SECONDARY SCHOOL STUDENTS' (MIS-)CONCEPTIONS OF URBAN ADAPTATION STRATEGIES FOR CLIMATE CHANGE

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With 6 figures and 3 tables
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Summary: The aim of this study is to provide an insight of students' (mis-)conceptions of urban adaptation strategies for climate change. For this purpose, drawings and texts were produced by secondary school students (n = 87) aged 16-18 years from four secondary schools in Hamburg, Germany. The data were analyzed using qualitative content analysis. The results show that the majority of students cannot distinguish between climate change adaptation and mitigation strategies. Regarding climate adaptation strategies in urban areas, students predominantly focus on non-building-related approaches, while some strategies in the field of building-related strategies and policy are not taken into account. There are no major differences between the drawn and text elements. Regarding the (mis-)conceptions and gaps in knowledge, there is a need for climate education to focus more thoroughly on urban adaptation strategies to successfully achieve conceptual change and enhance urban adaptive capacity.

Keywords: Students' conceptions, climate change adaptation strategies, urban climate, educational geography, education for sustainable development

1 Introduction

In the context of climate change, heat is a well-documented health risk factor that influences mortality rates across Europe, especially in cities. With no adaptation to heat, the increase in heat-related deaths consistently exceeds any decrease in cold-related deaths across all scenarios considered in European cities (Masselot et al. 2023, 2025). Under the lowest mitigation and adaptation scenario (SSP3-7.0), Masselot et al. (2025) projected a 49.9% increase in the net mortality burden attributable to climate change, with an estimated total of 2,345,410 climate change-related deaths (95% confidence interval = 327,603 to 4,775,853) between 2015 and 2099. This net effect has to decrease to protect people, even if it remains positive in scenarios with high levels of adaptation.

Heat and heat extremes comprise one factor that threatens people in the city; heavy rainfall events or an increase in flooding are also among the threats, making urban climate adaptation strategies necessary (IPCC 2023, Thiery 2021). In addition, climate change intensifies the typical urban climate: high surface temperatures, lower humidity, and reduced air exchange due to the high building density—and increases the existing risk of flooding in European cities located near water (IPCC 2023, Kuttler et al. 2023). To tackle the effects of climate change in cities, urban mitigation and adaptation strategies are necessary. To promote climate adaptation strategies, the Federal Climate Adaptation Act (Bundesklimaanpassungsgesetz) came into force in Germany in July 2024, which obliges the federal government, federal states, and municipalities to develop climate adaptation concepts (Deutscher Bundestag 2023). To enhance urban adaptive capacity, which is a task for the whole society that will last decades and require collective action, climate change education is needed to prepare people for current and future climatic changes (Chang 2022). Students as future decision-makers play an important role to effectively pursue climate action and adaptation in the future even if they are not the primary contributors to the current climate situation. In particular, knowledge is essential for climate action and the (social) implementation of climate adaptation strategies in cities (Anderson 2012, Olzabal et al. 2018, Pruneau et al. 2010). Following the constructivist learning theory, conceptual change is the goal of learning (Bada 2015, Duit & Treagust 2003). To achieve this conceptual change, students' conceptions must be considered. For this reason, this research project examines students' conceptions of urban adaptive strategies for climate change.

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2 Theoretical background

2.1 Urban adaptation strategies for climate change

Cities have specific climatic conditions, with the urban heat island effect playing a decisive role (Oke et al. 2017). While the urban heat island effect has been observed for a long time (Eriksen 1964), the impact of climate change on cities is a more recent research area (IPCC 2023). The urban heat island is "a difference in temperature between urban areas and their surroundings" and characterizes the urban climate (Oke et al. 2017). Due to human activities and urban infrastructure, the temperature in cities is higher during the day and at night than in surrounding areas. The development of this effect and the urban climate is a complex interplay. The decisive influencing factors for the associated radiation and heat balance include building and urban planning aspects as well as emissions of anthropogenic heat. These factors influence each other in complex urban climate systems (IPCC 2023). The urban heat island effect is the strongest during the summer. While there are usually temperature differences of 1–2 °C between the city and the surrounding area, the difference can sometimes be as much as 15 °C in the early morning hours. In the summer months, the urban heat island effect therefore causes an increased number of tropical nights in urban areas, where the air temperature does not fall below 20 °C (Kutter 2023). As a result of climate change, the intensity and frequency of heat events are currently increasing and, according to current projections, are set to rise even further in the future. In Central Europe, the probability of this increase is 99% (IPCC 2021). The effects particularly affect cities that already have higher temperatures than the surrounding areas.

