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ARTICLE

The Materiality of Children's Imaginative Sense-making in Climate Change Education

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Abstract
In this article, we discuss our investigation of children's imaginative sense-making and its materiality in climate change education. Drawing on a new materialist approach, our research contributes to knowledge about the material significance in children's sense-making related to climate change. During a project called Riddle of the Spirit in a Finnish primary school, we invited children to explore the concepts of global warming and carbon dioxide through narrative, playful and multimodal activities. Inspired by postqualitative methods, our relational analysis, based on video materials, maps and examines two episodes of children's small group inquiry. Our findings unfold the material–discursive intra-actions, through which a prop turned into a whale's head, the Titanic film appeared, and water and carbon dioxide became important to children's bodies. With these specific events, the study illustrates how various materials conjoined and came to matter in the children's sense-making of the concepts.

Keywords: Children; imagination; sense-making; climate change education; new materialism; postqualitative methods

Introduction

One of the primary goals of climate change education is to help children relate to and understand climate change (UNESCO, 2022). However, the science of climate change is difficult to understand, because it is a complex phenomenon with characteristics of being beyond our sensing capacities (Stevenson et al., 2017). Many children perceive climate change as a distant phenomenon, which is abstract and far away from their everyday lives (Lee & Barnett, 2020; Spiteri & Pace, 2023). Climate change is also an issue about socio-ecological justice, making it emotionally, morally and politically challenging to teach and learn about (Ojala, 2023). As a result, there is a need to develop educational approaches that recognise the complexity of climate change and that make climate change relevant and meaningful to children and their lives (Allen & Crowley, 2017; Rousell & Cutter-Mackenzie-Knowles, 2022). In our research, we are interested in contributing to knowledge about the material significance in children's sense-making of climate change during a project called Riddle of the Spirit, which is grounded in narrative, playful and multimodal activities. Specifically, we focus on two episodes in which children inquire about the concepts of global warming and carbon dioxide during the project and examine how various materials including props and books came to matter in the children's imaginative sense-making.

Children's sense-making of scientific concepts is widely argued as being imaginative and materially embedded (e.g., Fleer, 2011; Hilppö et al., 2016; Vartiainen & Kumpulainen, 2020). Previous research has shown how imagining enables children to grasp abstract and complex

phenomena, including climate change, by connecting emotions, ideas, material objects and everyday experiences (Byrne et al., 2014; Jensen, 2015; Kumpulainen et al., 2023). Through loops of imagination, children's sense-making expands across time and space, and the formation of scientific concepts becomes progressively refined (Hilppö et al., 2016). Children's imaginative acts, such as wondering, daydreaming, raising open-ended questions, making imaginary friends and creating imaginative situations, support them to relate to the science content in a personal way, leading to a deeper understanding of the scientific concepts (Seiki & Gray, 2020; Vartiainen & Kumpulainen, 2020). Materiality plays a vital role in children's imaginative sense-making. Fleer (2011) elaborates that children's engagement in the material world gives meaning to their imagination during conceptual exploration. Materiality, which nourishes imagination, is central to children's cognitive development and conceptual learning, as well as emotional expression and creative learning (Egan, 1992; Penfold, 2019).

In climate change education, there is a lack of research on *how* children make sense of concepts around climate change, even though some studies have suggested the importance to engage young children in learning such concepts (Lee & Barnett; 2020; Rousell & Cutter-Mackenzie-Knowles, 2020; Spiteri & Pace, 2023). Lee and Barnett (2020) suggest that introducing scientific concepts around climate change to young children can potentially reduce fear-inducing scepticism and misconceptions. Spiteri and Pace (2023) argue for the pressing need of engaging young children in learning such concepts, especially in critical and creative ways. Likewise, Rousell and Cutter-Mackenzie-Knowles (2020) suggest that climate change education should draw on the untapped capacity of children, and give them opportunities to learn climate change concepts, particularly in the ways that can engage their affective dimensions related to the issues. Therefore, in this study, we address this gap in climate change education by researching the materiality of children's imaginative sense-making related to climate change. Aligning with previous research on the importance of material engagement and imagination to children's sense-making (e.g., Fleer, 2011; Seiki & Gray, 2020; Vartiainen & Kumpulainen, 2020), through a new materialist approach our research adds nuances and new insights to further understand the complexity of material significance in children's sense-making of climate change. A new materialist approach guides us to think beyond an anthropocentric point of view, and we have turned to materials as the focus of our research (Barad, 2007; Hultman & Lenz Taguchi, 2010). Such research is important for informing the development of appropriate pedagogies for climate change education (Spiteri & Pace, 2023).

In this study, we focus on a project called Riddle of the Spirit, which aims to enrich children's imaginative sense-making of climate change through narrative, playful and multimodal activities. The activities are grounded on Baltic Finnic myths about nature spirits based on core pedagogical principles of storying, engagement with multimodal materials, play and imagination (Byman et al., 2023; Wong & Kumpulainen, 2020). The project was conducted in a Finnish primary school with 62 children (7–9 years old). In this article, we focus on two episodes, with five children and their material engagement during small group inquiry of global warming and carbon dioxide. Our research was guided by the following question: *How does materiality come to matter in the children's imaginative sense-making related to climate change?*

Inspired by postqualitative methods (Fassbender, 2021; Rousell, 2021), in our relational analysis we drew on video materials and produced mappings of material–discursive intra-actions, through which the sense-making of global warming and carbon dioxide emerged between the activity materials, children's imagination, bodies, emotions and lived experiences. Lastly, we discuss the fundamental role of materiality and children's embodiments in constituting their imaginative sense-making related to climate change. We also discuss the pedagogical possibilities and challenges of engaging children's imaginative sense-making in climate change education.

