

Research article

Green infrastructure as an operational tool in climate change education: A youth-informed framework for urban adaptation learning

Sabrina Sposito^{a,*}, Anna Palla^a, Lindsey McEwen^b, Ilaria Gnecco^a^a Department of Civil, Chemical and Environmental Engineering, University of Genoa, Genoa, Italy^b School of Architecture & Environment, University of the West of England, Bristol, UK

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ABSTRACT

As Green Infrastructure (GI) and related approaches inspired by natural systems have proven capacity in risk reduction and climate adaptation, this research explores how these approaches can encourage forms of Climate Change Education (CCE) for urban adaptation learning. In the framework of the Challenging the Climate Crisis: Children's Agency to Tackle Policy Underpinned by Learning for Transformation (CCC-CATAPULT) project, empirical data were collected through focus groups and narrative work with youth, and interviews with educators. A systematic analytical process based on a staged thematic analysis was developed and tested in the Genoa case study (Italy) aimed at organising and coding data through databases to identify themes. Whole dataset of the case study was collected in the period 2022–2023. While combined analysis of focus groups and narrative work highlights perspectives of involved young people ($n = 39$ in focus groups, of which $n = 27$ in subsequent narrative work), interview analysis shows multiple points of convergence with perspectives of involved educators ($n = 8$). These perspectives, relating to climate change, climate change education, and educational transformation, informed the identification of three core areas for cooperation between GI and CCE: GI as an intergenerational participatory approach, place-based GI literacy, and youth voices in GI plans. These areas are intended as a contribution to operationalise emergent demands and needs in the practice of CCE as captured through this empirical work. Results open avenues to further investigation on the role of GI–CCE cooperation mechanisms in promoting urban adaptation learning to support youth adaptive capacity.

1. Introduction

Complex linkages between cities and climate change pose significant challenges to society. Thus, there has been increased concern for the impacts of an altered climate, including the associated effects of urbanisation, in terms of pressures on ecosystems, biodiversity, and urban populations (Kabisch et al., 2016). There have been accompanying explorations into ways to reframe urban development across different scales of risk and adaptation (Carter, 2011). This has included novel or expanded research and praxis moving towards more integrated approaches to addressing built and natural areas as a means of pursuing ecological quality in cities whilst favouring multiple co-benefits. Green Infrastructure (GI) is a widely established approach (Fletcher et al., 2014). As Mell (2022) illustrates its conceptual development has encompassed an initial emphasis on types of green spaces and water resources that can variously network to form GI, followed by a greater

discussion around the functions they can perform, and the potential benefits yielded. As this discussion has centred primarily on the biophysical benefits of GI (McNabb et al., 2024), current research indicates the need to further investigate a spectrum of socio-cultural co-benefits (Whitten, 2023), including devoting increased attention to educational aspects (Cole et al., 2017). The present study contributes to this research area through promoting education on climate change using GI learning.

1.1. Green infrastructure as evolving concept

A defining aspect of GI is the traditional connection with spatial planning (Pauleit et al., 2017), yet with increased applications in stormwater and flooding management (Ashley et al., 2020; Fletcher et al., 2014). This evolutionary character finds evidence in the spreading of diverse interpretations of the concept, which coexist with different related concepts (Matsler et al., 2021; Ruanganpan et al., 2020) that

* Corresponding author.

E-mail addresses: sposito.sabrina86@gmail.com (S. Sposito), anna.palla@unige.it (A. Palla), lindsey.mcewen@uwe.ac.uk (L. McEwen), ilaria.gnecco@unige.it (I. Gnecco).<https://doi.org/10.1016/j.jenvman.2026.129069>

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exhibit degrees of overlay and complementarity with it (Haase, 2021). The most recent similar concepts include Nature-Based Solutions (NBS), whose emergence from the field of policy has been accompanied by studies to define its potential for use in relation to the diverse approaches that support it (Dorst et al., 2019).

