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"The Planet Is Broken" – A Qualitative Cross-Sectional Study on Elementary School Students' Conceptions of Climate Change

Students' conceptions of climate change are crucial in climate change education. This qualitative study examines the conceptions of climate change among 94 elementary students aged 9-11 through problem-centered interviews and student drawings. It focuses on conceptions about the causes, characteristics, impacts, and potential actions to climate change. The findings reveal heterogeneous conceptions ranging from no to sophisticated conceptions. Common patterns across conceptions include waste and cars as main causes and animal habitat loss as an impact, while humans are considered less often. To address differences in students' understanding of climate change, a five-level learning progression categorizes these conceptions and provides guidance for designing adaptive learning environments.

Keywords: climate change; conceptions; elementary school; learning progression; qualitative study

1 Climate Change as a Topic in Elementary Social and Science Education

Children and adolescents are increasingly affected by climate change (CC), not always physically, but often emotionally. They grapple with anxiety, helplessness and guilt in the face of its uncertainties (Léger-Goodes et al., 2022). These emotional responses, combined with the urgency and complexity emphasized in scientific discourse, underscore the importance of climate change education (CCE) (Lombardi, 2022).

Since CC-related negotiations touch on ecological, political, social, and economic aspects, this paper takes a holistic approach to CCE. CCE is defined as an educational approach that aims "to enhance public awareness, understanding, and engagement in CC issues, as well as foster adaptive capacity and support for climate action" (Muccione, Ewen & Vaghefi, 2025). Its aim is

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to encourage critical and creative thinking to enable learners to respond to the complexity of climate-related issues and promote climate action (Stevenson, Nicholls & Whitehouse, 2017). This includes exploring interconnections within climate knowledge, ethical considerations, societal structures and emotional responses, both locally, globally and over time (Rousell & Cutter-Mackenzie-Knowles, 2019).

Rousell and Cutter-Mackenzie-Knowles (2019) argue that CCE in curricula worldwide often focuses too narrowly on scientific content, neglecting the broader social, ethical, and political dimensions. This tendency is also evident in Germany. Siegmund et al. (2021) analyzed curricula across different types of schools and found that important aspects of CC, such as its consequences, mitigation and adaptation strategies, are not adequately covered. Similarly, research on student conceptions neglects younger learners, focusing predominantly on the views of secondary school students (Wildbichler, Haagen-Schützenhöfer & Schubatzky, 2025). Indeed, CCE at elementary level is still in its dynamic and emerging phase, both in curriculum development and research (Haltenberger et al., 2023; Nepraš, Strejčková & Kroufek, 2022). Due to the widespread uncertainties surrounding CC, including fake news, it is crucial to provide students with scientific information (Lämmer & Ohl, 2024). To address this, Wildbichler et al. (2025) suggest that in CCE, refining and expanding existing conceptions is more effective than replacing them. To design effective and developmentally appropriate learning environments, it is essential to first understand elementary school students' conceptions.

2 Student Conceptions in Climate Change Education

Research on elementary school children's conceptions of CC has been conducted in a wide range of countries, mainly in Europe and Asia. These studies reveal consistent patterns as well as differences, for example due to geographical context.

Emotional responses to CC emerge as a significant component of children's conceptions (Martin, Reilly, Everitt & Gilliland, 2022). Regarding the perception of CC as a challenge, cultural and socio-economic factors seem to shape children's conceptions. For example, children in climate-vulnerable regions such as parts of the Philippines often experience climate impacts directly, which can evoke feelings of anxiety, worry and helplessness alongside a sense of responsibility (Berse, 2017; Karpudewan, Roth & Abdullah, 2015; Kim, Lim, Lee, Widodo & Yun, 2024; Ramos, Rodrigues & Rodrigues, 2022).

The causes of CC are often simplified or misunderstood by children. They frequently attribute CC to visible pollution, factories, or natural phenomena without taking into account the complexity of greenhouse effect (Pala, 2025;

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Spiteri & Pace, 2023; Sutinah, Widodo, Muslim & Ernawulan Syaodih, 2024). Pala (2025) found that children initially expressed only basic environmental ideas, such as references to litter or trees. However, after taking part in a CCE program they were able to identify key causes of CC, such as emissions and deforestation, recognize effects like heat and death of animals, and began to express ideas for climate-friendly behavior.

Concerning characteristics of CC, a notable pattern is the frequent confusion of CC and short-term weather fluctuations or seasonal changes (Akaygun & Adadan, 2021; Sjöblom, Wolff, Vuorenpää & Grahn, 2022; Spiteri & Pace, 2023). This indicates that, although children may be aware of environmental change, they have a simplified conceptual understanding.