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A new materialist approach to researching children's imaginative sense-making of concepts around climate change

Our inquiry was inspired by new materialist perspectives, especially, Barad's agential realism (2003, 2007), Lenz Taguchi's (2010) and Murris' (2016) thinking on the materially entangled nature of concepts and imagination. The movement of new materialism, which draws on a relational ontology, challenges the over-emphasis of humans and static representations of materials in knowledge production and stresses the entanglements of materials with being and knowing (Barad, 2007). New materialist perspectives have increasingly been used in science education, environmental education research and childhood studies (e.g., Cutter-Mackenzie-Knowles et al., 2020; Jeong et al., 2021). These perspectives provide ways to think about materials as active agencies that affect children's thinking and sense-making, opening up new and divergent educational possibilities (Jukes, 2020; Lenz Taguchi, 2010). Following this orientation, in this study, we used "material" to refer to both tangible and intangible substances, including books, props, water and carbon dioxide, as well as any substances that are brought forth across time and space through children's imaginative sense-making processes (see also Penfold, 2019). Using a new materialist approach, we have been able to reconfigure global warming and carbon dioxide as more than abstract scientific concepts. These concepts can also be "in" us (Saari & Mullen, 2020) and entangle our imagination, emotions, bodies and the ways we act in the world.

Barad's agential realism (2003, 2007) has helped us to research the matter–meaning entanglements of abstract concepts in children's imaginative sense-making of climate change. Barad's theory considers entanglement to be a fundamental state instead of separateness as the original state of being (Brown et al., 2020). Barad's book on agential realism (2007) states that "we are a part of that nature that we seek to understand" (p. 26); in other words, we only know about the living world by participating in it. This position points to the inseparability of knowledge and the material conditions that create knowledge, highlighting the vital roles of materiality in thinking and its development. For Barad (2003), materials do not just "support" particular discourses, but they are the actual generative factors in the formation of bodies, conjoining the production of discursive practices. In this perspective, concepts are more than ideational; rather, they are defined by specific material–discursive configurations (Barad, 2007). Moreover, in an agential realist account, matter, as well as concepts, bodies and tools, are considered as *performative agencies* that can enact forces and *affect* one another (Hultman & Lenz Taguchi, 2010). Performative agency is understood as a quality that emerges in between different bodies involved in mutual engagements and relations; it is an "enactment" rather than a property that someone or something has (Barad, 2007). This places the human as part of an intra-active field in which affect is recognised as a precognitive unstructured intensity that passes and registers across human–nonhuman bodies (Dernikos et al., 2020).

As Barad (2003) writes, "all bodies, not merely 'human' bodies, come to matter through the world's iterative intra-activity — its performativity" (p. 823). Barad (2007) uses the term "intra-action" instead of "interaction" to describe the relationship between the involved human/nonhuman bodies; the agencies without inherent boundaries in between are always in a state of intra-activity with varying intensity (see also Hultman & Lenz Taguchi, 2010). By framing intra-active pedagogy, Lenz Taguchi (2010) suggests that during a learning activity, children, their imagination and the materials at hand, emerge simultaneously through intra-actions. This perspective positions children and their imaginative sense-making in a continuous state of becoming with the materiality the children bodily encounter. Similarly, Murris (2016) points out how picture books and their materiality (e.g., graphic design, art styles, colour and paper medium) can demand children's listening and affect children's imagination, emotion and the ways they inquire about philosophical concepts. Murris (2016) also discusses that, during philosophical thinking with picture books, children do not just explore the meanings of the concepts but also what the concepts could do beyond what is already known. Drawing on these new materialist

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perspectives, our research brings attention to the performative agencies of materials and how the materials come to matter through intra-actions in the children's imaginative sense-making related to climate change during the Riddle of the Spirit project.

The Riddle of the Spirit project

The Riddle of the Spirit project was part of a four-month study with 62 children (38 boys and 24 girls, 7–9 years old) conducted in a primary school in Finland. The project was organised collaboratively by the authors and four elementary school teachers, based on the Riddle pedagogical materials. Riddle materials (Wong et al. 2020) were developed by the authors with artists, designers, children, teachers and educators and included instructions for a series of activities, props and a riddle created by the authors. The riddle, inspired by Baltic Finnic myths about nature spirits, invited the children to help Ukko, a thunderstorm spirit who had lost his climate control power, which affected the livelihood of humans and other nature spirits. This myth-inspired story engages children's climate imaginaries with the ancestral heritage of ecological knowledge from Karelian, Finnish and Sámi traditions (Byman et al., 2023; Wong et al., 2020). Using the story as an imaginative invitation, the children were guided by teachers and researchers to rethink phenomena related to climate change through narrative, playful and multimodal activities with arts-based and sciences-based materials. Overall, the aim of the Riddle project (Wong et al., 2020) was to fuel children's imagination, creative thoughts and expressions regarding human–climate relations through narrative and multimodal imaginary ingredients. At the primary school, the teachers and children found the project, its pedagogical materials and the imaginative approach to learning about climate change new and different from the usual classroom activities in environmental studies.

