Eldri Scheie
University of Oslo
Berit Haug
University of Oslo
Sibel Erduran
University of Oxford

DOI: https://doi.org/10.5617/adno.9060

Critical thinking in the Norwegian science curriculum

Abstract

Critical thinking (CT) has been highlighted as a key goal of education internationally and is included in the Norwegian curriculum. Researchers from various scholarly traditions define critical thinking differently, but they agree that critical thinking involves both cognitive skills – or abilities – and dispositions. In this study, we examined how different aspects of critical thinking are expressed in the Norwegian core curriculum and science curriculum. In addition to the abilities, dispositions and knowledge aspect of CT, we included ethical, cultural and civic dimensions to build a comprehensive framework of CT that we applied when analyzing the curriculum. From our results, we can conclude that there are few references to CT in the Norwegian core and science curricula. Formulations of CT in the curriculum are both vague and scarce, which is unfortunate because we know that many teachers lack an understanding of what CT actually entails, and they often feel unprepared to teach CT. To support teachers, we suggest that all aspects of CT need to be elaborated and concretized in the curriculum.

Keywords: critical thinking, science education, curriculum

Kritisk tenking i læreplanen i naturfag

Sammendrag

Kritisk tenking (KT) er beskrevet internasjonalt som en sentral kompetanse elever må tilegne seg og det er også inkludert i den norske læreplanen. Forskere fra ulike fagtradisjoner definerer KT noe ulikt, men de er enige om at KT involverer både kognitive ferdigheter og disposisjoner. I denne studien har vi undersøkt hvordan ulike aspekter ved KT kommer til uttrykk i overordnet del av læreplanen og i naturfagplanen i LK20. I tillegg til ferdigheter, disposisjoner og kunnskapsdimensjonen ved KT, inkluderte vi etiske, kulturelle og samfunnsmessige dimensjoner for å bygge et helhetlig syn på KT. Disse kategoriene ble brukt som retningslinjer når vi analyserte læreplanen. Fra våre resultater kan vi konkludere med at det er få referanser til KT i overordnet del og i læreplanen i naturfag. Formuleringer om KT i læreplantekstene er både vage og knappe, noe som er uheldig fordi vi vet at mange lærere mangler forståelse for hva KT faktisk innebærer, og de føler seg ofte uforberedte til å undervise i KT. For å støtte lærere foreslår vi at alle aspekter knyttet til KT bør utdypes og konkretiseres i læreplanen.

Nøkkelord: kritisk tenking, naturfag, læreplan

Introduction

Critical thinking (CT) has been highlighted as a key goal of education internationally (EU Commission, 2016) and it is included in the Norwegian curriculum (Ministry of Education, 2017). Researchers from separate scholarly traditions define CT differently, but they agree that CT is synonymous with "good thinking" and that CT involves both cognitive skills – or abilities – and dispositions (Lai, 2011). In other words, a truly critical thinker has both the ability to think critically and the disposition to do so. CT is, however, not self-explanatory, and in this study we examine how CT is expressed in the Norwegian curriculum. From our background with research in the field of education, we understand CT as higher order thinking skills applied by students to decide what to believe or do in different situations. Our understanding is much in line with the frequently used definition by Ennis (1985, 2013) who built on Dewey and defined CT as "reasonable reflective thinking focused on deciding what to believe or do".

A major issue when CT is operationalized in a school context is whether CT is to be understood as general or subject-specific. While CT has been seen as a key competence that students should acquire in school, and this has been promoted in many countries' curricula, it is still unclear how this should be included in different subjects. Several researchers suggest that CT should be prompted within the context of different subjects and that knowledge of a subject is necessary for CT (Bailin et al., 1999; Willingham, 2008). Furthermore, CT should be considered a core feature of science teaching (Bailin, 2002; Sadler et al., 2002), given that it constitutes a central feature of the nature of science (Yacoubian, 2020). Therefore, this study examines both the core curriculum and the science curriculum in an effort to trace how CT is situated not only in the context of a specific subject but also in the broadest sense of skills and knowledge that students are expected to acquire in school.

In Norway, the curriculum consists of a core curriculum across all subjects and subject-specific curricula. The subject-specific curricula are competence based, with the following definition of competence (Ministry of Education, 2017):

> Competence is the ability to acquire and apply knowledge and skills to master challenges and solve tasks in familiar and unfamiliar contexts and situations. Competence includes understanding and the ability to reflect and think critically.

Furthermore, it continues:

> This understanding of the competence concept must underpin school's work with the subject curricula and the assessment of the students' competence in the subjects.

Although CT is included in the Norwegian curriculum, there is limited research on how different aspects of CT are represented in relation to the domain-general and the domain-specific aspects of science as a school subject. Moreover, in the Nordic perspective, empirical studies reveal that students lack CT skills. In a report from the 2018 PISA study, Frønes and Jensen (2020) summarized that Norwegian students do not know how to consider the credibility of sources. Students repeat and blindly trust information if it occurs several places, and they have a naïve perception of how knowledge is developed (Frønes & Jensen, 2020). Also, Bråten and his colleagues have published a number of studies regarding students' sourcing, stating that both upper secondary students and undergraduates disregard source information such as author, document type, and publisher (Bråten, Strømsø et al., 2016; Bråten, Jason et al., 2015).

Furthermore, Lundström and Jakobsson (2009) studied the pseudo-scientific ideas of 300 Swedish upper secondary students. Their results revealed that a great number of students expressed high confidence in non-science explanations. In Norway, Pettersen (2005) examined the attitudes of 473 health science students and found that most students considered health claims in media to be true, despite the lack of scientific evidence. It seemed as the students had not learned scientific evaluation skills, neither during upper secondary education, nor during their ongoing college education.

Even though CT is emphasized in curricula, it is challenging for teachers to address CT in their teaching practice. In a Norwegian study, Munkebye and Gericke (2022) found that primary teachers had a coherent idea of CT, but their understanding was quite limited. Their teaching of CT focused primarily on attitudinal aspects such as scepticism, source criticism and argumentation as generic skills. Mostly cognitive strategies were used to achieve CT, but no assessment criteria were mentioned, and the influence of the subject hardly addressed. This is in line with Alazzi's (2008) study of Jordanian secondary and high school teachers' understanding of CT who found that teachers often describe CT as being inherently sceptical through asking questions.

These studies imply that teachers recognize the importance of CT, but many of them lack an understanding of what the concept actually entails, and they often feel too unprepared to teach CT (Alazzi, 2008; Schulz & FitzPatric, 2016). Consequently, it is not enough to emphasize CT in curricula. The concept must be elaborated and concretized in different subjects with specific skills and dispositions that belong to the subject. For science, this means that teachers know what aspects in science there are to be critical about and how CT should be addressed in science teaching and learning.

When examining aspects of CT in the Norwegian curriculum, our study was guided by the overarching research question *How is CT expressed in the Norwegian core curriculum and science curriculum?* The research question is intended to generate knowledge about how CT is situated within the core and science curricula in Norway and how they are related to each other. Although many studies have been conducted about CT, such nuance in the content of the curricula has been underemphasized in the research literature.

Research on critical thinking in education

The literature offers many definitions of CT. One leading definition arose from a Delphi consensus panel of 46 experts, published as a report by Facione in 1990. They offered a rather broad definition of CT:

> Critical thinking is purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. (Facione, 1990, p. 3)

Some years earlier, one of the experts, Ennis (1985) defined CT as "reasonable reflective thinking focused on deciding what to believe or do". This captures the core of the definition of the complex concept CT. Ennis (2013) points out that there is no one formula for teaching CT, and Sadler et al. (2002) state that CT forms an integral part of science as a way of knowing, but there is disagreement regarding what CT actually involves. Sadler and colleagues are among several researchers who refer to Dewey as one of the first to use the term CT, or reflective thinking, as an educational goal (Hitchcock, 2020; Sadler et al., 2002; Higgins, 2014). Dewey defined reflective thinking as "active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends" (Dewey, 1910, p. 6).

In the report from the Delphi panel, CT is conceptualized in terms of two dimensions: abilities and dispositions. There are various definitions and descriptions of both abilities and dispositions proposed by different authors, but most seem to agree that abilities refer to the cognitive aspects and dispositions to the affective (Facione, 1990; Bailin, 2002; Hitchcock, 2020). There is also largely agreement regarding the need for both aspects in order to be called a critical thinker. As Bailin (2002, p. 363) puts it:

> simply carrying out a set of procedures is not sufficient to ensure critical thinking since any procedure can be carried out carelessly, superficially or unreflectively – in other words, in an uncritical manner.