When it comes to impacts, children mainly focus on ecological aspects. Effects frequently mentioned include rising temperatures, extreme weather events such as floods and droughts, sea level rise, loss of animal habitats, and altered rainfall patterns (Akaygun & Adadan, 2021; Anagbogu, Nwokolo & Anyamene, 2014; Berse, 2017; Götz & Mendel, 2024; Morote & Hernández, 2024; Ramos et al., 2022). In Samoa, for instance, children reported local environmental changes, including those triggered by CC, such as stronger winds, increased rainfall, and cyclones, with rising sea levels being perceived more as a future rather than a current issue (Niusulu, Taulealo & Connell, 2024). Despite this, many children have difficulty naming concrete impacts or show uncertainty about the scope and nature of the consequences (Götz & Mendel, 2024; Ramos et al., 2022).

Finally, actions related to personal and collective responsibility are sometimes expressed, but the understanding of adaptation and mitigation strategies often remains limited (Baker, Loxton & Sherren, 2013; Berse, 2017; Pala, 2025). Afacan (2013) found that students suggested a variety of solutions for preventing global warming, such as raising awareness about saving electricity and water, as well as preventing pollution.

These conceptions are shaped by children's information sources. Television, the internet, school, personal experiences, and family conversations are commonly cited, although these may not always offer accurate or comprehensive explanations (Niusulu et al., 2024; Ramos et al., 2022; Wang et al., 2022).

Existing studies rarely differentiate with regard to student heterogeneity or variations in their conceptions. To describe systematically how students' understanding of CC can develop from simple initial ideas to more complex, scientifically accurate conceptions, the approach of learning progressions in CCE seems very valuable (Alonzo, 2012; Krajcik, Sutherland, Drago & Merritt, 2012; National Research Council, 2007). Learning progressions are empirically validated models that describe learning as progressing through successive levels characterized by an increasingly elaborated understanding (Duncan & Hme-

lo-Silver, 2009). As such, learning progressions serve both as a diagnostic tool and as a guide for designing adaptive learning environments (Bernholt, Neumann & Sumfleth, 2018). Typically, they consist of a lower anchor representing naive conceptions, intermediate levels capturing transitional thinking, and an upper anchor reflecting expert-like understanding (Alonzo, 2012).
Numerous learning progressions on CC have been developed for various school types and specific aspects of the topic (Breslyn, McGinnis, McDonald,& Hestness, 2016; Hestness, McGinnis, Breslyn, McDonald & Mouza, 2017; McGinnis, Breslyn, McDonald & Hestness, 2017; Parker, Santos & Anderson, 2015; Shepardson, Niyogi, Roychoudhury & Hirsch, 2012), for instance about sea level rise (Breslyn et al., 2016). Some of the existing learning progressions include elementary school age in addition to older age groups (Chang, Tan, Tan & Kwek, 2020; Mohan, Chen & Anderson, 2009) or focus on specific aspects of CC (Jin, Zhan & Anderson, 2013). The aim of this study is to enhance this body of research by examining elementary students' conceptions of CC and developing a learning progression. Thereby, we acknowledge the complexity and urgency of CC by considering the conceptions of CC regarding its causes, characteristics, impacts and potential courses of action.

3 Research Design

This section outlines the methodological framework.

3.1 Purpose of the Study and Research Questions

The study addresses the following research questions:

- RQ 1: How do elementary students perceive CC as a challenge?
- RQ 2: What are elementary students' conceptions of the causes, characteristics, and impacts of CC?
- RQ 3: What are elementary students' conceptions of actions to address CC?

3.2 Sample and Data Collection

A total of N = 94 third- and fourth-grade students of three different elementary schools in Southern Germany participated in the study. 28 students took part in an interview (average duration: 28 minutes) and created a drawing (approximately 15 minutes), while 66 students only created a drawing. The participants were between 9 and 11 years old (average: 9.4). Data collection took place in June and July 2025.
Prior to the interviews, students were asked to create drawings about CC. The task was introduced as follows: „I'm interested in what you know about CC.

