounds find relevant connections to their lived experiences
- Various learning preferences and abilities are accommodated through methodological diversity
- Different forms of knowledge and expression are valued through varied practical experiences

Structural coherence helps everybody construct meaningful understanding and find anchor points taking into account their prior knowledge.

An example for the interplay of different uses of contexts

We would like to illustrate the interplay of different understandings of *contexts* by using an example: The topic of mountains of rubbish and packaging waste is introduced as a relevant environmental *topic* (C1), to which the learners add their individual interests and questions. As a *structuring element* (C4), the topic of waste must structure the entire lesson (common thread), from which societally, vocationally or individually relevant (Stuckey et al., 2013) *situations* (C2) (for example an excursion to the supermarket, picking up litter in the community, etc.) emerge. Based on these situations, stimulating, relevant *questions and tasks* are developed (C3), e.g. which different characteristics does the packaging of different food products like eggs, cheese, milk or vegetables have, or how much and what kind of waste do we find in the neighbourhood during one week. Questions can also be linked to social perspectives and political problems (C6), e.g. which packaging is more environmentally friendly than plastic with the same good properties or how can packaging be avoided or be re-used as a resource. In order to enable different ways of access and learning paths, a variety of *experiments and analyses* are possible, but also research, e.g. on the identification and composition of different packaging and plastics (C5). Overall, this combination of context understandings could contribute to making science learning more accessible and sensitive to diversity. It thus enhances to scientific literacy in the sense of Vision II+, as well as eventually creates links to social and political problems (scientific literacy in the sense of Vision III). If all students get engaged in socio-political actions regarding this context, and not only the privileged ones, Vision III+ can be achieved.

Some authors (Çiğdemoğlu & Geban, 2015; Soobard & Rannikmäe, 2015) suggested contexts to be a *starting point for assessment* (C8). As it becomes obvious through the exemplary unit sketched above, again this would provide more opportunities in the sense of DEI, because a variety of competencies become visible that could be assessed. However, assessment is not the first thing that comes to mind when thinking about DEI, because it often involves standardisation and selection. Apart from this fundamental position, context-based assessments could be a step in the direction of Vision II+, because they imply more open forms that allow an individualised evaluation of achievement – like the idea of universal design for assessment promotes (Rose et al., 2018).

When considering the various ways contexts can be understood and the pedagogical advantages they offer, it is essential to re-emphasise an original demand of CBSE (Pilot & Bulte, 2006a) for DEI: Contexts should take precedence in curriculum design (C7), replacing the more traditional focus on science content. Furthermore, as discussed by Guerrero and Torres-Olave (2022), curricula determine what individuals should learn, thereby setting socio-political priorities. Given the importance of science-related social issues, ignoring these contexts in science education is no longer justifiable.

After discussing the understandings and functions of contexts that we could derive from the science education literature, it becomes obvious that for diversity-sensitive CBSE we discuss a thin methodological line, and most of the ideas are not new by themselves. Still, the only relevant criteria from the perspective of DEI are clear and simple: Can *everybody* in a class participate equally and gain science competencies to become scientifically more literate or not?

Which relations of understandings and functions of contexts have the potential to promote DEI?

As shown in the results (Table 4), the most often coded functions and understandings of context show the most overlap. For example, as expected, there is a large overlap between the understanding of *context as topic* (C1) and the function *contexts for* *influencing affections* (Cf1). However, even with these frequent combinations, the special potential for DEI is hardly mentioned.

As expected, there is little or no overlap in the lower right quarter of Table 4, although many relations could harbour potential for DEI (see especially discussion on functions above). For example, the function *contexts for providing accessibility* (Cf4) does not appear in any paper together with the understanding *context as starting point for curriculum design* (C7), which suggests that context-oriented curriculum design has not yet been focused on by the authors from the perspective of promoting DEI.

Conversely, the overlap between the categories *context as socio-scientific issue* (C6, 8 out of 11 papers) and the function *contexts for promoting scientific literacy* (Cf3, 8 out of 25) is higher than expected. This hints towards a possibility of targeting Vision III of scientific literacy in the sense of empowerment by focusing on contexts that allow the critical examination of current political and social issues.