In addition to heat, water is also a key factor in the city when it comes to climate change. The IPCC (2021: 19) stated: "Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events." For Europe, it is projected that the predicted increase in the frequency and intensity of heavy precipitation (high confidence) will lead to an increase in local flooding caused by rain (medium confidence). In this regard, cities are particularly vulnerable considering the high population density and building characteristics (IPCC 2023).

Two complementary strategies are being pursued to counter these changes, e.g., regarding temperature and water, caused by climate change: mitigation and adaptation. Mitigation focuses on "reduc[ing] the sources or enhance the of sinks of greenhouse gases" (IPCC 2014: 1769), while adaptation focuses on preventing and minimizing the negative effects due to climate change. The IPCC (2014: 1758) defined climate change adaptation as a "process of adjustment to actual or expected climate and its effects [...] [that] seeks to moderate or avoid harm or exploit beneficial opportunities."

Adaptation strategies can be categorized into three different areas. These include the following selected elements; see Table 2 for a detailed list (Kuttler et al. 2023, Mehra 2021, StMUV 2023):

- Building-related urban climate change adaptation measures
- Non-building-related urban climate change adaptation measures
- Climate change adaptation policy, including public outreach

2.2 Students' knowledge and conceptions of urban adaptation strategies of climate change

To enhance urban adaptive capacity, climate change education is needed to prepare young people for current and future climatic changes (Chang 2022). These people will experience the serious consequences throughout their lives, make decisions and take action even though they are not the main contributors of the current climate situation. In particular, knowledge is essential for building climate-friendly behavior and take action (Anderson 2012, Olzabal et al. 2018, Pruneau et al. 2010). To achieve learning success in this context, teachers need to know how to teach climate change knowledge to students (pedagogical content knowledge), e.g., knowledge about students' conceptions (Baumert et al. 2013, Leve et al. 2023) to take these conceptions into account when planning lessons (see the model of didactic reconstruction (Kattmann et al. 1997)). Students' conceptions "… are conceptions of their own world and mental representations of objects of knowledge that people of all ages have formed through their socialization" (Fridrich 2010: 306, translated by authors). Due to their subjectivity, they are usually inconsistent with the scientific ideas of a subject matter and are referred to as misconceptions. They can represent both a starting point for new knowledge and an obstacle to learning (Gerber & Barthmann 2023), but they are essential for achieving a conceptual change (Duit & Treagust 2003, Heller 2022), defined "as learning that requires the revision of prior knowledge and the acquisition of new concepts" (Heller 2022: 84).

Studies on content knowledge suggest that despite feeling informed and being concerned, many young people seem to have an unclear understanding about climate change, including misconceptions about its causes and consequences and the possibilities of mitigation and adaptation (Lee et al. 2020). When it comes to adaptation, Graulich et al. (2021) showed that young people do not feel well informed about adaptation strategies in general - less than one out of four participants can define climate change adaptation. Students often confuse adaptation and mitigation or concepts of environmental protection (Bofferding & Kloser 2015, Graulich et al. 2021, Schrot et al. 2019). One explanation for this confusion is students' lack of familiarity with this term, as education and communication mainly focus on mitigation (Anderson 2012, Bofferding & Kloser 2015).

With regard to climate adaptation in the city, various studies (see Graulich et al. 2021, Ratinen 2021, Ellerbrake 2022) also show that students have less knowledge in this regard and in comparison to climate mitigation and protection; they also sometimes follow scientifically incorrect conceptions. One example of this is the study by Ellerbrake (2022), in which it was shown that urban green and building greening are listed as an urban adaptation measure by students, but the purpose of use is stated as the reduction of CO_2 (= mitigation) by the students (Ellerbrake 2022).

As most of these studies predominantly use a quantitative research methodology and refer to a global perspective, there is a lack of data on (mis-)conceptions that relate specifically to urban areas. Taking into account what we know about students' conceptions of urban adaptation strategies for climate change, we defined the following research questions, which are aimed at better understanding student's conceptions and promoting conceptual change.