More specifically, in this article, we focused on "Ask the Spirits" activity, the goal of which was to invite the children to explore and make sense of scientific concepts around climate change through open-ended small group inquiry. The pedagogical materials used in the activity included props, such as graphics of spirits communicating messages in a pretend-play spiritual language, the Dictionary for translating the language and the Hint Paper for expressing thoughts, as well as books with scientific information about climate change which were selected by the researchers (see Figure 1). In the analysis, we investigate how the props and books performatively intra-acted out in the children's imaginative sense-making of global warming and carbon dioxide.

During the Ask the Spirits activity, the children engaged in semi-guided small group inquiry, exploring ideas collectively and building narratives about concepts related to climate change. The activity started by inviting the children to "ask" nature spirits for hints to find out the reasons why Ukko the thunderstorm spirit has lost his climate control power. First, using the Dictionary prop, the children decrypted the spirits' secret messages, which revealed terminology prepared by the researchers, such as "global warming," "carbon footprint," "carbon dioxide," and "greenhouse gases." Then, the children explored these concepts by consulting books and educational videos and discussing them with peers, teachers and researchers. During the 30-minute activity, the teachers and researchers assisted the children with their inquiry. The children expressed their ideas on the Hint Paper by writing and drawing, and shared their thoughts with the class.

Overall, during the entire Riddle of the Spirit project, five research sessions were conducted with the children at the school (one session per week and each session lasting for two hours). The Ask the Spirits activity was organised as part of the first research session. The research materials for the analysis consisted of 11.2 hours of video recordings of children's engagement during the Ask the Spirits activity. Other research materials supporting the analysis included photographs of the artefacts produced by the children, two transcribed group interviews with teachers, and the researchers' field notes.

Following the ethical research guidelines of the Finnish National Board on Research Integrity (https://www.tenk.fi), parental permission was obtained for the child participants to join the study

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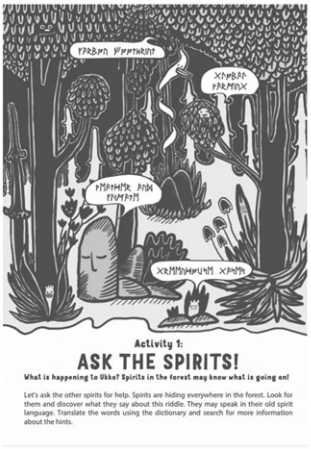

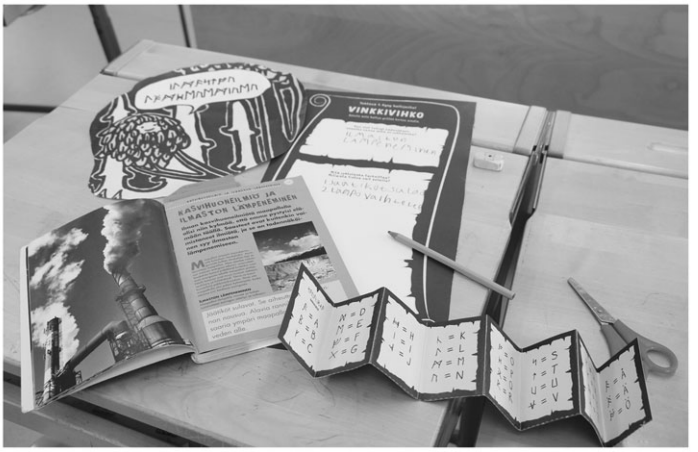

Figure 1. Ask the Spirits activity card, which combines props, including the spirit's secret messages, the Hint Paper, and the Dictionary, and books with scientific information about climate change (Wong et al., 2020).

and its data production. The children were also informed about the study and could withdraw from the data production at any time. To protect the participants' confidentiality, all names presented in this article are pseudonyms. The photographs of the children and adults presented in the figures have been edited with photo filters to conceal the recognisable details of their identities.

A relational analysis

In the analysis, we sought to understand the role of materiality in the children's imaginative sense-making of climate change. Our analysis of the research material was inspired by postqualitative perspectives (Le Grange, 2019; Ulmer, 2017), mostly based on the relational materialist approach by Hultman and Lenz Taguchi (2010; Lenz Taguchi, 2011), as well as more-than-representational methods in visual data analysis (Fassbender, 2021; Lorimer, 2013) and a cartographical mapping approach by Rousell (2021). These approaches enabled us to turn to and map creatively the materiality of the children's imaginative sense-making. This relational analysis supports the de-centring of humans in knowledge production, highlighting the embodied and affective dimensions in imagining the concepts around climate change.