This means that a person might be skilled at CT without being fair-minded or ethical in the use of those skills (Facione, 1990; Higgins, 2014). It also means that being disposed toward CT does not assure that one is skilled (Facione, 2000). In the context of education, it is suggested that CT should be seen as a process where students recognize, adapt and implement criteria and standards. This includes attaining the knowledge, abilities and dispositions of a critical thinker and extending it to their everyday lives as informed citizens (Facione, 2000; Hitchcock, 2020). One obstacle for implementing CT in classrooms is that teachers do not have a clear idea of what CT entails (Alazzi, 2008; Vieira et al., 2011). A number of abilities and dispositions are suggested, and for this study we have reviewed the literature and concentrated on abilities and dispositions most researchers agree upon.

Firstly, *abilities* are closely connected to argumentation skills, including identifying and analyzing claims and arguments, evaluating evidence and determining whether a conclusion is supported by evidence, and seeing both sides of an issue (Osborne, 2010; Facione, 1990; Ennis, 2013; Vieira et al., 2011). According to Osborne (2010), disagreement, questioning and critique are at the front when it comes to learning science, and engaging students in these activities foster CT in science classrooms. In addition to argument analysis and evaluation, Ennis (2013) considers judging the credibility of sources as a core concept of CT. Several scholars also emphasize the need for information literacy in CT (Ventura et al., 2017; Ennis, 2013; Facione, 1990). This includes the ability to recognize when information is needed and know how to locate, evaluate and use the needed information. Lastly, the Delphi panel suggested six cognitive skills as the core of CT, mirroring the experts' definition of CT and closely related to the skills already mentioned: interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 1990).

Regarding *dispositions*, Lai (2011) presented seven dispositions that researchers agree upon in her review of CT literature. These are: (1) open-mindedness, (2) flexibility, (3) inquisitiveness, (4) propensity to seek reason, (5) desire to be well-informed, (6) respect for, and willingness to entertain, others' viewpoints, and (7) fair-mindedness. Open-mindedness refers among other things to the willingness to include new evidence and examine questions that already have accepted answers, and flexibility points to the willingness to consider alternative opinions and options (Facione, 1990; Ennis, 2013). Inquisitiveness, the disposition to inquire, is for many scholars at the core of CT (Dewey, 1910; Ennis, 1989; Facione, 1990; Bailin, 2002; Halpern, 1998) alongside trust in reason (Facione 1990; Bailin, 2002). According to Paul and Elder (2012), fair-mindedness is closely connected to ethics, and the experts in the Delphi-study also included facing one's own biases, willingness to reconsider and revise views and being persistent as essential dispositions for CT.

While abilities can be identified directly in both curricula and classrooms, dispositions are more indirectly observed through the exercise of abilities (Hitchcock, 2020). This might be one reason for the predominant focus on cognitive skills in curricula (Paul & Elder, 2012). In a literature review, Sævik (2021) examined existing research on how CT can be taught in science in grades 5 to 10. From 1108 studies about CT in science education, he identified twelve studies with a pre- and post-test of students' CT outcome and they were included in the review. Only one of these studies included CT dispositions in their teaching.

Most researchers working in the field of CT agree that background *knowledge*, and knowing how to find and use knowledge, is important when students practice

CT (Facione, 1990; Ennis, 1989; Vieira et al., 2011). However, there are discussions regarding CT as a generic set of skills that can be transferred between contexts or if it is subject specific. The generalist view holds that several skills, like the ability to identify flaws in reasoning, are easily transferable between contexts, while the specifist view argues against, stating that CT cannot be separated from knowledge of concepts or domain-specific methodological principles (Abrami et al., 2015; Bailin, 2002). Several combine the two, viewing CT as a set of skills that can be transferred across domains but relies on subject specific knowledge (Ennis, 2013; Ventura et al., 2017). Especially the epistemology of the domain, including the kinds of explanations, evaluations and evidence that are most valued, vary from one domain to another (Facione, 1990; Ennis, 1989). In the context of science as a domain, there is a substantial amount of research, often referred to as “nature of science” (NOS), that includes considerations about the epistemology of the domain including the methodological rules, scientific knowledge and practices, and the values and beliefs instrumental in the development of scientific knowledge (Erduran & Dagher, 2014). Some researchers have made explicit links between research in CT and NOS (e.g., Yacoubian, 2020) highlighting the importance of CT in the development of scientific knowledge.

Ennis (2013) believes CT skills can be transferable if it is made clear to the students how the principles of CT apply in different situations. However, Nygren et al. (2019) found that developing CT within one subject does not necessarily mean that it is transferable to other disciplines or situations. They studied 76 students’ CT across four subjects as expressed in National tests, and found low correlations between different aspects of CT, both within and across the four subjects. However, students’ grades in different subjects were closely linked to their CT abilities. CT was formulated explicitly and implicitly in both curriculum and tests, but the same formulation of CT varied in meaning between the subjects when translated into assessment. Based on the results, Nygren et al. (2019) supported the perspective that disciplines may hold distinct CT aspects.

In addition to the abilities, dispositions and knowledge aspect of CT, Santos Meneses (2020) suggests to include *ethical*, *cultural* and *civic* dimensions. The skills-based CT perspective has been dominant in curricula (Paul & Elder, 2012), and Santos Meneses (2020) put forth that we need a comprehensive view of CT that embraces ethical reasoning, social awareness, and prepare children to become active democratic citizens. Furthermore, Santos Meneses alongside Davies & Barnett (2015), argued that dispositions in the sense of willingness or propensity to use thinking skills not necessarily include an ethical dimension. As mentioned earlier, Paul and Elder (2012) view ethics as vital for the disposition fair-mindedness, while others do not promote ethics explicitly in this regard. The focus has mainly been on others’ thinking rather than one’s own, looking for flaws in others’ argumentation without paying attention to one’s own, which imply a lack of metacognitive and ethical dimensions (Paul & Elder, 2012; Davies & Barnett, 2015).

The cultural dimension embraces the view that CT is not context-free but culturally embedded and includes awareness of culturally influenced learning and thinking traditions, while the civic dimension points to the public good as a central idea (Santos Meneses, 2020). The civic dimension refers to purposes beyond individual self-interest and a collective reflection on values held in common. This has also been advocated by Sjøberg (2009) and Kolstø (2001), stating that science education should prepare students for independent, reflective and critical participation in a democratic society. Similarly, Yacoubian (2020) introduced a framework for thinking critically about and with NOS, targeting socio-scientific decision making. He calls for a science curriculum that engages students in developing critical understandings about NOS and prepares future citizens to make informed decisions on socio-scientific issues in democratic societies. Also, Scheie and Stromholt (2019) reported that students (from both primary and secondary schools) involved in authentically socio-ecological challenges in their local communities increased their argumentation skills and raised their faith in own abilities to influence the environment for sustainability.

Based on the literature review, we extracted several of the most agreed upon abilities and dispositions connected to CT and developed a framework for analyzing the curriculum which is described in the methodology section of the article. We also included the knowledge domain and Santos Meneses' (2020) *ethical*, *cultural* and *civic* dimensions which are in agreement with the intention of education as expressed in Norwegian as well as international policy documents and reports (NOU, 2014:7, 2015:8; OECD, 2017; NRC, 2012). It should be noted, however, that some limitations of the literature that we are relying on have been documented. For example, Claris and Riley (2012) indicated that

> The mainstream approach to CT is perhaps best captured in the Delphi report [which] is still too limited because it does not acknowledge the centrality of social relations in criticality, presuming instead that critical processes occur within an individual.

Although we have embedded the *ethical*, *cultural* and *civic* dimensions of CT, drawing on the work of Santos Meneses (2020), we recognize that further articulation of the conceptual framework on CT can potentially draw from other studies related to science and its role in society (see e.g. Prescod-Weinstein, 2020; Mensah & Jackson, 2018; Ladson-Billings & Tate, 1995; Tate, 1995). In the next section, we turn to the empirical component of the article, focusing on the methodological approaches taken to investigate how CT is represented in the core and science curricula in Norway.

Methodology

Research Questions

Our study is guided by the overarching research question:

How is CT expressed in the Norwegian core curriculum and science curriculum?

More specifically, we wanted to look at:

a) How is the distribution of different categories of CT in the core- and science curricula?
b) What aspects of the CT categories are most prominent in the different curriculum texts?