- What are (mis-)conceptions German secondary school students hold about urban adaptation strategies for climate change?
- To what extent do the (mis-)conceptions German secondary school students hold about urban adaptation strategies for climate change differ among their drawings and texts?
- To what extent do German secondary school students differentiate between urban adaptation and mitigation to climate change?

3 Materials and methods

3.1 Sampling

The sample (see Tab. 1) compromised secondary school students (n = 87) from four secondary schools (upper secondary education (ISCED 3)) in Hamburg, Germany. All the participants were in the 11th grade, 16–18 years old, and had selected geography as one of their subjects. The topic of urban climate adaptation strategies was mentioned in the curriculum as part of two optional modules "urban planning in the context of sustainable urban development" and "urban geo-ecosystems" (FFH BSB 2022, translated) but had not been discussed in the classroom before the data collection since the curriculum in lower secondary education (ISCED 2) covered only the basics and effects of climate change and climate action, but not in relation to the city (FFH BSB 2024). All secondary schools had the same social index, which means that the socio-economic circumstances of the students were similar. The secondary school students were made aware of the study, and their participation in the study had no impact on their success or grades in class.

3.2 Data collection

The recording of the conceptions of secondary school students was determined to be qualitative with a two-part questionnaire. The questionnaire consisted of a combination of (1) text (mostly in note form) and (2) drawing, which provided a more comprehensive insight into the students' conceptions.

Tab. 1: Overview of the sample

self-reported gender			age				participants (total)
male	female	diverse	16 years	17 years	18 years	n.s.	
48 (55%)	35 (40%)	4 (5%)	15 (17%)	69 (80%)	2 (2%)	1 (1%)	87 (100%)

First, the participants were asked about their understanding of urban adaptation strategies for climate change using an open-ended question. The short explanatory texts are appropriate for this study because they enable a more holistic view of the conceptions. Drawings are often complex and difficult to analyze in detail (Schuler 2015).

Second, the participants were asked to draw urban adaptation strategies for climate change using a pre-structured drawing. The pre-structuring included a street, two houses, a river, and a bank. The pre-structuring is intended to encourage the students to draw and to make it easier to compare the results. Drawings are particularly suitable for the study of analyzing mental models and comparing them with scientific concepts (Schuler 2015). The students were allowed to label aspects but were not explicitly instructed to do so.

The authors conducted the questionnaire during a geography lesson to ensure that the participants answered and made the drawings without any assistance or the influence of their teachers.

3.3 Data analysis

The drawings were analyzed using content-structuring content analysis (Kuckartz & Rädiker 2023). This method usually refers to texts, so the original steps were adapted with regard to the evaluation of drawings. Deductive–inductive categorization was used. The final category system consisted of four main categories and 14 sub-categories. This included a main category for climate mitigation (main category 2.0), as mitigation is often confused with adaptation (main category 1). Both categories were formed deductively. In addition, the categories emergency measures (main category 3.0) and other measures (main category 4.0) were formed inductively. The latter main category included all graphic elements or explanatory approaches that could not be assigned to the other main categories, such as the harbor, a kiosk, or sports fields. The main category of emergency measures comprised emergency measures in the event of a crisis, such as emergency warning systems, sandbags, and emergency shelters. A frequency analysis and an analysis of the content aspects were carried out. After analyzing and counting the coded elements, the students were assigned to one of the following four conception types—types 1–3 were formed deductively, and type 4 was formed inductively:

- Predominant conception of urban adaptation strategies for climate change (main category 1)
- Predominant conception of urban mitigation strategies for climate change (main category 2)
- Mixed conception of urban adaptation and mitigation strategies for climate change (main categories 1 and 2)
- Conception of emergency strategy measures in response to climate change (main category 3)

4 Results

4.1 Students' conceptions of urban adaptation strategies for climate change

In total, 734 elements were categorized across 87 drawings and texts (see Tab. 2). A total of 358 (48.8%) of the elements were assigned to main category 1 (climate change adaptation strategies), and 336 (45.8%) were classified as main category 2 (climate change mitigation strategies). Main category 3 (emergency measures) comprised 16 elements (2.2%), and main category 4 (other strategies) included 24 elements (3.3%).