The relational materialist approach (Hultman & Lenz Taguchi, 2010) motivated us to reflect on our researcher roles with the research materials, and the way we analyse materiality. Analysing the materiality of children's imaginative sense-making is challenging because of our habitual ways of seeing materials as passive substances, seeing sense-making as humans' mental capacities and seeing concepts as static representations (Hultman & Lenz Taguchi, 2010). The relational materialist approach urged us to be aware of the way we foreground children's sayings and doings in the analysis as a reflection of what the materials can do with the children (Lenz Taguchi, 2011). To turn our attention to the agentic roles of materials, we repeatedly viewed the video recordings to become affected and to sense the possible entanglements between bodies within intra-actions, which would shape the imaginings of climate change (Fassbender, 2021). Every viewing of the footage was seen as a particular encounter with the research materials, and something new always emerged, such as thoughts, feelings and questions (Lorimer, 2013).

We chose two specific episodes for the relational analysis because of the children's rich exploration of the scientific concepts that involved unexpected connections between the classroom materials, the children's emotions, their embodied imaginings and past experiences, as well as popular culture and global discourses related to climate change. The cartographical mapping

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approach (Rousell, 2021) and the more-than-representational methods (Fassbender, 2021) helped us to visually analyse the video recordings of the episodes and pay attention to how the children expressed their imagination with bodies. These two episodes, with five children, namely Silja, William, Rami, Mattias and Morris (pseudonyms), were chosen because their material engagement affected us by evoking questions and curiosity (e.g., How did the concepts of global warming and carbon dioxide, the children and the materials used in the activity intra-actively emerge in these moments of imagining? What affected them to do so, and what potentials did this involve?). There was an indeterminacy in the episodes that pushed us further to investigate the role of materiality in the children's imagination about climate change.

To grasp the material–discursive intra-actions that emerged in the episodes, we produced mappings with an arts-based cartographical approach (Rousell, 2021). Rousell (2021) describes mapping as an open-ended process that "can be entered, altered, extended, intensified, and reconfigured in ways that carve out new trajectories for thought and experience" (p. 581). A map of matter-meaning entanglements can reconfigure the affective conditions of episodes, amplifying the relationalities that potentially unfold in children's imagination. In our analysis, we produced visual maps with images and sketches to bring out the material entanglements of global warming and carbon dioxide in the children's imagination. We used the mapping as a method to understand what matters have acted out in the children's imagination, and how these matters could have conjoined the children's sense-making of the scientific concepts. Making the maps helped us to delve into the relations between concepts, children, adults, pedagogical props, books, polar bears, the sea, water, oxygen and other matter. Mapping also helped us to de-centre language-driven and scientific representational thinking and address children's "seemingly nonsense" improvisational expressions (Wohlwend et al., 2017).

The material entanglements of global warming and carbon dioxide in the children's imaginative sense-making

Our inquiry focuses on the question: *How does materiality come to matter in the children's imaginative sense-making related to climate change?* We examined two episodes of material–discursive intra-actions during the Ask the Spirit activity. Episode 1 illustrates how diverse objects and matter, including books about global warming, sea, water, oxygen, plants, people and cinema films, acted out in the imagination of two children, Silja and William, when exploring global warming with their teacher Alma. Episode 2 illustrates how in a group with three children Rami, Matias, Morris and a researcher Alisa, a book passage about carbon dioxide, the substance of carbon dioxide in the air and the children's sensing bodies intra-actively produced the children's realisation of the existence of carbon dioxide. Through mapping these specific events, we could show how the materials emerged as performative agencies, intra-acting with other matter and conjoining the children's imaginative sense-making of global warming and carbon dioxide.

Episode 1: How books, props, cinema films and water came to matter in the children's imaginative sense-making of global warming

After decrypting the message from the "spirit language" into Finnish, Silja and William started to explore the concept of "global warming" (ilmaston lämpeneminen). This concept seemed to be new to the children, and they were not certain about its spelling or pronunciation. The teacher, Alma, checked their progress several times and brought them relevant books to read (Figure 2). With the books, the Dictionary prop, pencils and the Hint Paper, a narrative about global warming emerged with concepts such as temperature, sea level, floods, water, plants, polar bears and human survival.

We analysed the 30 minutes of Silja's and William's inquiry about global warming and produced a mapping (Figure 3) to speculate on how matter intra-acted with their imaginative

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With the books and props, various matter, such as plants, people, oxygen, Earth, water, whales, and the Titanic film, came into Silja's and William's inquiry of global warming.

(The teacher Alma comes to Silja and William)
Alma: *Well, what have you found out so far? Temperature is fluctuating, good. What else?*
Silja: *Temperature was my idea.*
Alma: *Good.* (Skims through the book and mumbles to herself)
William: *Plants… Plants are dying?*
Alma: *Well… yeah… Um, this book might not be the best for you. Let's see if we can find something else.* (Walks away to find another book)
Silja: *This is fun like this.* (Fiddles around with the Dictionary prop while showing it to William)
William: *Plants… are dying.* (Mumbles to himself, trying to figure out the task)
William: *People do not get oxygen, people are dying, plants are dying and the Earth looks just horrible…*
Silja: *But guess what. Without plants we couldn't get oxygen. Plants are good for us. And without water we wouldn't have plants and we would die. And humans are almost completely full of water. You see.*