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You can express your own conceptions about CC." The drawings were used in the interviews as a prompt, to explore the students' individual conceptions in more depth (Brailas, 2020) and to ensure a more accurate interpretation of the children's drawings. This approach helped to avoid misinterpretations that may result from varying drawing abilities and offered deeper insights into individual perspectives (Baumgardt, 2022).
The interviews were conducted using a semi-structured guide developed in line with methodological recommendations (Trautmann, 2010; Vogl, 2021; Witzel & Reiter, 2022).
The final guide was divided into two sections, the first focused on students' conceptions of CC, particularly its causes, characteristics, impacts and actions. The second section addressed the sources of information about CC. They were asked about their use of media sources, and whether they encountered climate-related content. A short teacher questionnaire was developed to gather background information such as teaching content dedicated to CC.

3.3 Data Analysis

Both the interview transcripts and the drawings were analyzed using a qualitative content analysis (Kuckartz & Rädiker, 2024) in MAXQDA. A coding system (65 codes) consisting of deductive (49 codes) and inductive categories (16 codes) was used. The deductive categories originated mainly from Schuler (2011), while the inductive categories were formed from the material. For example, deductive codes included emissions from transportation, whereas inductive codes included environmental pollution as a cause.
In the analysis of the drawings in particular, the three main areas of observation according to Billmann-Mahecha and Drexler (2017), the drawing itself, the overall impression it conveys, and comparisons with other childrens' drawings, were taken into account.
Based on the coding process, each case (each interview and each drawing) was analyzed with regard to the differentiation of the students' conceptions about CC as a challenge, the causes, characteristics, consequences, and possible courses of action. On this basis, the cases could be systematically assigned to five levels, which gradually emerged from the data material. This resulted in the learning progression shown in Table 1.
To ensure the reliability of the coding process and reduce potential bias in the interpretation of the data, inter-coder reliability was calculated for ten drawings (Cohen's kappa = .92) and three interviews (Cohen's kappa = .84), which represent 10 % of the total material. This reflects a very high level of agreement between the two independent reviewers (Brennan & Prediger, 1981).

4 Findings

The developed learning progression serves as the foundation for the findings discussed below and is therefore presented first as an overview of the conceptions (Table 1).

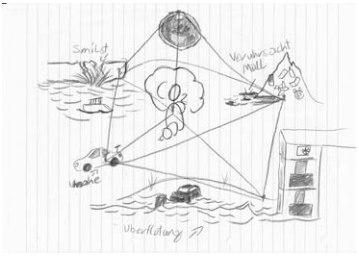
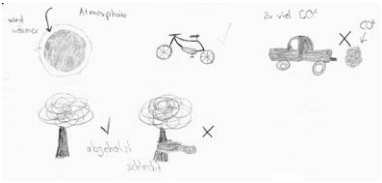
4.1 Learning Progression of Climate Change Conceptions

Each level of the learning progression demonstrates increasing complexity and coherence in explaining causes, characteristics, impacts, and actions of CC. It is important to note that these levels are not fixed categories, and the assignments sometimes differ between drawings and interviews. Seventeen out of 28 students were assigned to different levels for their drawings and interviews.

Tab 1: Learning Progression of Elementary Students' Climate Change Conceptions in Grades 3 and 4 in Germany*

Level 4: interconnected and sophisticated conceptions	drawings n = 8/94 interviews n = 5/28
Climate change is perceived as a challenge, often with references to both local and global dimensions, although this distinction is not always clearly recognized. Explanations of its causes, characteristics, impacts and potential actions become more coherent and logically structured. Key conceptions are progressively connected, supporting a deeper and more integrated understanding. *"Glaciers are melting because it's getting warmer in the mountains. This causes floods and more forest fires. Driving less helps because cars release carbon dioxide, which warms the air and leads to more fires."* (s6)	 (s68)

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Level 3: initial subject-specific frameworks	drawings n = 24/94 interviews n = 3/28
Climate change is perceived as a challenge. Initial conceptions of causes, characteristics, consequences, and possible courses of action are identified. Sometimes, basic connections are made, but often, conceptions are fragmented or occur in an isolated manner. *"It's getting hotter, so the glaciers melt. That makes the seas higher, and then there are more floods. Cities near the coast get flooded more often."* (s23)	 (s42)
Level 2: pre-structured conceptions	drawings n = 37/94 interviews n = 2/28
Climate change is perceived as a challenge. There are initial references to scientific aspects such as causes, characteristics, impacts, and possible actions. However, connections between these aspects are either not yet recognized or only made sporadically. *"Cars are bad."* (s10)	 (s14)
Level 1: naive conceptions	drawings n = 15/94 interviews n = 9/28
Climate change is not perceived as a challenge. Understanding is based on intuitive ideas. Many notions are overly simplified. Climate change is associated in the broadest sense with unrelated phenomena such as weather, seasons (e.g., summer and winter), environmental protection (sometimes leading to a positive interpretation of climate change), or pollution. Changes are often seen as natural or interpreted from a one-sided perspective, leading to confusion and alternative conceptions. *"Sometimes it's warm and sometimes it's cold."* (s21)	 (s21)