Regarding climate adaptation measures, it became evident that the students primarily illustrated and mentioned non-building-related urban climate change adaptation measures (n = 228; 31.1%) (see Tab. 1). In particular, urban green spaces (n = 133; 18.1%) and flood and inundation protection for urban rivers (n = 55; 7.5%) appeared frequently (see Fig. 1). The installation of ventilation systems, heat-adaptive building designs for new constructions, and the establishment of public cooling centers did not appear. Among building-related urban climate change adaptation measures, building greening (n = 65; 8.9%) (see Fig. 2) and radiation and heat protection measures on buildings (n = 49; 6.7%) were commonly illustrated or mentioned. In contrast, policy measures, including outreach, were rarely represented (n = 11; 1.5%) (see Fig. 3).

In total, 336 climate change mitigation measures (45.8%) were illustrated or mentioned (see Tab. 2). The most frequently depicted measures were sustainable mobility (n = 132; 18.0%) (see Fig. 4) and the utilization of renewable energy (n = 108; 14.71%) (see Fig. 4). These were followed by carbon emission reduction (n = 35; 4.8%), sustainable water and waste management (n = 38; 5.2%) (see Fig. 4), and sustainable consumption (n = 23; 3.1%). In some cases, adaptation strategies, such as urban green spaces, were depicted, but they were linked to CO_2 reduction through photosynthesis rather than evapotranspiration or similar process-

Tab. 2: Overview of all results

Main category (mc)		Subcategory (sc)	Coded elements (n = 734)		
1.0 Climate change adaptation strategies	1.1 Building-related urban climate change adaptation measures	1.1.1 Radiation and heat protection measures on buildings	49 (6.7%)	119 (16.2%)	358 (48.8%)
		1.1.2 Building greening	65 (8.9%)		
		1.1.3 Installation of ventilation systems	0 (0.0%)		
		1.1.4 Heat-adaptive building design for new constructions	0 (0.0%)		
		1.1.5 Flood and inundation protection for buildings	5 (0.7%)		
		1.1.6 Establishment of public cooling centers	0 (0.0%)		
	1.2 Non-building-related urban climate change adaptation measures	1.2.1 Urban green spaces	133 (18.1%)	228 (31.1%)	
		1.2.2 Implementation of blue infrastructure and decentralized rainwater management	7 (1.0%)		
		1.2.3 Development of urban water features	8 (1.1%)		
		1.2.4 Flood and inundation protection for urban rivers	55 (7.5%)		
		1.2.5 Establishment of cold air corridors and cold air generation areas	10 (1.4%)		
		1.2.6 Reduction of impervious surfaces	8 (1.1%)		
		1.2.7 Installation of shading structures	7 (1.0%)		
		1.2.8 Installation of public water fountains	0 (0.0%)		
	1.3 Climate change adaptation policy including public outreach		11 (1.5%)	11 (1.5%)	
2.0 Climate change mitigation strategies		2.1. Carbon emission reduction	35 (4.8%)	336 (45.8%)	336 (45.8%)
		2.2 Sustainable consumption	23 (3.1%)		
		2.3 Sustainable mobility	132 (18.0%)		
		2.4 Utilization of renewable energy	108 (14.7%)		
		2.5 Sustainable water and waste management	38 (5.2%)		
3.0 Emergency measures in response to climate change					16 (2.2%)
4.0 Other strategies					24 (3.3%)

Note: Values are rounded to two decimal places; totals may therefore deviate slightly from 100 %.

es, thus categorizing them as mitigation measures (see Fig. 5).

Furthermore, emergency measures in response to climate change, such as hospitals and emergency shelters, were depicted 16 times (2.2%), while other measures appeared 24 times (3.3%) (cf. Tab. 2). No significant differences were observed regarding age, gender, or school.