(Alma comes to Silja and William with another book)
Alma: *Okay, read from here about global warming and what's happening.*
Silja: *Um…*
Alma: *In this yellow box.* (Points at a page in the book and walks away)
(Silja and William are together reading and spelling some syllables)
Silja: *So um, for example, glaciers…That glacier, um. Glacier…*
(William points at the picture and mumbles to himself)
Silja: *I can't come up with anything.* (Fiddles around with the Dictionary prop while mumbling something)
William: *How can a flood occur when the sea level rises…*
Silja: *Hey, look. It's a whale's head going into the water.*
(Playing with the Dictionary prop as if it is a whale's head and showing it to William)
William: *Have you seen the Titanic?*
Silja: *Um no, but…*
(The school bell rings)

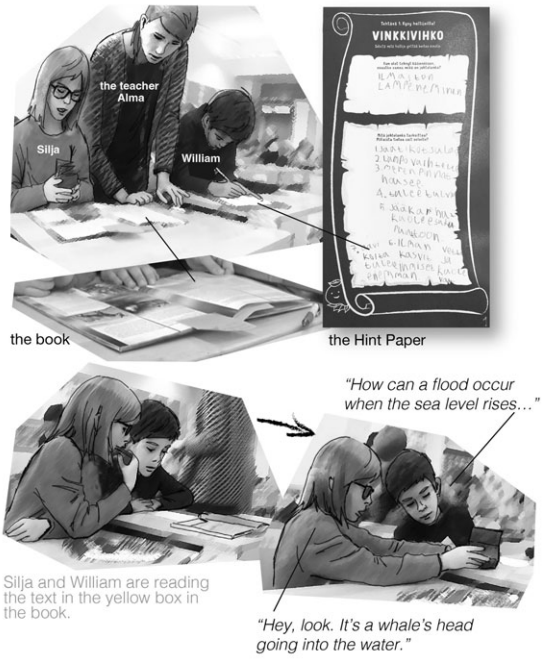

Figure 2. With the books and props, various matters, such as plants, people, oxygen, Earth, water, whales and the Titanic film, came into Silja's and William's inquiry of global warming.

sense-making. Thinking with Barad (2007) and Lenz Taguchi (2010), we understand that the children's conceptual exploration of scientific concepts is inseparable from their bodily participation with materials in the activity. Children, their imagination and the concept of global warming and materiality do not pre-exist each other, rather they are co-emergent through intra-actions (Lenz Taguchi, 2010). All the materials and bodies involved, including the pencil, the props and we the researchers who participated in the activity, played a part in intra-acting the children's imaginative sense-making about global warming.

By mapping, we understand that Silja's and William's inquiry about global warming would expand, along with the changing material conditions of the activity. When Silja and William explored rising sea levels, the materiality of the Dictionary prop intra-acted with the scientific narrative in the book and with Silja's body, becoming a whale's head and translating Silja's sense-making of rising sea levels and global warming into embodied movements. Through this specific intra-action, the material–discursive significance of the Dictionary prop changed, and along with other material agencies, became a unique way of making sense of rising sea levels. Simultaneously, through the event of writing, the Hint Paper and the pencil intra-acted with William's body and the ongoing discussion and came to matter by exercising their agencies in co-producing William's imagination of fluctuating temperatures, dying plants and flooding.

Our mapping unfolds how diverse matters from the children's everyday lives became part of their sense-making of global warming. At the beginning of the inquiry, when Silja heard the phrase "global warming", she briefly mentioned the film, the *Hobbit* ("hey, in the Hobbit there were these . . . "). Similarly, when William was wondering about how floods occur when sea levels rise, he quickly thought of the *Titanic* film. In William's improvisational expression, the ship, the sea and the film became agencies performatively constituting his imagining of global warming. These unexpected associations of films evoked us as researchers to speculate about what material–discursive significance the films might bring to the children's imaginative sense-making of global

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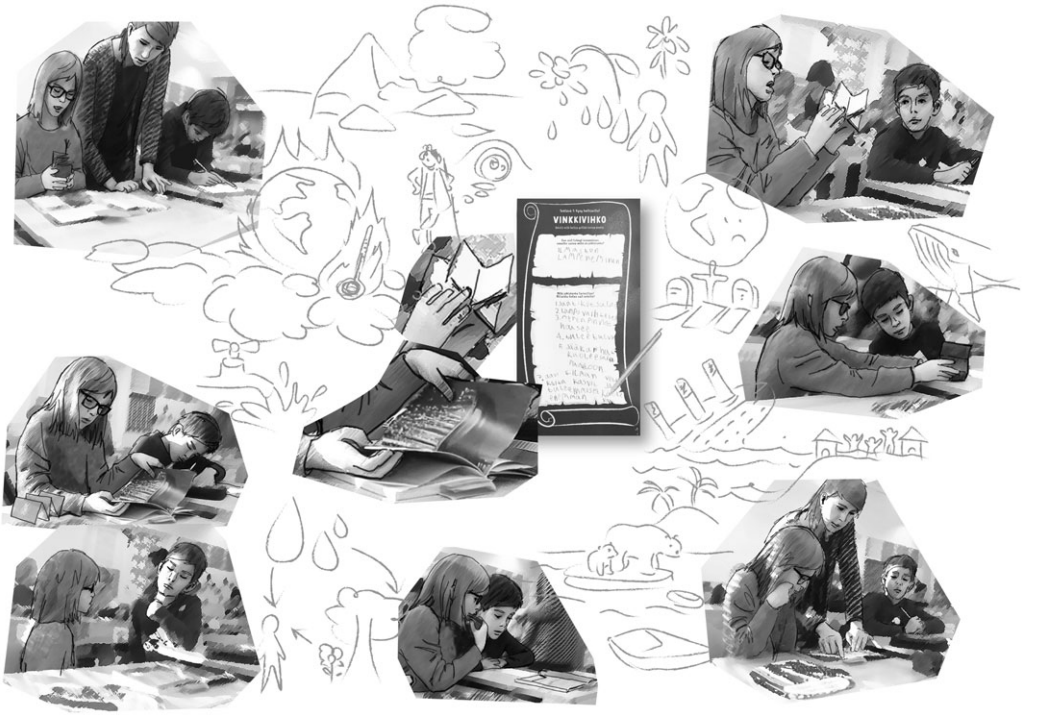