Context

In this section we describe the Norwegian curriculum as a context for our analyses before elaborating on how we used the framework (Table 2) to analyse the curriculum and answer our research questions. In Norway, the national curriculum is web-based and consists of a core curriculum across all subjects and subject specific curricula (Table 1). The *core curriculum* is based on the essential values stated in the Education Act and the overriding principles for primary and secondary education and training (Ministry of Education, 2017). The subject specific curricula have the same structure for all subjects and include two main categories. The first category, *about the subject*, consists of four sub-categories: 1) the subject's relevance and central values; 2) core elements (for science: scientific practices; technology; energy and matter; earth and life on earth; and body and health), 3) the subject's role within three interdisciplinary topics (health and life skills; democracy and citizenship; and sustainability), and finally, 4) basic skills as part of the competence in each subject (oral skills, writing, reading, numeracy, and digital skills).

Table 1. How the Norwegian curriculum is organized.

a) *Core curriculum* (8123 words)	Values and principles for primary and secondary education and training.
b) *Science Curriculum* (3540 words)	*About the subject* Relevance and central values (272 words) Core elements (391 words) Interdisciplinary topics (247 words) Basic skills (489 words) *Competence aims and assessment* (2141 words) For science: after grades 2, 4, 7, 10 and 11

Core elements and interdisciplinary topics are introduced for the first time in the curriculum from 2020 (Norwegian Directorate for Education and Training, 2020), while the focus on basic skills in each subject has been emphasized in Norwegian curricula since 2006 (Ministry of Education, 2006/2013). The second category in the subject specific curriculum, *competence aims and assessment*, establishes the expected competences for students after grades 2, 4, 7, 10 and 11 (children start in grade 1 when they are 6 years old). The competence aims are designed to meet the ideas expressed in the core elements. The intention of introducing core elements was to narrow the content in order to promote deeper learning (Ministry of Education, 2017). Even so, there are over 20 competence aims listed for each of the grades stated, except for grade 2 with 10 competence aims. Lastly, the assessment part consists of a couple of paragraphs emphasizing assessment for learning and formative assessment in general with a few adjustments for each grade.

The different curriculum texts vary in scope, which is important to bear in mind when interpreting the results. The core curriculum consists of 8123 words while the science subject curriculum covers 3540 words, which is less than half of the core curriculum. We also inform that the curriculum has an official English translation, and we used the translated version in our work.

Analytical framework

Based on the literature, we developed a framework that included abilities, dispositions, knowledge and ethical, cultural and civic dimensions as main categories (Table 2). We used this framework as our coding scheme. The coding scheme is not intended to be exhaustive but rather indicative of some of the broad categories that relate to CT. The categories include individual as well as social and societal links to how CT can be considered in relation to science. Here, we were guided by the holistic approach by Erduran and Dagher (2014) who consider NOS as a cognitive-epistemic as well as a social-institutional system. Hence, what students are expected to be critical about will relate not only to the cognitive aspects (e.g., abilities, knowledge) but also the social and institutional aspects (e.g., civic and cultural dimensions). As such, the choice of CT categories is meant to be coherent with how the particular subject context of science may or may not cohere with its nature. In other words, we have strived to develop a CT framework that would be coherent with a NOS framework and thus illustrate where potential limitations about the domain-specific aspects of the curriculum may need to be reformed.

In order to use the framework as a tool for analysis, each of the categories needed to be operationalized. When selecting codes to elaborate and describe the six chosen categories, we found that both abilities and dispositions often are quite broadly described in the literature. For example, abilities like argumentation, analyzing and evaluating are referred to without any definitions or further explanations of what argumentation entails or what should be analyzed or evaluated. Therefore, we strived to make the codes as descriptive and detailed as possible.

Table 2. Framework for analyzing critical thinking in curricula.

CT categories	Codes
Abilities	make decisions or solve problems
	identify and analyze claims and arguments
	evaluate evidence and arguments
	present arguments and justify procedures
	information literacy
	judge the credibility of sources
	questioning and clarifying meaning
	interpret, explain, infer or conclude
	see several sides of an issue
	self-regulation
Dispositions	flexibility in considering alternative opinions
	inquisitiveness
	open-mindedness
	desire to be well-informed
	facing own biases
	fair-mindedness
	persistence
	propensity to seek reason
	willingness to entertain others' viewpoints
	willingness to revise views
Knowledge	epistemology
	use knowledge to make decisions
Ethical dimension	human values, morality, commitment towards fair-minded attitudes, and awareness of one's own biases and defects in reasoning
Cultural dimension	awareness of culturally influenced learning, thinking traditions and values
Civic dimension	reflection of norms and values held in common, social awareness and socio-critical consciousness

For the first category, abilities, we developed and concretized 10 codes building on the CT literature. The code *make decisions or solve problems* is included to cover CT more vaguely described in the curriculum, but still explicit enough to be coded as CT. Codes related to argumentation are described as: *identify and analyze claims and arguments*, *evaluate evidence and arguments*, and *present arguments and justify procedures*. We decided to separate *information literacy* and *judge the credibility of sources* where the former includes the ability to recognize when information is needed and knowledge of how to locate, evaluate and use the needed information. Codes related to questioning, interpreting, inferring and seeing several sides of an issue are all at the core of CT abilities emphasized by several authors (Ennis, 1989; Facione, 1990; Vieira et al., 2011). Lastly, we included *self-regulation* as an ability of CT. This is not always explicitly expressed in the CT literature, even though it is part of the widely used definition of CT from the Delphi panel (Facione, 1990).

The ability to think critically is distinct from having the dispositions to do so, and empirical evidence shows that CT abilities and dispositions are separate entities (Facione, 2000). Dispositions are not always defined, and it varies between researchers what they include as dispositions. In our framework, we chose to include ten dispositions varying from those encouraging students to see beyond egocentrism and socio-centrism like *open-* and *fair-mindedness*, *flexibility in considering alternative opinions*, *facing own biases* and *willingness to revise views* and *entertain others' viewpoints* to those stimulating students to be *persistent*, *inquisitive*, *seek reason* and *be well-informed*.

The next category, knowledge, is described by the two codes *epistemology* and *use knowledge to make decisions*. It is widely agreed within the field of CT that background knowledge, and knowing how to find and use knowledge, is important when students practice CT (Facione, 1990; Willingham, 2008). The epistemology includes the kinds of explanations, evaluations and evidence that are most valued within a domain, and this will vary from one domain to another (Bailin, 2002; Facione, 1990). Therefore, this aspect is important to include when analyzing a subject specific curriculum.

In addition to the abilities, dispositions and knowledge aspect of CT, Santos Meneses (2020) put forth that we need a comprehensive view of CT that embraces ethical reasoning, social awareness, and prepares children to become active democratic citizens. Thus, we included ethical, cultural and civic dimensions in our CT framework. When describing the three dimensions, we leaned on Santos Meneses' (2020) descriptions, with the ethical dimension explained as *human values, morality, commitment towards fair-minded attitudes, and awareness of one's own biases and defects in reasoning*. Some of these overlap to a certain degree with dispositions like *fair-mindedness* and *facing own biases*. The cultural dimension comprises *awareness of culturally influenced learning, thinking traditions and values* while the civic dimension includes *reflection of norms and values held in common, social awareness and socio-critical consciousness*.

Data analysis

In order to analyze the core curriculum and the science subject curriculum we applied a deductive approach, using NVivo 12 to categorize and code the curriculum texts based on the framework (Table 2). In the coding process, two of the authors coded the curriculum texts together. Codes were not mutually exclusive, and one formulation could be assigned several codes. For example the phrase

> All the participants in the school environment must develop awareness of minority and majority perspectives and ensure that there is room for collaboration, dialogue and disagreement

was coded as both Abilities (see several sides of an issue) and Civic (reflection of norms and values held in common, social awareness and socio-critical consciousness). There were several discussions along the way, mainly about whether the text actually expressed the code or if it was our interpretation based on knowledge of CT. The third author was also involved in these discussions, and we decided to strive strictly to code formulations that explicitly expressed CT and not formulations that only had potential to involve CT depending on how it was interpreted by the reader in a more implicit sense. An example of formulations that we discussed and decided were too vaguely expressed to be included as CT, was: *The pupils shall develop awareness of how our lifestyles impact nature and the climate, and thus also our societies*. More examples of our coding are demonstrated in Table 3 in the result section.

Results and findings

In the result section we present an overview of the number of occurrences for the different codes in the core and science curricula and examples of formulations that were coded, before addressing each of the two research questions. Table 3 includes number of occurrences for the different codes in both the core curriculum and the science curriculum together with examples of the coding. The codes in Table 3 are not mutually exclusive. Given that our intention was to trace the main codes, we did not pursue a more nuanced analytical approach to differentiate how the different codes may have overlapped or related to each other. Such an approach may be taken up in the future to provide a more in-depth analysis of how the different curriculum statements are related to each other.

Table 3. Frequency of codes in the core curriculum (CC) and the science curriculum (SC) according to the framework presented in Table 2.