4.2 Comparison of students' conceptions of urban adaptation strategies for climate change in drawings and texts

In total, 347 drawings and 387 text elements were coded, resulting in only a small difference between the two forms of representation. Within the subcategories, the differences were generally minor. A notably

Fig. 1: Drawing: Flood and inundation protection for urban rivers: Flood protection walls, water drains and elevations for houses (Participant B11)

Fig. 2: Drawing: Building with urban greening (Participant C3)

Fig. 3: Drawing: Policy measures: "commercials that educate about climate change" (Participant B3)

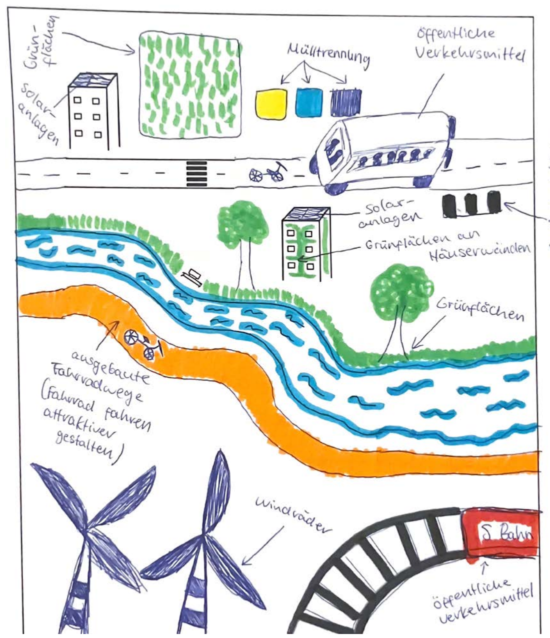

Fig. 4: Conception type B: Predominant conception of urban mitigation strategies for climate change: sustainable mobility, sustainable waste management, and utilization of renewable energy (Participant A4)

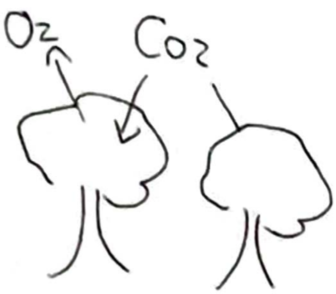

Fig. 5: Drawing: Photosynthesis through urban green (Participant D5)

Fig. 6: Drawing: Emergency measures: Emergency shelter and evacuation vehicle (Participant A16)

higher number of drawings compared to text elements was observed only in building greening (37 drawings, 28 text elements) and other strategies (17 drawings, 7 text elements). Conversely, substantially more text elements were found in the subcategories establishment of cold air corridors and cold air generation areas (2 drawings, 8 text elements), reduction of impervious surfaces (1 drawing, 7 text elements), installation of shading structures (2 drawings, 5 text elements), climate change adaptation policy including public outreach (3 drawings, 8 text elements), carbon emission reduction (8 drawings, 27 text elements), sustainable consumption (9 drawings, 14 text elements), and sustainable water and waste management (14 drawings, 24 text elements) (see Tab. 3).

4.3 Students' differentiation between urban adaptation and mitigation strategies for climate change

At 20.7%, the proportion of students with a predominant conception of urban adaptation strategies for climate change was almost as high as the proportion of students with a predominant conception of urban mitigation strategies for climate change (21.8%). Over half of the students (55.2%) had a mixed conception of urban adaptation and mitigation strategies for climate change; therefore, they were unable to distinguish between the two strategies. Only two students (2.3%) had a conception of emergency measures in response to understanding climate change.

5 Discussion

5.1 Interpretation of the findings

The purpose of this study was to get an insight into secondary school students' conceptions of urban adaptation strategies for climate change. Thus, the research is connected to existing discussions in the field of climate change adaptation (IPPC 2023, Kuttler et al. 2023), students' conceptions (Bofferding & Kloser 2015, Ellerbrake 2022, Graulich et al. 2021) and climate change education (Chang 2022). Looking back at the research questions, three key findings can be presented:

The first finding relates to the first research question, which investigated students' conceptions of urban adaptation strategies for climate change. It is noticeable that (1) green infrastructure is particularly frequently depicted, whereas blue infrastructure is primarily associated with flood and inundation protection, and (2) non-building-related measures are more frequently illustrated than building-related measures. This more frequent mention can be attributed to the fact that these aspects play a larger role in the curricula in Hamburg (FHH BSB 2022). The topic of flooding is also covered in grades 9/10 in Hamburg (FFH BSB 2024). Consequently, students have more knowledge of flood and inundation protection and non-building-related measures than building-related measures.