Figure 3. Mapping the materiality of Silja's and William's imaginative sense-making of global warming.

warming. Thinking about the Titanic film, the scene of an enormous ship sinking into the dark ocean surfaces in our imagination. The imaginings of the hopeless scenario of drowning people in the film aroused our awareness of what seawater could do to humans in situations such as floods and tsunamis caused by global warming. Considering this possibility, the Titanic film with its material–discursive forces could conjoin William's imaginative sense-making of the rising sea levels and the destructive power of floods. This resonates with the perspectives of Rousell, Cutter-Mackenzie, and Foster (2017) on speculative fiction and its ability to open up new spaces for thinking, feeling and acting differently in relation to climate change. The authors wrote that speculative fiction, such as science fiction fantasy, fairy tales and myths, could give room to children's critical and creative thought experiments and to respond to climate change in individual and affective ways.

After the recess, an image of a running tap in the book provoked Silja and William to continue their discussion about the significance of water (Figure 4). Then, "without water, humans and plants won't live" was written as a meaning of global warming on the Hint Paper.

When Silja and William were reading about water in the book, a "chain" of relational links was imaginatively formulated with scientific knowledge of natural phenomena and water was recognised as being vital for plants and humans. At this moment of imagining, water materially resonated as part of the children's bodies and plants' bodies. Imagining themselves as "bodies of water" (Neimanis, 2018) could also change the ways the children thought about water and their entangled relationships with it. Imagining the interdependence between water, plants, oxygen and humans, the children might have recognised that global warming was not just a matter of melting glaciers or the extinction of polar bears but also a threat to other earthly inhabitants.

This episode shows how the materiality of the present activity intra-acted with other agencies across time and space, and new meanings emerged through children's imaginative sense-making.

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While reading about water in the book, the agency of water emerges through Silja's and William's imaginative sense-making of global warming.

(Silja reads through the pages about tap water in the book and turns to William)
Silja: *For example… without water humans won't live. How's that? Hey, William.*
(William is reading the book)
Silja: *Listen to me!* (Slaps William with the Dictionary prop, trying to get his attention)
William: *Hey.* (Continues reading the book)
Silja: *The thing is that… did you get it that we should write that without water humans and plants won't live. Plants are important to us.*
William: *Yeah…*
Silja: *They create oxygen for us.*
William: *Oh right. Water is used a lot.*
Silja: *Yup. And it is important for us because plants will get water then. So water is important. Write water is important.*
William: *So…wh- what happens then?*
Silja: *Well, without water we would die. And plants...*
William: *Without water, plants and humans will die. That'll be long (to write).* (Starts writing on the Hint Paper)
Silja: *Yup.*
William: *So, without water.* (Spelling the words while writing)
Silja: *When we have written this paper full, we will get free time.*

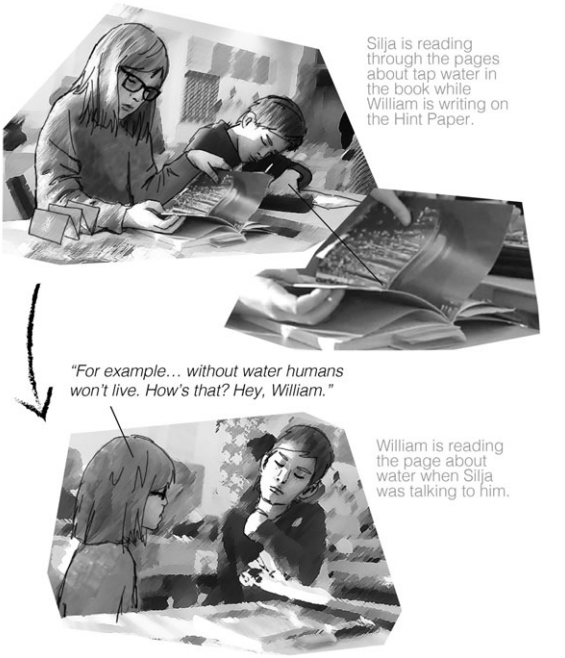

Figure 4. While reading about water in the book, the agency of water emerges through Silja's and William's imaginative sense-making of global warming.