CT Categories	**Codes**	**Number of references**		**Examples of formulations in the curriculum**
		CC	SC	
Abilities	make decisions or solve problems	1	3	"pupils shall be able to take a critical approach to health-related information and to use this to make good and responsible choices related to health, safety and the environment"
	identify and analyze claims and arguments	0	2	"the ability to identify and analyse claims and arguments"
	evaluate evidence and arguments	1	3	"if new insight is to emerge, established ideas must be scrutinised and criticised by using theories, methods, arguments, experiences and evidence"
	present arguments and justify procedures	0	3	"assess the quality of one's own and others' explorations"
	information literacy	0	4	"the ability to write increasingly complex texts and to use different types of text

				which build on a critical and varied use of sources adapted to the purpose and receiver”
	judge the credibility of sources	1	2	“pupils must be able to assess different sources of knowledge”
	questioning and clarifying meaning	1	1	“query, ask questions, formulate hypotheses and explore them to find answers”
	interpret, explain, infer or conclude	0	3	“make explanations based on data”
	see several sides of an issue	4	1	“to learn to listen to others and also argue for one’s own views will give the pupils the platform for dealing with disagreements and conflicts”
	self-regulation	1	2	“be able to understand that their own experiences, points of view and convictions may be incomplete or erroneous”
Dispositions	flexibility in considering alternative opinions	3	0	“learn to deal with conflicts of opinion and respect disagreement”
	inquisitiveness	1	0	“school shall help pupils to be inquisitive and ask questions”
	open-mindedness	0	1	“natural science shall also contribute to openness for experience-based and traditional knowledge the Sami have of nature”
	desire to be well-informed	0	0	
	facing own biases	0	0	
	fair-mindedness	0	0	
	persistence	0	0	
	propensity to seek reason	0	0	
	willingness to entertain others’ viewpoints	0	0	
	willingness to revise views	0	0	
Knowledge	epistemology	3	7	“understanding that the methodologies for examining the real world must be adapted to what we want to study, and that the choice of methodology influences what we see”
	use knowledge to make decisions	1	4	“learning about Earth as a system and how people impact this system, shall give the pupils the foundation for making sustain-able decisions”
Ethical dimension	human values, morality, commitment	4	1	“learn to think critically and act ethically and with environmental awareness”

	towards fair-minded attitudes and awareness of one's own biases and defects in reasoning			
Cultural dimension	awareness of culturally influenced learning, thinking traditions and values	1	1	"natural science shall also contribute to openness for experience-based and traditional knowledge the Sami have of nature"
Civic dimension	reflection of norms and values held in common, social awareness and socio-critical consciousness	2	6	"develop awareness of minority and majority perspectives and ensure that there is room for collaboration, dialogue and disagreement"

Distribution of CT categories in the core and science curricula

To get an overview of CT in the core and science curricula, we first focused on the different CT categories (Abilities, Dispositions, Knowledge, Ethical, Cultural and Civic) and the number of references within each category. In order to present the number of references in the curriculum texts for each category, every formulation was only counted once within the same category, even if it applied to several codes within that category. For example, if a formulation was coded for both *information literacy* and *judge the credibility of sources* within the category ability, it counted as one reference to the category ability. However, to find the number of unique references within each category, the same formulation could be assigned to more than one category, for example both ability and knowledge. The first two figures (Figures 1a and 1b) show the relative distributions of CT categories in the core curriculum versus the science curriculum. The total number of unique references coded within each category was 23 in the core curriculum and 35 in the science curriculum.

We see that abilities dominate in both curricula, which could be expected based on the predominance of cognitive skills in curricula found in other studies (Paul & Elder, 2012). Dispositions, knowledge and the ethical dimension are evenly distributed in the core curriculum, while knowledge dominates the science curriculum with only one reference to each of the categories dispositions, the ethical dimension and the cultural dimension. This indicates that the dispositions and ethical dimension expressed in the core curriculum are hardly visible in the science curriculum. The civic dimension is larger in the science curriculum, which was surprising as we expected the core curriculum that is based on values and principles to entail more of the civic dimension. The cultural dimension is barely mentioned in the core and the science curricula.

Figure 1. Relative distributions of unique references within each category in the core curriculum (a) and in the science curriculum (b).

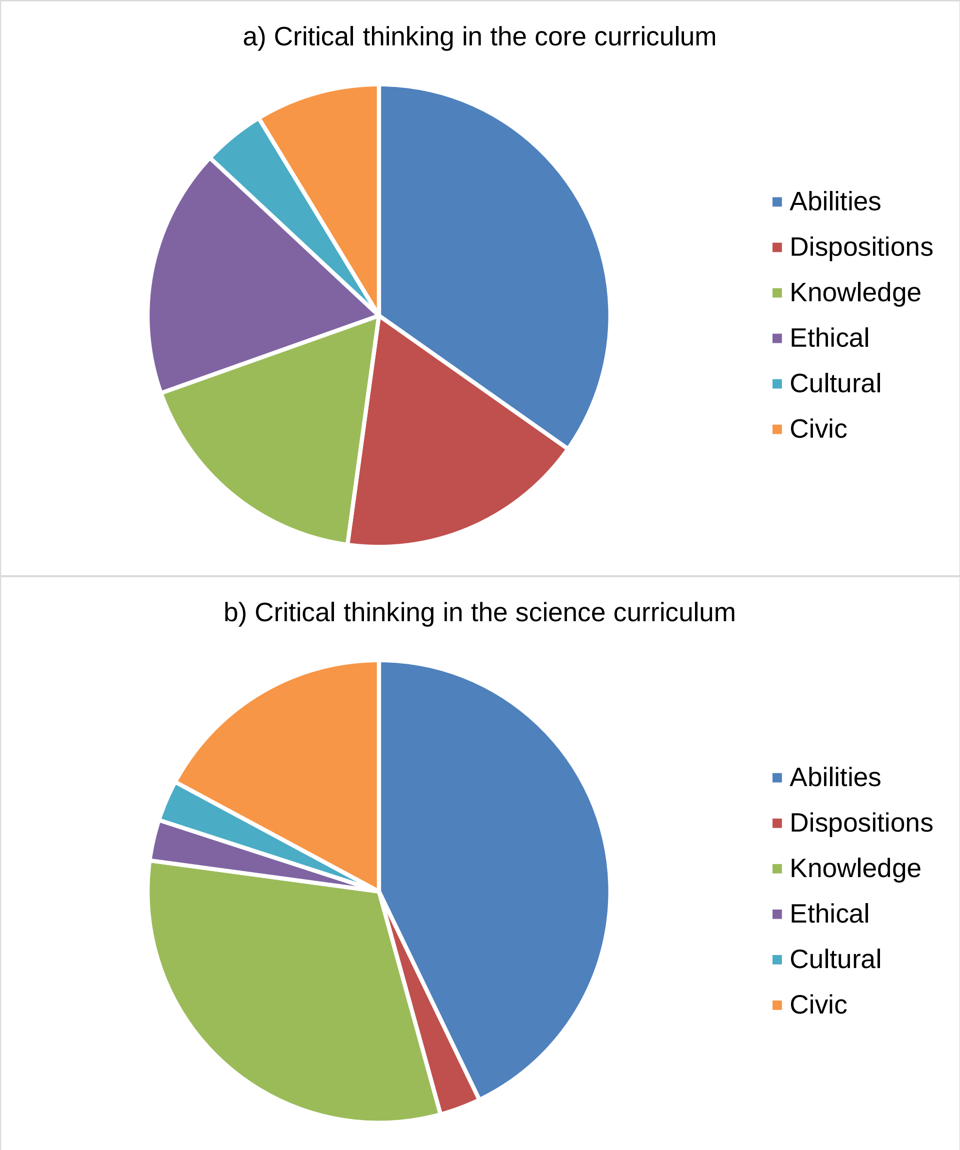
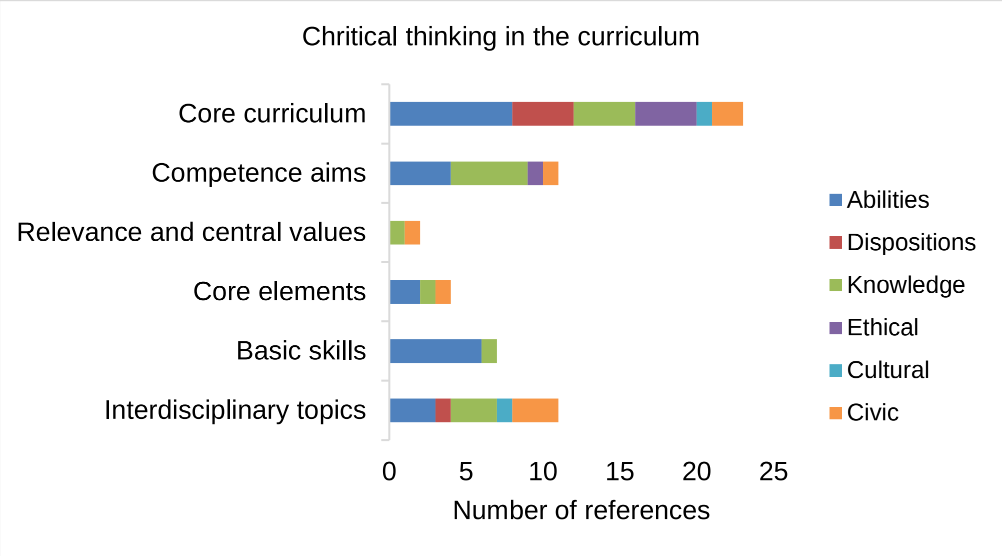