The absence of elements such as the installation of ventilation systems, heat-adaptive building design for new constructions, the establishment of public cooling centers, and the installation of public water fountains could be attributed to the fact that students do not directly classify these aspects as climate adaptation measures. This may indicate a simplification of climate change and the climate system. Another reason for ignoring the mentioned measures could be that they consider the impact on the micro- and mesoclimate to be low, as they have learned about climate change on a global level. Moreover, students often experience a perceived psychological distance from climate change phenomena, preventing them from linking certain aspects to their immediate environment (Keller et al. 2022, Lee et al 2020, Gubler et al. 2019, Maiella et al. 2020. Milfort 2010). The fact that only a few students depicted emergency measures could be explained by their prioritization of an immediate stop to the crisis scenario, as presented in the media, or by climate change anxiety (Höhnle et al. 2024, Whitlock 2023)

The second finding related to the methodological question, how the conceptions of students differ among their drawings a text. The results showed that there are 5.5% less drawings than texts. This concerns elements from subcategories that are more difficult to draw, e.g., climate change adaptation policy including public outreach or carbon emission reduction. Nature-based solutions, such as building greening, are easier to depict in drawings. In addition, these are elements from subcategories that were mentioned less frequently overall.

The third finding relates to the third research question, which explores to what extent students can differentiate between urban adaptation and mitigation strategies. The results (cf. Tab. 2) showed that the students in this survey predominantly referred to both climate adaptation and urban climate mitigation strategies (n = 48; 55.2%), although they were

Tab. 3: Results differentiated by drawings and texts

<table>
<tr><th colspan="2">Main category (mc)</th><th>Subcategory (sc)</th><th>Drawings (n = 347)</th><th>Texts (n = 387)</th><th>Total (n = 734)</th></tr>
<tr><td rowspan="15">1.0 Climate change adaptation strategies</td><td rowspan="6">1.1 Building-related urban climate change adaptation measures</td><td>1.1.1 Radiation and heat protection measures on buildings</td><td>24 (3.3%)</td><td>25 (3.4%)</td><td>49 (6.7%)</td></tr>
<tr><td>1.1.2 Building greening</td><td>37 (5.0%)</td><td>28 (3.8%)</td><td>65 (8.9%)</td></tr>
<tr><td>1.1.3 Installation of ventilation systems</td><td>0 (0.0%)</td><td>0 (0.0%)</td><td>0 (0.0%)</td></tr>
<tr><td>1.1.4 Heat-adaptive building design for new constructions</td><td>0 (0.0%)</td><td>0 (0.0%)</td><td>0 (0.0%)</td></tr>
<tr><td>1.1.5 Flood and inundation protection for buildings</td><td>3 (0.4%)</td><td>2 (0.3%)</td><td>5 (0.7%)</td></tr>
<tr><td>1.1.6 Establishment of public cooling centers</td><td>0 (0.0%)</td><td>0 (0.0%)</td><td>0 (0.0%)</td></tr>
<tr><td rowspan="8">1.2 Non-building-related urban climate change adaptation measures</td><td>1.2.1 Urban green spaces</td><td>67 (9.1%)</td><td>66 (9.0%)</td><td>133 (18.1%)</td></tr>
<tr><td>1.2.2 Implementation of blue infrastructure and decentralized rainwater management</td><td>4 (0.5%)</td><td>3 (0.4%)</td><td>7 (1.0%)</td></tr>
<tr><td>1.2.3 Development of urban water features</td><td>5 (0.7%)</td><td>3 (0.4%)</td><td>8 (1.1%)</td></tr>
<tr><td>1.2.4 Flood and inundation protection for urban rivers</td><td>27 (3.7%)</td><td>28 (3.8%)</td><td>55 (7.5%)</td></tr>
<tr><td>1.2.5 Establishment of cold air corridors and cold air generation areas</td><td>2 (0.3%)</td><td>8 (1.1%)</td><td>10 (1.4%)</td></tr>
<tr><td>1.2.6 Reduction of impervious surfaces</td><td>1 (0.1%)</td><td>7 (1.0%)</td><td>8 (1.1%)</td></tr>
<tr><td>1.2.7 Installation of shading structures</td><td>2 (0.3%)</td><td>5 (0.7%)</td><td>7 (1.0%)</td></tr>
<tr><td>1.2.8 Installation of public water fountains</td><td>0 (0.0%)</td><td>0 (0.0%)</td><td>0 (0.0%)</td></tr>
<tr><td>1.3 Climate change adaptation policy including public outreach</td><td></td><td>3 (0.4%)</td><td>8 (1.1%)</td><td>11 (1.5%)</td></tr>
<tr><td colspan="2" rowspan="5">2.0 Climate change mitigation strategies</td><td>2.1. Carbon emission reduction</td><td>8 (1.1%)</td><td>27 (3.7%)</td><td>35 (4.8%)</td></tr>
<tr><td>2.2 Sustainable consumption</td><td>9 (1.2%)</td><td>14 (1.9%)</td><td>23 (3.1%)</td></tr>
<tr><td>2.3 Sustainable mobility</td><td>63 (8.6%)</td><td>69 (9.4%)</td><td>132 (18.0%)</td></tr>
<tr><td>2.4 Utilization of renewable energy</td><td>54 (7.4%)</td><td>54 (7.4%)</td><td>108 (14.7%)</td></tr>
<tr><td>2.5 Sustainable water and waste management</td><td>14 (1.9%)</td><td>24 (3.3%)</td><td>38 (5.2%)</td></tr>
<tr><td colspan="2">3.0 Emergency measures in response to climate change</td><td></td><td>7 (1.0%)</td><td>9 (1.2%)</td><td>16 (2.2%)</td></tr>
<tr><td colspan="2">4.0 Other strategies</td><td></td><td>17 (2.3%)</td><td>7 (1.9%)</td><td>24 (3.3%)</td></tr>
</table>