Level 0: no conceptions	drawings n = 10/94 interviews n = 9/28
There are no identifiable conceptions related to climate, weather, or environmental systems. Learners show no awareness of changes associated with climate change or related phenomena. *"It's something to do with the earth, I think, but I'm not sure."* (s24)	 (s24)

** All quotes from students were translated into English by the authors and are presented as anchor quotations.*

4.2 Students' Conceptions of Climate Change as a Challenge

Many students view CC as a significant issue in the past, present and future. Their understanding encompasses both global and local dimensions. Students tend to view CC as either a significant challenge or not at all; intermediate views are rare.

Especially students at higher learning progression levels exhibit emotional responses such as fear and worry. One student expressed a sense of concern and apprehension about the future: *"If people keep doing exactly what they're doing now, then it will be like it is now, but only worse. I even think much worse"* (s28). The more developed students' conceptions are, the more severe their perceived impacts tend to be (4.3).

4.3 Students' Conceptions of Causes, Characteristics, and Impacts of Climate Change

Students often describe CC by blending causes, characteristics, and impacts. Regarding causes of CC, cars, airplanes, ships, and factories are commonly identified. Even when students' conceptions are at lower levels, they often mention CO_2 and can frequently establish a basic link such as "exhaust gases warm the air" (s50). Deforestation, pollution and waste (sometimes including cigarettes and toxic substances) are seen as harmful to the climate. Plastic pollution in the ocean is described as a major cause, which is notable given that these students do not live near the sea. At higher learning progression

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levels, the greenhouse effect is explicitly mentioned, with explanations such as: *"Because of the CO_2, because cars emit it as exhaust gas and then it gets blown into the sky, and then it's like a wall, where the sun can no longer get back into space and that's why it keeps getting hotter"* (s23). At higher levels, the drawings contain more arrows and cycles that illustrate processes. Students who participated in a unit on CC in school (n = 39) often depicted the greenhouse effect and were less frequently in the lowest levels, though their conceptions still varied.

In terms of characteristics, there is considerable confusion between CC and related topics such as environmental protection, pollution, weather, or seasonal changes. Consequently, students often express uncertainty, incorrectly attribute causes to CC, or associate it positively, such as by referring to warm summers. However, across different levels, the increase in global average temperature is the most frequently perceived characteristic.

Students rarely distinguish between regional and global effects. The most named global impact is a general rise in average temperature. Local impacts are limited to the polar regions or nearby areas. Flooding is often mentioned, likely due to direct personal experience, while melting glaciers are especially noted by students from regions near the Alps. Other reported impacts include forest fires, heavy rainfall, and reduced snowfall. Economic impacts are rarely addressed. They typically refer to damage to the built environment, such as houses. Far more frequently, students highlight the loss of habitat for animals and changes in vegetation. Notably, humans are mentioned almost exclusively in relation to health aspects, e.g. *"one day we might run out of air"* (s28) or *"it can make us sick"* (s3).

4.4 Students' Conceptions of Climate Actions

Although students identify a similar number of causes, characteristics, and impacts of CC, mentions of potential actions are significantly less frequent. Students expressed divergent views on whether CC can be addressed through human action. Some explicitly denied the possibility, with statements such as, *"You can't control the earth, unless you have superpowers"* (s8). Only 30 out of 94 students recognized that actions could be taken. For example, a student emphasized the urgency of action by stating *"the planet is broken [...] we have to do something now, the planet is already taking revenge with all these natural disasters"* (s35).

The majority of suggestions focused on mitigation measures, primarily at an individual level by classifying actions in binary terms as either "right" or "wrong". The most frequently suggested solution was to opt for more climate-friendly mobility, such as avoiding car use and choosing active transport

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modes. Waste separation played a major role in many students' conceptions. This was often tied to the broader and sometimes mistaken conception that environmental protection automatically equals climate protection. Only a few students mentioned reducing meat consumption or buying local products as ways to mitigate CC.

At the societal and political level, actions were mentioned only sporadically. Some students referred to public demonstrations, such as climate protests, as meaningful actions. Others suggested expanding renewable energy sources, developing electric mobility, and promoting sustainable forestry. Educational strategies such as raising awareness or promoting climate education were not mentioned at all as potential avenues for action.