Limitations

Despite extensive findings from the SLR, the following limitations must be considered:

By choosing to include only English peer-reviewed papers, contributions from other communities or work that has not (yet) been published in an international journal were excluded. This decision may reinforce the perspective of the Global North over that of the Global South. With today's capabilities of AI as a translation tool, providing access to papers that were previously inaccessible due to authors' language limitations, our future decisions may differ.

As outlined above, we have limited our scope to primary and secondary education, because of our own position in the research field. We are aware of, and have reflected on, our own positionality regarding disciplinary differences: For example, in the German educational system, sub-disciplines such as engineering and informatics are more likely to be categorised as part of vocational education or are mainly taught in higher education (and were therefore excluded in this review), whereas in other countries they are part of primary and/or secondary science education.

In addition, only those papers that explicate their understanding of the term *context* were included in the final corpus. Other research studies, that might implicitly address CBSE without defining it, were ignored.

Conclusions

Our systematic literature review identifies different functions and understandings of contexts. In summarising the findings, we propose the following intentionally broad definition:

The context is the basis for selecting, organising, and designing content and activities in a meaningful learning environment and can serve different functions.

Such contextualisation can be achieved via various aspects of lesson design (C1: topic, C2: situation, C3: educational form, C4: structuring element, C5: practice, C6: SSI), curriculum design (C7) or assessment (C8). A context can play different roles at different points during a lesson (e.g. first introducing a topic or situation in a certain educational form, thereby initiating certain practices, and subsequently structuring the entire lesson according to a logic that corresponds to the context).

Depending on the teacher's focus, the context thereby can have different, possibly multiple functions (Cf1-Cf7) in the resulting contextualised lesson, e.g. developing scientific competencies, influencing affections, or enhancing accessibility.

We see the greatest potential in combining different context understandings and functions to design more and more various access points considering the high diversity of students. We advocate for an understanding of *contexts* that allows further development of the idea of 'science for all' in terms of DEI. At the same time, we see the necessity of educational strategies that align more closely with current science education than Vision III is yet. The core idea of Vision III is that knowledge should help to understand the world from pluralistic perspectives, enabling and empowering students to participate in 'glocal' actions. Still, engaging learners in socio-political actions and using their cultural backgrounds as contexts can be challenging, as the relation to science content and curricula and to teachers' beliefs about science education is sometimes not obvious. We think, though worthwhile, not every unit must or can strive for Vision III. On the one hand, finding a meaningful political context for, e.g. Valence-Shell-Repulsion-Theory is likely to be very difficult. On the other hand, if no (relevant) context for Valence Shell Electron Repulsion Theory can be found, should it be taught?

We consider *contexts* to be more accessible for students than pure content as learners can relate them to their diverse experiences and perceive greater relevance. Thus, aiming solely for the pure science learner (Vision I) or merely attracting lure students into content learning by introducing but not maintaining a context throughout the unit ('decontextualisation', cf. Parchmann et al., 2006) does not aid DEI.

To become equitable and inclusive, the educational system must realise the fundamental change of perspective that is inherent in programmes like *Salters', Chemistry in Context*, etc. and take the idea of scientific literacy *for all* seriously with a DEI meaning. Curricula consequently must cover context-based questions or problems that are or can be made relevant to the students while the content serves to answer or solve them. The challenge regarding DEI is that contexts need to be developed that allow for engaging everybody in meaningful science learning. Thus, CBSE needs a re-interpretation to accomplish the paradigm shift, or in other words: CBSE needs a paradigm shift itself, as Vision II is not enough. In this decade, science education must become DEI sensitive and follow the everybody approach transmitted in the suggested Vision II+ of scientific literacy. Using all variety of context functions and understandings shown in our literature review is a helpful starting point to develop equitable science education providing access for every learner.

Acknowledgements

The authors are thankful to Anna-Celina Gundlach, Franziska Frey, and Oliver Schneide for supporting the work methodically and by reviewing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

We used Claude 3.5 Sonnet AI to review and correct the language in this text to ensure clarity and proper grammar.

Data availability statement

In addition to the tables in this paper, a detailed category system is provided in the supplementary material. The MAXQDA file is available on request. The references lists all core documents (~) and analysed papers (*).

Funding

The work of the leading author was funded by the Federal Ministry of Education and Research as part of the joint “Quality Initiative in Teacher Education” of the Federal Government and the Federal States [FKZ 01JA1903]. The authors are responsible for the content of this publication.

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