Note: Values are rounded to two decimal places; totals may therefore deviate slightly from 100 %.

asked explicitly about urban climate adaptation measures. Prior knowledge of urban climate adaptation measures is therefore present among the students, but they have problems identifying them as such and distinguishing them from climate mitigation measures. This aligns with findings from other studies, such as the study by Graulich et al. (2021), in which students reported being less informed about climate adaptation and expressed uncertainty about its meaning and scope. Specifically, 56.4% of participants did not perceive themselves as well informed about climate change adaptation, whereas only 36.8% felt uninformed about climate change mitigation. Furthermore, a study by Bofferding & Kloser (2015) found that 13% of participants were unfamiliar with mitigation strategies, 36% were unaware of adaptation strategies, and 24% confused adaptation with mitigation. Moser (2014) identified various challenges in communicating climate change adaptation, including difficulties related to terminology and wording, the complexity of the topic, its relative novelty to the public, and the frequent misinterpretation of climate change adaptation as mitigation. These factors may provide valuable insights into the interpretation of this study's findings. A possible explanation for this result is that they are either unfamiliar with the term or have limited knowledge of it. Another possible explanation is that they are choosing mitigation measures over adaptation measures due to the perceived higher priority of mitigation when directly comparing climate change mitigation and adaptation. Ellerbrake (2022) attributed this explanation to the fact that students do not consider the inertia of the climate, making mitigation more important. This prioritization could also be influenced by media coverage, as adaptation-focused content remains limited in relation to impacts and mitigation (Oschatz 2018). Another potential reason could be that in contrast to climate change mitigation, climate change adaptation is underrepresented in curricular guidelines in Hamburg (FHH BSB 2022) and school textbooks (Ciprina & Ellerbrake 2024).

The conception of emergency measures in response to climate change, as held by two students, may be attributed to a significant emotional component of climate change in general. The topic of measures could be driven by fear, which, according to the current Shell Youth Study (2024), affects 63% of adolescents.

The described lack of understanding of urban climate adaptation, also regarding the lack of differentiation from climate mitigation, can represent a learning barrier for students. Therefore, it should be proactively considered in teaching (preparations) (see implications).

5.2 Limitations

This study has some limitations. First, this study was confined to a limited number of participants from four secondary schools (upper secondary education (ISCED 3)), and the results are necessarily indicative of the students from these schools. The fact that all students are from schools in the same city is likely to bias their exposure to climate information. Further empirical work is needed to generalize these findings. Due to the differences among federal states in Germany, the curricula are different; thus, the results cannot simply be transferred.