In contrast to measures to mitigate CC, adaptation strategies were mentioned far less frequently. On a high learning progression level, there were occasional mentions of modified building techniques, increased green spaces in cities, river renaturalization, demonstrations and migration. On lower learning progression levels activities were mentioned, such as going swimming and eating ice cream.

5 Discussion

The findings of the study reveal that, at higher learning progression levels, students describe phenomena related to CC with greater reference to scientific terms, such as the greenhouse effect or natural disasters. The complexity, coherence and interconnections of causes, characteristics, impacts, and actions of CC increase with the levels. This highlights the topic's inherent complexity, requiring more advanced cognitive engagement.

It is notable that many students' drawings are assigned to the middle levels of the learning progression (levels 2 and 3), whereas students' interviews are predominantly classified as levels 0, 1 and 4. This may be due to methodological reasons, since more complex aspects tend to be easier to express verbally. However, more data would be needed to confirm this pattern.

Elementary school students predominantly perceive CC as a global challenge that spans the past, present, and future. This indicates a broad understanding of the phenomenon's temporal dimension. However, awareness of CC is often polarized: students either clearly acknowledge or confuse it with related topics and remain unaware of it.

Regarding the causes of CC, children primarily focus on human-induced factors, which aligns with scientific consensus. Throughout the learning progression, a common and highly simplified conception is that waste directly causes CC. While waste is related to CC, this overemphasis reveals a persistent conception. For example, students may draw the atmosphere and components of the greenhouse effect, but also include waste and environmental pollution.

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Results on characteristics and impacts show that students differentiate only minimally between regional and global effects. Their focus on global temperature rise oversimplifies the spatial complexity of characteristics and impacts of CC. Local impacts tend to be personally relatable phenomena like flooding or glacial melt. Additionally, students prioritize animals "losing their home" (s13) over humans. If humans are mentioned, the focus is mostly on health-related effects. This indicates that students do not perceive their own vulnerability as very high and give less consideration to the social impacts. This might be influenced by the extent to which the research area is affected by CC.

Concerning actions to address CC, mitigation strategies are mentioned far more often than adaptation measures, even though they are both important scientifically (Intergovernmental Panel on Climate Change [IPCC], 2023). Notably, the vast majority of proposed actions focus on changing individual behaviors. Few students suggest societal or political measures. This focus on individual responsibility is also reflected in CCE approaches (Trott, 2022). Thus, political and societal responsibility should be more strongly integrated into these approaches.

A common way of describing actions is to categorize them in binary terms as either "good" or "bad". Such a simplistic dichotomy may oversimplify climate-related decisions and limit critical reflection on their complexities. Research on children's cognitive development and intelligence supports this interpretation, indicating that learners often categorize complex issues dichotomously (Lohaus, Vierhaus & Lemola, 2024; Piaget & Cook, 1952).

Concerning the research methodology, the combination of drawings and problem-centered interviews proved fruitful, as the two approaches complemented each other. This combination of methods made it possible to bring out nuances in the learning progression. The substantial number of collected drawings provided a strong empirical basis. Integrating visual and verbal data made it possible to identify conceptual patterns and developmental steps more comprehensively. However, when children produced only drawings without verbal elaboration, interpretation relied solely on visual material, which may limit the depth of insight (Gal & Gan, 2021).

6 Future Directions

Elementary students' conceptions are strongly ecologically. Therefore, an age-appropriate educational approach that integrates ecological, political, social, and economic dimensions is crucial to adequately reflect the complexity of CC (Trott, 2022). Additionally, CCE should address both mitigation and adaptation strategies, as both are relevant (IPCC, 2023), yet unevenly represented in students' conceptions. This underlines the need for a holistic approach.

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To achieve this, appropriate teaching materials and curricular guidelines are needed (Nepraš et al., 2022). Such resources would enable adaptive learning that can effectively advance students' conceptions across various levels of the learning progression.

Specifically, studies should examine how students' conceptions of CC, particularly their emotional responses, differ based on their exposure to CC impacts. This highlights the importance of context- and region-specific CCE approaches (Sjöblom et al., 2022). Moreover, research is needed on how CCE can be effectively designed in elementary schools to support adaptive learning.

Overall, the findings of this qualitative, cross-sectional study of elementary school students' conceptions of CC suggest that CCE should begin in elementary school through adaptive learning opportunities aligned with children's existing conceptions. The learning progression developed in this study provides a framework to guide these processes and support CCE tailored to elementary education.

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