The book, water and dying plants intra-acted with the children's imagination and their bodies, resulting in the children's speculation about how water as a vital substance could become scarce ("climate is warming, all the water dries out"; "water is used a lot"). In the activity, water was not a specific inquiry topic suggested by the teachers, but engaging with the concept of global warming brought forth water as an important intra-acting agency constituting the children's imaginative sense-making. This also reflects the unpredictable and indeterminate nature of intra-action (Barad, 2007; Lenz Taguchi, 2010). As Barad (2007) wrote, "it is through specific agential intra-actions that a differential sense of being is enacted in the ongoing ebb and flow of agency" (p.140). This highlights the dynamic and transformative potential of intra-actions in bringing forth unexpected matter and meanings in children's imaginative sense-making (see also Lenz Taguchi, 2010; Wohlwend et al., 2017).

As Saari and Mullen (2020) point out, the overbearing event of global warming has its dark, mysterious and uncanny dimensions that can make us feel anxious and uneasy. Similar to Silja and William during the Riddle of the Spirit project, many other children in our study expressed concerns about the destructive consequences of climate change, human's pollution to the environment and the well-being of the Earth. For example, one group of children discussed the challenges of building houses, finding food and producing electricity without harming the environment and causing pollution. The children also pondered that the spirit Ukko would not like humans using plants and animals as resources. These events show how the concepts of climate change and global warming can also "haunt" children, their emotions and imagination about human–animal–environment relations.

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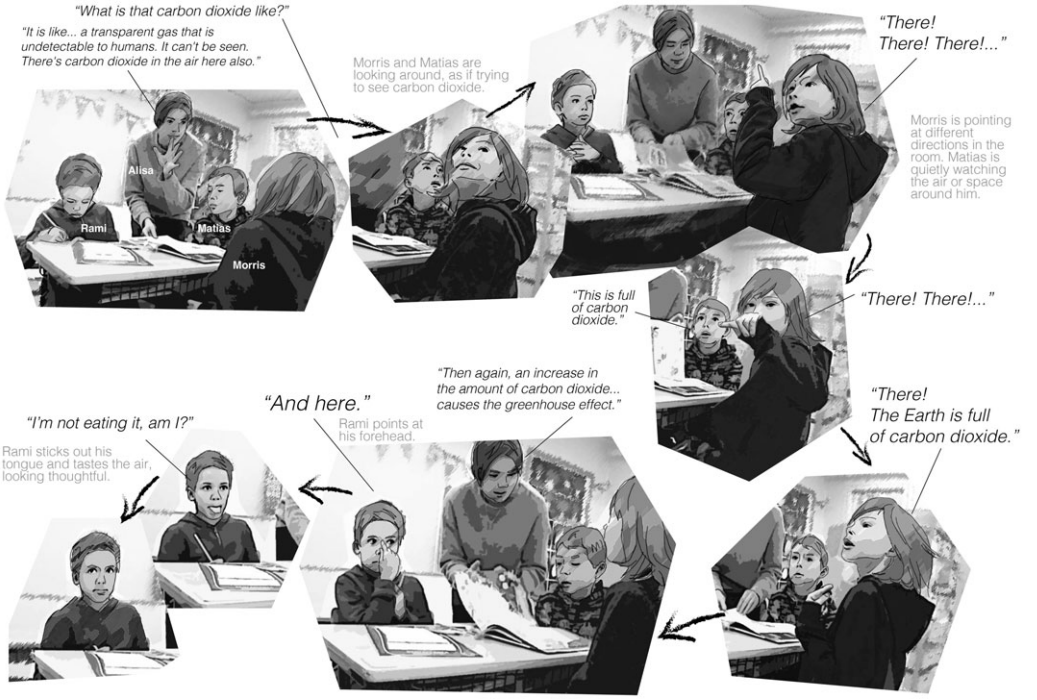

Figure 5. Rami's, Matias' and Morris' inquiry of carbon dioxide.

Episode 2: How the book, the substance of carbon dioxide and children's bodies came to matter in the children's imaginative sense-making of carbon dioxide

Analysing this episode, we produced a mapping (Figure 5) to consider the material–discursive intra-action between a book passage about carbon dioxide, the substance of carbon dioxide, and the children's and the researcher's bodies.

Listening to Alisa reading out about carbon dioxide as an undetectable gas from the book, Rami, Matias and Morris together imagined carbon dioxide with their sensing bodies, driven by feelings of surprise, awe and curiosity. Even though the children were told that the gas was undetectable, they were still trying to sense it, imagining that carbon dioxide was "here" materially entangled with their bodies and that they had been touching, tasting and breathing it without knowing. With the book information and the carbon dioxide gas in the classroom, the children became aware of the close connections between their bodies and carbon dioxide and realised that the Earth was full of this gas.

Similar to Episode 1, the book and its scientific description as performative agencies acted out material–discursive forces, evoking the children's curiosity and embodied imagination of carbon dioxide. The undetectable nature of carbon dioxide was so surprising and mysterious to the children that it was actively "inviting" the children to sense it. We also noticed other embodied imaginings during our research with the children, for example when the phrase "carbon footprint" and the image of a footprint in the book invited another group of children to speculate this concept as an actual footprint, which people and animals could physically print with their feet. With the information from the book, the children considered how traffic and pollution are connected to carbon footprints and, simultaneously, they drew out a picture of humans' and rabbits' footprints in the snow.