Second, it would have been beneficial to ask to what extent related topics had already been discussed in class and what the sources for the knowledge presented were. Media use seems particularly relevant in this context. Any political activities, political interests and self-efficacy would also be of interest to better classify the results and see them in a broader context (Hornsey et al. 2016, Hu et al. 2017, Hurst Loo & Walker 2023, Ziegler 2017).

Third, this study refers only to existence (mis-)conceptions. No explanatory patterns have yet been found for the confusion between mitigation and adaptation in the context of climate change in urban areas. To identify these explanatory patterns, further interview studies must be conducted with students.

Fourth, interviews would also be beneficial in order to avoid mixing aspects such as building greening (adaptation) and photosynthesis (mitigation). Greening that was depicted could also be part of climate mitigation even if CO_2 was not directly mentioned; in this case, the results could point to a larger share of students who confused mitigation and adaptation strategies. Furthermore, it remains unclear if students knew about the connection between sustainable waste disposal and mitigation. Thus, the measures could also point to a confusion of environmental protection (Bofferding & Kloser 2015, Graulich et al. 2021, Schrot et al. 2019).

Fifth, the study results do not provide any information on the extent to which pupils integrate the climate adaptation measures and associated behavioral patterns they are familiar with into their own living environments (e.g., in the school playground). The associated action–knowledge gap is frequently discussed in the scientific community (Colombo et al. 2023, Chang 2022, Mooney et al. 2022).

Despite its limitations, this study provides insights that have several potential implications. Our findings demonstrate that the majority of students mix climate change adaptation strategies and mitigation strategies. Climate adaptation strategies in urban areas mainly focus on non-building-related approaches, while some strategies from the field of building-related strategies and policy are not taken into account. The students focused on a greater variety of mitigation strategies, although they were asked about adaptation strategies.

5.3 Implications

In conclusion, this study offers initial results and suggestions for the development of climate change education. Students should engage more thoroughly with the topic of adaptation in school to develop a deeper understanding and scientifically accurate conceptions. Conceptions of climate change adaptation among Italian and Austrian students were effectively enhanced through climate change education (Schrot et al. 2019). Furthermore, teaching materials that counter misconceptions seem necessary to promote students' understanding and conceptions. In particular, the concrete distinctions between mitigation and adaptation appear to be useful. In German-speaking countries, corresponding teaching material has recently been published to promote an understanding of urban adaptation strategies for climate change in the classroom. The material often focuses on the local area: school, school environment, and city district (for an example, see Ciprina & Süssmann 2024). In this context, Schuler (2015) suggested that students can use drawings, such as those used in this study, to self-diagnose their ideas. This can be integrated into learning units on climate adaptation. In addition, approaches such as simulations and creative or action-oriented tasks could be implemented in schools to support a conceptual change regarding the confusion between mitigation and adaptation strategies.

Through the education of today's youth, future decision-makers will be equipped with the necessary knowledge to make informed decisions regarding climate adaptation in the face of future challenges (Anderson 2012) regardless of unresolved questions of responsibility or time perspective. Further research is needed in this area to identify explanatory patterns of students' perceptions and to plan good lessons. In the long term, this should lead to people making full use of urban adaptive capacity and protecting them from heat deaths.

6 Conclusion and outlook

Considered collectively, this study demonstrates that secondary school students possess substantial misconceptions regarding urban climate change adaptation, particularly when it comes to differentiating it from mitigation. The predominance of non-building-related strategies, such as urban green spaces, and the neglect of building-related and policy-oriented measures reveal significant conceptual deficiencies. No clear differences could be identified between the collected drawings and texts, meaning that both are suitable for collecting students' conceptions. The findings suggest that current educational frameworks and public discourses insufficiently address the complexity and specificity of climate adaptation although fostering scientifically accurate conceptions of adaptation among students is essential to strengthen societal adaptive capacity in the face of accelerating urban climate risks. To overcome these deficits, climate change education could systematically integrate the distinction between adaptation and mitigation while emphasizing context-sensitive urban examples. Future research should employ in-depth qualitative and longitudinal approaches to identify explanatory patterns of misconception formation and assess the long-term effects of targeted instructional interventions.

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