Figure 2 gives an overview of how the CT categories are distributed in the different curriculum texts. The part of the science curriculum called *Competence aims and assessment* in Table 1, is shortened to only *Competence aims* because CT was not present in the assessment texts. The assessment texts are very short and generic, and there is no mention of how to assess CT in the curriculum. Overall, explicit references to CT are scarce in both the core curriculum and the science curriculum.

To get an overview of the CT categories in the different curriculum texts (Figure 2) the results are presented with codes that are mutually exclusive within the category but not between the categories, as explained for Figures 1a and 1b. The core curriculum consists of only one text, and the results are included in the description of Figure 1a above. For the five texts that constitute the science curriculum, CT is primarily found in the competence aims and interdisciplinary topics with 11 references each. The text interdisciplinary topics, which is the shortest text of all, includes all categories except an ethical dimension. Even if interdisciplinary topics refer to dispositions and cultural dimension only once, the results indicate that this short text has managed to combine several aspects of CT. An example is the phrase *Natural science shall also contribute to openness for experience-based and traditional knowledge the Sami have of nature*. We interpreted this as an encouragement for students to reflect on norms and values held in common (Civic) and be aware of, and open-minded to culturally influenced learning (Disposition, Cultural).

Figure 2. Overview of the distribution of CT categories in the core curriculum and in the five texts that comprise the science curriculum.



In the curriculum text describing competence aims, abilities and knowledge are predominant. There are no dispositions, which altogether are scarcely represented (Figure 4). For basic skills, six out of seven references are coded for abilities, which could be expected as this text refers to skills students need to master in the subject.

The most prominent aspects of the CT categories in the different curriculum texts

In the following, we present the codes within each category and how these codes are distributed across the curriculum texts. The codes presented are not mutually exclusive, and one reference could for example be coded for several abilities. We start with the abilities category (Figure 3), where the code *see several sides of an issue* is most coded for with five occurrences, mainly in the core curriculum. To see several sides of an issue has been regarded as a key feature of CT for decades

(Ennis, 1989; Facione, 1990; Vieira et al., 2011). One example of text we assigned this code, was the description of ethical awareness in the core curriculum, stating that in order to be a reflective (and critical) thinker students need to consider more than one side of an issue: *Ethical awareness, which means balancing different considerations, is necessary if one is to be a reflecting and responsible human being*.

In Figure 2, we see that the basic skills text has several references within the abilities category, and Figure 3 shows that these references are distributed between several abilities. Three of the references in the basic skills text are coded as *information literacy*, emphasizing how students should select relevant information and critically assess sources and how science information is presented and used. This is closely related to, and also coded as, *judge the credibility of sources* and *evaluate evidence and arguments*. Although all codes are addressed within the ability category, many of them occur only once in each of the curriculum texts and none of the abilities are represented in all texts (Figure 3).

Figure 3. Distribution of abilities in the core curriculum and science curriculum texts.

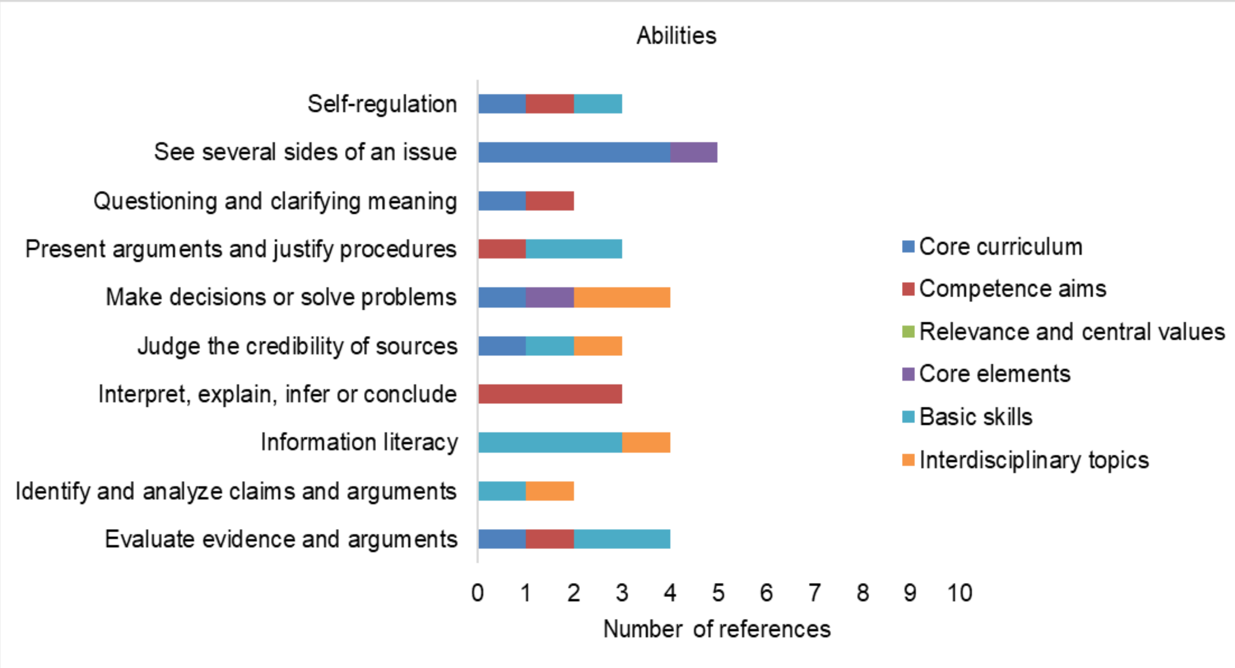
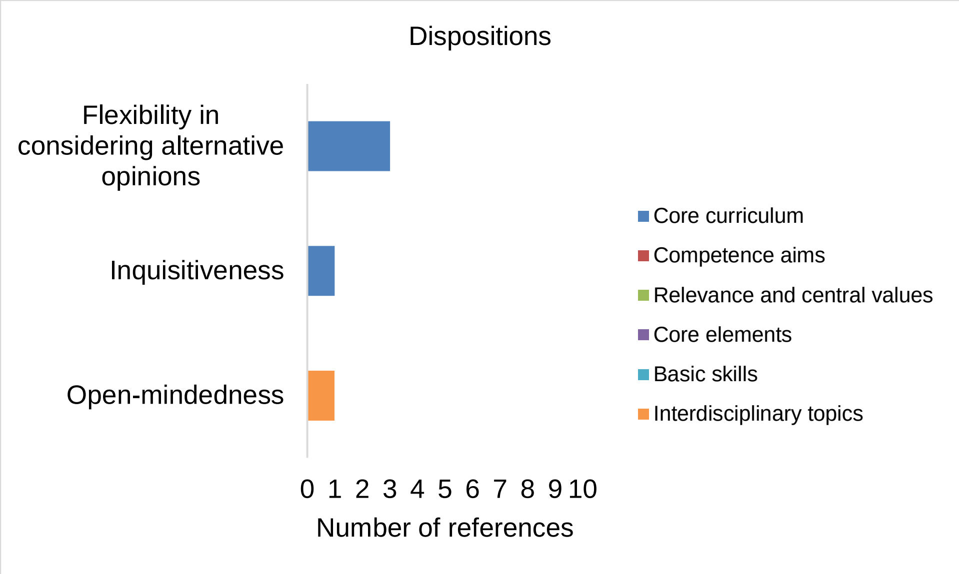