With a new materialist approach, in this episode, we understand that the words and images shown in the book and the substance of carbon dioxide have strong performative agencies in

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intra-acting the children's imagination of carbon dioxide. In agential realism, Barad (2003) wrote, "knowing is a matter of part of the world making itself intelligible to another part" (p.829). Thinking about this, the children knew about the existence of carbon dioxide as much as carbon dioxide made itself intelligible to the children through exercising its material–discursive agencies and making a difference in the children's imaginative sense-making. The children's realisation of carbon dioxide as part of their bodies might become another layer of meaning, potentially leading to a deeper and more personal way of understanding the gas, as well as its role in climate change. This also resonates with previous research (Seiki & Gray, 2020; Thomas Jha & Price, 2022), which demonstrates the importance of children's embodiment in scientific learning.

Discussion

With a new materialist approach (Barad, 2007; Lenz Taguchi, 2010; Murris, 2016), in this article, we investigated how materiality came to matter in children's imaginative sense-making of concepts around climate change, namely global warming and carbon dioxide. Our research shows how the books and props, which the children engaged with during an inquiry activity in the Riddle of the Spirit project, conjoined within the formation of children's sense-making of the concepts. In Episode 1, during the children's speculation of rising sea levels, flooding and fluctuating temperature, the Dictionary prop turned into a whale's head, the Titanic film appeared and water became important to humans and plants. Through these specific events, materials such as the props, water, sea, oxygen, plants, human bodies, whales and the Titanic, came to matter through material–discursive intra-actions and conjoined with the children's lingering thoughts about the unsettling issue of global warming and of what this issue could mean and do with these matters. In Episode 2, our research also shows how the materiality of carbon dioxide and its scientific narratives emerged as generative forces, surprised the children, and aroused their awareness of its existence entangling their bodies. In these episodes, the materiality of the activity, including the books presenting scientific information, and the props, intra-acted with the children's imagination, bodies, emotions, memories from the past and speculations of the future. The materiality of the activity performed as a "speculative space" (Byman et al., 2023) in which new imaginaries about climate change emerged through intra-actions, blurring the lines between bodies and materials, scientific narratives and fictional stories, past and future, sense and nonsense.

With a new materialist approach, our research is attuned with how materials with generative forces can affect children to imagine climate change in unique and unexpected ways. In agential realism, Barad (2007) recognises that intra-actions are always indeterminate, contingent and dynamic phenomena. Barad (2007) elaborates on the concept of "diffraction" that "matter" (the material) and "meaning" (the discursive) are always entangled, similar to waves interfering with one another, diffractively creating newness without clear boundaries. In our research, we found that the children's imaginative sense-making was rich, sensitive and responsive to the changing material conditions of the activity. This resonates with how Rousell and Cutter-Mackenzie-Knowles (2022) describe children's imagination of climate change as "worlds-in-the-making" (p.159), entangling the specific conditions through which they live and think, and the shifting challenging ecological circumstances posed by climate change.

With this study, we suggest that viewing children's imaginative sense-making as material–discursive intra-actions brings unexplored educational opportunities to climate change education. As Lenz Taguchi (2010, 2011) reveals in intra-active pedagogy, learning is always an encounter in the world and embracing the multiplicities of children's unique encounters can bring new opportunities for learning. Lenz Taguchi points to the need for teachers to be aware of how the classroom, space, time and matter are structured, and what intra-actions between different agencies might be possible. In climate change education, while it is important for educators to

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make sure that children grasp the scientific mechanisms of climate change, they should also give room to children's imagination, so as not to foreclose on the options of the emergence of new learnings. For instance, Silja's and William's speculations of water drying out and dying plants could be guided towards discussions on other topics related to global warming, such as water conservation, endangered and extinct plant species, as well as the importance of the sea and plants in neutralising carbon dioxide. As Elkin Postila (2022) shows, water issues connect closely to climate change and exploring topics such as water shortage and water purification can engage children in the debate of climate-entangled environmental issues. The Titanic film and other popular culture can also be engaged as speculative fiction (Rousell et al., 2017) and give room to children to explore the uneasy and dark sides of climate change in creative and affective ways.

Fostering children's imaginative sense-making in climate change education also poses pedagogical challenges. In the Riddle of the Spirit project, although the teachers and researchers might have structured the activity with ideas of what scientific narratives the children should discuss, the materiality of the activity can also lead the children to unplanned discussions (see also Lenz Taguchi, 2011). As Lenz Taguchi (2011) argues, besides the forces of teachers' words and instructions, pedagogical materials, popular culture and everyday experiences have their agential forces in shaping how children imagine, feel and act. Children may explore topics beyond what the teachers intend, which makes it difficult to facilitate and manage learning outcomes. Children's creative and whimsical imaginaries could also lead to scientific misconceptions of climate change (Spiteri & Pace, 2023), as well as hopeless envisionment of the future (Ojala, 2023). These reflections also urge us, as pedagogical designers, educators and researchers, to examine the performative power of materials, as well as our actions in designing pedagogical materials and our perspectives on children's sense-making related to climate change. In all, we acknowledge the need for further research and teacher professional development to embrace the richness of children's imaginative sense-making in climate change education.

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Ethical standard. This study follows the ethical standards of the Finnish Advisory Board on Research on Integrity (https://www.tenk.fi) and was reviewed and approved by the Education Division of the City of Helsinki (HEL 2019-008574 T 13 02 01). Informed consent was obtained from all participants and the children's guardians. Pseudonyms were used for all participants.

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