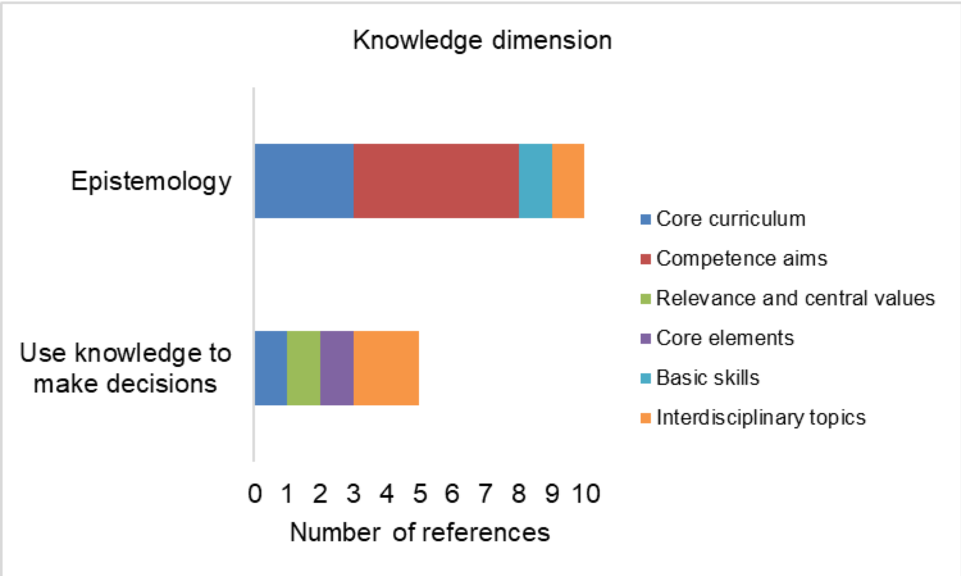
Figure 4 shows the distribution of the five references coded as dispositions. As mentioned above, not many dispositions were found in either the core curriculum or the science curriculum. Four out of five are from the core curriculum, while the last one is in the text interdisciplinary topics in the science curriculum. In the other texts there was no mention of dispositions.

Figure 4. Distribution of dispositions in the core curriculum and science curriculum texts.



The two codes for the knowledge dimension are *epistemology* and *use knowledge to make decisions* (Figure 5). The epistemology of a subject concerns what count as knowledge within that subject, its methods and values. This was the most frequent code with ten occurrences distributed across four curriculum texts: core curriculum; basic skills; competence aims; and interdisciplinary topics. We present examples from all four texts as we consider these references to be strong indicators of the close relationship between CT and science, as proposed by several researchers (Sadler et al., 2002; Vieria et al., 2011).

Figure 5. Distribution of the knowledge dimension in the core curriculum and science curriculum texts.



The first example that shows this relationship is from the core curriculum, emphasizing how students should be able to think critically about established ideas and how knowledge is developed. It is followed by the text on basic skills, describing how students can use the language of science to promote critical thinking through argumentation and reflection, including awareness of one's own attitudes as advocated by Paul and Elder (2012).

> If new insight is to emerge, established ideas must be scrutinised and criticised by using theories, methods, arguments, experiences and evidence. The pupils must be able to assess different sources of knowledge and think critically about how knowledge is developed. (Core curriculum)

> Oral skills also refers to using natural-science terminology and concepts to describe, demonstrate understanding, present knowledge, develop questions, argue, explain, reflect and give grounds for one's own attitudes and decisions. (Basic skills)

Other indications of the importance of CT in the development of scientific knowledge, as highlighted by Yacoubian (2020), are found in the competence aims and interdisciplinary topics texts. Here students are asked to explain how new knowledge is developed through a critical approach and they should learn to distinguish between science and pseudo-science:

> Give examples of current research and explain how new knowledge is generated through collaboration and a critical approach to existing knowledge. (Competence aims)

> In natural science the interdisciplinary topic of democracy and citizenship refers to providing the pupils with the basis for distinguishing between knowledge based on science and knowledge that is not based on science. (Interdisciplinary topics)

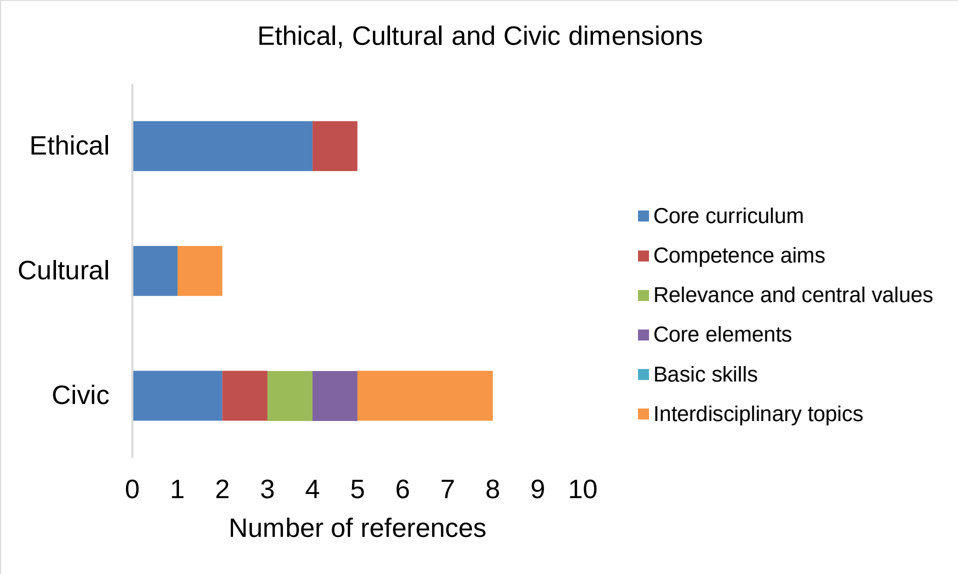
The second code within the knowledge dimension, *use knowledge to make decisions,* has only four references. What we find striking is that it is not mentioned either in the core curriculum or the competence aims in the science curriculum. However, the knowledge category combined is the only one represented in all curriculum texts.

Figure 6 illustrates the distribution of the ethical, cultural and civic dimensions, where the civic dimension with eight references is present in all texts except the basic skills text. Even with few references altogether, this tells us something about the emphasis put on this dimension in the Norwegian curriculum. Three of the references are from the text that comprises the interdisciplinary topics, which might be expected as democracy and citizenship is one of the topics. Several of the references in the civic dimension are also assigned to other CT categories, indicating a more comprehensive view. For example, the following phrase relating to social awareness is coded as civic, knowledge (use knowledge to make decisions) and ability (identify and analyze claims and arguments):

> Competence in natural science shall be the underpinning for understanding and being critical about argumentation in public debates and is important so that pupils will be active citizens and contribute to technological development and sustainability. (Interdisciplinary topics)

The predominance of the ethical dimension in the core versus the science curriculum is addressed in the description of Figure 1.

Figure 6. Distribution of the ethical, cultural and civic dimensions in the core curriculum and science curriculum texts.



Discussion

There is a widespread acceptance that CT should be an important dimension of science education (Bailin, 2002; Sadler et al., 2002) and a key competence that students should acquire in school. This has been promoted in many countries' policy documents and curricula (EU Commission, 2016; NOU, 2015:8; OECD, 2017; NRC, 2012), but there is some evidence, especially in the PISA results (Frønes & Jensen, 2020), that the implementation of CT competences in school is not entirely successful. Our intention in this study was to contribute to this discourse by elaborating how CT is expressed in the Norwegian core and science curricula. Here we discuss categories and codes from the framework and how CT is distributed in the Norwegian core and science curricula. Lastly, we discuss some consequences this may have for the future implementation of the curriculum.

Categories of critical thinking in the Norwegian core curriculum and science curriculum

Overall, there were few CT references in both the core and the science curriculum. Although there seemed to be many references based on Figures 2–6, several of these references were coded more than once. We believe that this is rather a positive phenomenon in the sense that involving different CT categories and codes can contribute to a more comprehensive CT competence. However, it tells us that less text in the curriculum focuses on CT.

Abilities and dispositions

A truly critical thinker needs both the ability to think critically and the disposition to do so (Facione, 1990), but there are only few citations related to dispositions compared to abilities in the curriculum texts. Dispositions can be described as the inner motivations that stimulate critical thinkers to apply their critical abilities (Facione, 1990). However, none of these references are coded for any other CT categories. Four of the five codes for dispositions were expressed in the core curriculum and referred to the codes *flexibility in considering alternative opinions* (3) and *inquisitiveness* (1). The last code was *open-mindedness*, a text we located in the interdisciplinary topics of the science curriculum. Even though these references link CT to ethical awareness, disagreements and conflicts, democracy and scientific thinking, they are few in numbers, vague and touch on large topics in the curriculum. For teachers to include CT dispositions in their teaching, the text and the intention need to be further developed and concretized. These findings are in agreement with Paul and Elder (2012) who claim that there is a predominant focus on cognitive skills in curricula. Likewise, Sævik (2021) who examined existing research on how CT can be taught in science in grades 5–10, found that only one of 12 studies included CT dispositions in their teaching.

Knowledge

When thinking critically, a person consciously and deliberately must seek and use knowledge and know how to use knowledge relating to the issue or question under consideration. Knowledge dimension codes included in our framework were *epistemology* and *use knowledge to make decisions*, and as such, they relate to aspects of NOS (Erduran & Dagher, 2014). The codes were distributed, as the only category, in all the curriculum texts, indicating an emphasis on this category. This is consistent with a study conducted by Ott (2019) who reported that the knowledge dimension dominates in the Norwegian core curriculum.

Especially the *epistemology* of science, including some of the kinds of explanations, evaluations and evidence that are most valued in science, was elaborated in the curriculum texts. This is in line with several researchers stating that science education is closely related to CT (e.g., Ennis, 1989; Sadler et al., 2002). Moreover, and pointed out by Bailin (2002), what is involved in thinking critically is closely tied to various kinds of knowledge in the particular area. The curriculum and especially the science curriculum texts facilitate pedagogical focus on the principles, concepts and criteria of methodological rules, scientific knowledge and practices, and the values and beliefs inherent to scientific knowledge and its development. Collectively, all of this relates to aspects of NOS (Erduran & Dagher, 2014).

This way of viewing CT highlights its contextual nature, where CT is closely connected to knowledge with both the epistemology of the subject and to use proper knowledge from that particular domain to make decisions. However, there are discussions regarding whether CT is a generic set of skills that can be transferred between contexts or if it is subject specific. This combination of seeing CT both as subject specific, but also including some general set of aspects, has implications for how CT should be taught. Ennis (2013) suggested that CT principles need to be explicitly taught in the subject, but he believes CT skills can be transferable if it is made clear to the students how the principles of CT apply in different situations. In addition, one can argue in the same way as Bailin (2002) that many aspects of CT have a very wide range of applications, like the rules of logic, which can be applied in every area of critical endeavor. Moreover, dispositions tied to CT, such as open-mindedness, fair-mindedness and commitment to make judgements on the basis of reasoned assessment, are relevant to thinking critically in any area across the curriculum.

Ethical, cultural and civic dimensions

In addition to the abilities, dispositions and knowledge aspect of CT, we followed Santos Meneses' (2020) suggestion and included ethical, cultural and civic dimensions in our framework. All three dimensions were represented in the core curriculum, although most of the civic dimension was found in the science curriculum.

We saw an emphasis on the civic dimension in the science curriculum, referring to purposes beyond individual self-interest and a collective reflection on values held in common. This emphasis is promising and might increase students' CT competences in several ways. For instance, Scheie and Stromholt (2019) reported that students involved in authentic socio-ecological challenges in their local communities increased both their CT skills and raised their faith in own abilities to influence the environment in a sustainability direction. Furthermore, this provides opportunities to engage students in critical understandings about NOS and empower them as future citizens to make informed decisions on socio-scientific issues in democratic societies, as promoted by Yacoubian (2020).

Another result from our analysis is the limited occurrence of the ethical dimension with only five references. These references are vague and scarce and leave it to the reader to interpret what this ethical dimension exactly entails. Santos Meneses (2020) put forth that we need a comprehensive view of CT that embraces ethical reasoning and social awareness, and prepares children to become active democratic citizens. Likewise, Davies and Barnett (2015) argue that dispositions in the sense of willingness or propensity to use thinking skills not necessarily include an ethical dimension.

One reference (coded for the disposition *flexibility in considering alternative opinions*) can visualize the absence of the ethical dimension:

> To learn to listen to others and also argue for one's own views will give the pupils the platform for dealing with disagreements and conflicts, and for seeking solutions together. (Core curriculum)

The text asks for students to learn to listen to others, but then argue for personal views. The focus is primarily on others' thinking rather than one's own, looking for flaws in others' argumentation without paying attention to one's own, which imply a lack of metacognitive and ethical dimensions (Paul & Elder, 2012; Davies & Barnett, 2015).

Conclusion and implications

From our analysis, we can conclude that there are few CT references in the Norwegian core and science curricula. Most references are coded for abilities while dispositions are scarcely represented. These findings are in agreement with Paul and Elder (2012) who claim that there is a predominant focus on cognitive skills in curricula. CT requires both the ability to think critically and the disposition to do so, and ideally includes ethical, cultural and civic dimensions. Thus, neither the core nor the science curricula are realizing what is considered as necessary to be a truly critical thinker.

Formulations of CT in the curriculum are both vague and scarce, which is unfortunate because we know that many teachers lack an understanding of what CT actually entails and they often feel unprepared to teach CT (Alazzi, 2008; Munkebye & Gericke, 2022). To support teachers, CT needs to be elaborated and concretized in the curriculum.

Our framework can be applied in several ways to embrace and operationalize CT in education. First of all, the framework can support teachers to be aware of and include CT in their teaching. We applied the framework in analyses of the Norwegian core and science curricula, providing readers with details about CT in these texts, which ultimately can assist teachers and students to elaborate their understanding of CT. Moreover, this framework can be a central element in overcoming the discrepancies between the intended and the implemented curriculum. Finally, curriculum developers can use the framework as a support in developing curricula that take into account the important role of CT, and researchers may benefit from adopting the framework coding for CT in curricula elsewhere.

About the authors

Eldri Scheie is Associate Professo in Science education at the Norwegian Centre for Science Education. Her research explores critical thinking and interdisciplinary sustainability education in professional development for teachers as well as implementation perspectives.
Institutional affiliation: Norwegian Centre for Science Education, University of Oslo, P. O. Box 1106, Blindern, 0317 Oslo, Norway.
Email: eldri.scheie@naturfagsenteret.no

Berit Haug is Associate Professor in Science education at the Norwegian Centre for Science Education. Her research interests include inquiry-based teaching and learning, language of science and professional development for teachers and teacher educators.
Institutional affiliation: Norwegian Centre for Science Education, University of Oslo, P. O. Box 1106, Blindern, 0317 Oslo, Norway.
Email: berit.haug@naturfagsenteret.no

Sibel Erduran is Professor of Science Education and Director of Research in the Department of Education at the University of Oxford. Her research interests focus on the applications in science education of epistemic perspectives on science in general and in chemistry in particular. Her work on argumentation has received awards from NARST and EASE.
Institutional affiliation: University of Oxford, Department of Education, 15 Norham Gardens, Oxford OX2 6PY, United Kingdom.
Email: sibel.erduran@education.ox.ac.uk

References

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: a metaanalysis. *Review of educational research*, *85*(2), 275–314. https://www.jstor.org/stable/24434258

Alazzi, K. F. (2008). Teachers' perceptions of critical thinking: A study of Jordanian secondary school social studies teachers. *The social studies*, *99*(6), 243–248. https://doi.org/10.3200/TSSS.99.6.243-248

Bailin, S. (2002). Critical Thinking and Science Education. *Science & Education, 11*(4), 361–375. https://doi.org/10.1023/A:1016042608621

Bailin, S., Case, R., Coombs, J. R., & Daniels, L. B. (1999). Conceptualizing Critical Thinking. *Journal of Curriculum Studies, 31*(3), 285–302. https://doi.org/10.1080/002202799183133

Bråten, I., Braasch, J. L. G., Strømsø, H. I., & Ferguson, L. E. (2015). Establishing Trustworthiness when Students Read Multiple Documents Containing Conflicting Scientific Evidence. *Reading Psychology*, *36*(4), 315–349. https://doi.org/10.1080/02702711.2013.864362

Bråten, I., Strømsø, H. I., & Andreassen, R. (2016). Sourcing in professional education: Do text factors make any difference? *Reading and Writing*, *29*(8), 1599–1628. https://doi.org/10.1007/s11145-015-9611-y

Claris, L., & Riley, D. (2012). Situation critical: critical theory and critical thinking in engineering education. *Engineering Studies*, *4*(2), 101–120. https://doi.org/10.1080/19378629.2011.649920

Davies, M., & Barnett, R. (2015). *Introduction.* In M. Davies & R. Barnett (Eds.), *The Palgrave handbook of critical thinking in higher education* (pp. 1–25). Springer.

Dewey, J. (1910). *How We Think*. Boston: D. C. Heath.

Ennis, R. H. (1985). A logical basis for measuring critical thinking skills. *Educational leadership*, *43*(2), 44–48. https://jgregorymcverry.com/readings/ennis1985assessingcriticalthinking.pdf

Ennis, R. H. (1989). Critical thinking and subject specificity: Clarification and needed research. *Educational researcher*, *18*(3), 4–10. https://doi.org/10.3102/0013189X018003004

Ennis, R. H. (2013). Critical thinking across the curriculum: the wisdom CTAC program. *Inquiry: Critical thinking across the disciplines*, *28*(2), 25–45. https://doi.org/10.5840/inquiryct20132828

Erduran, S., & Dagher, Z. (2014). *Reconceptualizing the Nature of Science for Science Education. Scientific Knowledge, Practices and Other Family Categories*. Springer.

EU Commission (2016). *A new skills agenda for Europe: Working together to strengthen human capital, employability and competitiveness*. Brussels: European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0381

Facione, P. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction (The Delphi Report).* The California Academic Press.

Facione, P. A., C. (2000). The Disposition Toward Critical Thinking: Its Character, Measurement, and Relationship to Critical Thinking Skill. *Informal Logic*, *20*(1), 61–84. https://doi.org/10.22329/il.v20i1.2254

Frønes, T. S., & Jensen, F. (Eds.) (2020). *Like muligheter til god leseforståelse? – 20 år med lesing i PISA* [Equity in reading comprehension – 20 years of reading in PISA]. Universitetsforlaget. https://doi.org/10.18261/9788215040066-2020-02

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring. *American psychologist*, *53*(4), 449–455. https://doi.org/10.1037/0003-066X.53.4.449

Higgins, S. (2014). Critical thinking for 21st-century education: A cyber-tooth curriculum? *Prospects*, *44*(4), 559–574. https://doi.org/10.1007/s11125-014-9323-0

Hitchcock, D. (2020). Critical Thinking. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy*. https://plato.stanford.edu/archives/fall2020/entries/critical-thinking

Kolstø, S. D. (2001). 'To trust or not to trust,…' – pupils' ways of judging information encountered in a socio-scientific issue. *International Journal of Science Education*, *23*(9), 877–901. https://doi.org/10.1080/09500690010016102

Ladson-Billings, G., & Tate IV, W. (1995). Toward a Critical Race Theory of Education. *Teachers College Record*, *97*(1), 47–68. https://doi.org/10.1177%2F016146819509700104

Lai, E. R. (2011). *Critical thinking: A literature review*. Pearson's Research Reports. http://images.pearsonassessments.com/images/tmrs/CriticalThinkingReviewFINAL.pdf

Lundström, M., & Jakobsson, A. (2009). Students' ideas regarding science and pseudo-science in relation to the human body and health. *Nordic Studies in Science Education, 5*(1), 3–17. https://doi.org/10.5617/nordina.279

Mensah, F., & Jackson, I. (2018). Whiteness as property in science teacher education. *Teachers College Record*, *120*(1), 1–38. http://doi.org/10.1177/016146811812000108

Ministry of Education (2006/2013). *The (LK06) National Curriculum for Knowledge Promotion in Primary and Secondary Education and Training*.

Ministry of Education (2017). *Core curriculum – values and principles of primary and secondary education.* https://www.udir.no/lk20/overordnet-del/?lang=eng

Munkebye, E., & Gericke, N. (2022). Primary School Teachers' Understanding of Critical Thinking in the Context of Education for Sustainable Development. In B. Puig & M. P. Jimenez-Aleixandre (Eds.), *Critical Thinking in Biology and Environmental Education: Facing Challenges in a Post-truth World* (pp. 249–266). Springer.

Norwegian Directorate for Education and Training (2020). *Curriculum for Natural science (NAT01-04)*. https://www.udir.no/lk20/nat01-04?lang=eng

NOU (2014: 7). *Elevenes læring i fremtidens skole – Et kunnskapsgrunnlag* [Students' learning in the school of the future – A knowledge base]. Ministry of Education. https://www.regjeringen.no/contentassets/e22a715fa374474581a8c58288edc161/no/pdfs/nou201420140007000dddpdfs.pdf

NOU (2015: 8). *Fremtidens skole* [The School of the Future]. Ministry of Education.

NRC (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. National Research Council. Washington, DC: The National Academies Press. https://doi.org/10.17226/13398

Nygren, T., Haglund, J., Samuelsson, C. R., Af Geijerstam, Å., & Prytz, J. (2019). Critical thinking in national tests across four subjects in Swedish compulsory school. *Education Inquiry*, *10*(1), 56–75. https://doi.org/10.1080/20004508.2018.1475200

OECD (2017). *PISA 2015 assessment and analytical framework.* OECD ilibrary. https://doi.org/10.1787/9789264281820-en

Osborne, J. (2010). Arguing to learn in science: the role of collaborative, critical discourse. *Science*, *328*(5977), 463–466. https://doi.org/10.1126/science.1183944

Ott, A. (2019). Kritisk tenkning og bærekraft i fagfornyelsen [Critical thinking and sustainability in the curriculum]. In M. Ferrer & A. Wetlesen (Eds.), *Kritisk tenkning i samfunnsfag* [Critical thinking in social science] (s. 30–44). Universitetsforlaget.

Paul, R., & Elder, L. (2012). *Critical thinking: Tools for taking charge of your learning and your life* (3rd ed.). Boston: Pearson Education.

Pettersen, S. (2005). Critical Thinking in Norwegian Upper Secondary Biology Education: The Cases of Complementary-Alternative Medicine and Health Claims in the Media. *Nordic Studies in Science Education, 1*(2), 61–71. https://doi.org/10.5617/nordina.485

Prescod-Weinstein, C. (2020). Making Black women scientists under white empiricism: the racialization of epistemology in physics. Signs: *Journal of Women in Culture and Society, 45*(2), 421–447. https://doi.org/10.1086/704991

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2002). *Investigating the crossroads of socioscientific issues, the nature of science, and critical thinking*. Paper presented at the National Association for Research in Science Teaching Annual Meeting in New Orleans, LA, April 7–10, 2002. https://files.eric.ed.gov/fulltext/ED466401.pdf

Santos Meneses, L. F. (2020). Critical thinking perspectives across contexts and curricula: Dominant, neglected, and complementing dimensions. *Thinking Skills and Creativity, 35*, 100610. https://doi.org/10.1016/j.tsc.2019.100610

Scheie, E., & Stromholt, S. (2019). "The Sustainable Backpack": Exploring possibilities in education for sustainable development through a nationwide professional development program. *Acta Didactica Norge, 13*(2), Art. 5. https://doi.org/10.5617/adno.6473

Schulz, H. W., & FitzPatrick, B. (2016). Teachers' understandings of critical and higher order thinking and what this means for their teaching and assessments. *Alberta Journal of Educational Research*, *62*(1), 61–86. https://doi.org/10.11575/ajer.v62i1.56168

Sjøberg, S. (2009). *Naturfag som almenndannelse – en kritisk fagdidaktikk* [Science literacy – a critical view on subject didactics] (3rd ed.). Oslo: Gyldendal Akademiske.

Sævik, H. J. (2021). *Undervisning av kritisk tenkning i naturfag. En litteraturstudie av intervensjoner for undervisning av kritisk tenkning i naturvitenskapelige skolefag fra 5. til 10. trinn* [Teaching critical thinking in science. A literature study of interventions for teaching critical thinking in science from 5th to 10th grade]. Master thesis, Norges tekniske naturvitenskapelige universitet, NTNU. https://hdl.handle.net/11250/2785106

Tate, W. F. (1995). Returning to the root: A culturally relevant approach to mathematics pedagogy. *Theory into practice*, *34*(3), 166–173. https://doi.org/10.1080/00405849509543676

Ventura, M., Lai, E., & DiCerbo, K. (2017). *Skills for Today: What We Know about Teaching and Assessing Critical Thinking*. London: Pearson. https://www.pearson.com/content/dam/one-dot-com/one-dot-com/global/Files/efficacy-and-research/skills-for-today/Critical-Thinking-FullReport.pdf

Vieira, R. M., Tenreiro-Vieira, C., & Martins, I. P. (2011). Critical thinking: Conceptual clarification and its importance in science education. *Science Education International*, *22*(1), 43–54. https://eric.ed.gov/?id=EJ941655

Yacoubian H. A. (2020). Teaching Nature of Science Through a Critical Thinking Approach. In W. McComas (Ed.), *Nature of Science in Science Instruction* (pp. 199–212). In the book series Science: Philosophy, History and Education. Springer, Cham. https://doi.org/10.1007/978-3-030-57239-6_10

Willingham, D. T. (2008). Critical thinking: Why is it so hard to teach? *Arts Education Policy Review*, *109*(4), 21–32. https://doi.org/10.3200/AEPR.109.4.21-32