NBS and GI are usually documented as frameworks that similarly stimulate multifunctionality, strengthening ecosystem services supply (Pauleit et al., 2017). In incorporating ecological and socio-economic functions (Mell, 2022), they require the contextual embedding of interventions as part of an implementation process that depends on collaborative governance, inclusiveness, and effective alliances of varied disciplines (Dorst et al., 2019; Maurer et al., 2023). Further to identifying commonalities, research and development posit that NBS is an *umbrella* term wherein various principles from related concepts are subsumed, while referring more directly to actionable options in response to specific societal challenges (Nesshöver et al., 2017). Given the difference of their originating fields, NBS and GI are often considered mutually beneficial to serve the complex aims of urban sustainability (Haase, 2021). GI provides NBS with an infrastructure focus and a strategic design of urban nature to build our interconnected “natural life-support system” (Benedict and McMahon, 2006, p. 1). On the other hand, NBS research offers GI an expanded scope for experimentation (European Commission [EC], 2021).

1.2. Green infrastructure and climate change education for mitigation and adaptation

Global and European policies increasingly recognise the contribution of NBS, GI, and related concepts to a variety of objectives, including developing climate change adaptation and mitigation and improving disaster risk management (EC, 2015, 2019; European Environment Agency [EEA], 2021; Organisation for Economic Co-operation and Development [OECD], 2025). Drawing on existing empirical evidence, Demuzere et al. (2014) examine the critical services and benefits contributing to climate change adaptation and mitigation provided by urban GI. Their analysis indicates that, in addition to a range of key biophysical benefits such as a decrease in carbon dioxide, urban GI produces profound social benefits. These mostly pertain to the capacity of GI to provide places that promote health, education, and deployment of individual and social resources such as community-based relations in favour of adaptive strategies and resilience to extreme weather and climate change.

Cole et al. (2017), indeed, suggest a model of “urban environmental education *in, about, and for* green infrastructure”, which recognises the educational value of GI components and their socio-ecological functioning in cities (p. 262). This model shows the manifold education opportunities unlocked by urban GI: place-based learning which engenders interactions with local urban nature; system-wide, multidisciplinary, and relational understanding of services and benefits flowing from GI to urban residents, including those contributing to urban adaptation and mitigation; and roles for education in promoting public involvement in GI which may in turn inspire citizens to endorse or design new ones (Cole et al., 2017). However, there remains limited research that works to integrate urban GI and current education strategies associated with climate change. In particular, little has been discussed of how GI and related approaches sit within a context of a growing debate on Climate Change Education (CCE) as a critical element in providing learning needed to cultivate adaptive capacity alongside behaviour, lifestyle, and social norms change for mitigation (Anderson, 2012). In this respect, Stevenson et al. (2017) advocate adaptation and mitigation be approached as “socially transformative” (p.70), and that education for adaptation and risk management be developed as “an iterative process, where students develop the capacity for anticipatory and participatory learning and learn by doing” (p. 69). Likewise, an area still requiring targeted research is how GI and related approaches can help operationalise adaptation education, beyond experiments of

greening school estates (e.g., Baró et al., 2022), given the insufficient mechanisms in the different types of education to support adaptation learning (Feinstein and Mach, 2020) in a time when youth demands an improvement in modes of CCE provision (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2022).

1.3. Study objectives and outline

Against this background, this paper aims to determine climate adaptation learning opportunities through examining the role of GI as a contributing factor to transformative CCE. This is realised through empirical research involving youth and educators that is driven by the following specific objectives:

- (1) Develop a systematic analytical process for detailed exploration, comparison, and synthesis of perspectives held by youth and educators on diverse aspects of climate change and CCE.
- (2) Investigate potentials of GI to facilitate—or help develop—adaptation education responsive to emergent demands and needs in the learning and teaching practices associated with CCE.

Pursuing these objectives, the paper explores the status and the desirable scenarios of CCE in the view of study participants to assess the possibility of pedagogic strategies working synergistically with GI to enact urban adaptation learning. This study forms part of wider research undertaken by a transnational consortium in the framework of Challenging the Climate Crisis: Children's Agency to Tackle Policy Underpinned by Learning for Transformation (CCC-CATAPULT) project, with case studies in Bristol (UK), Galway (Ireland), Genoa (Italy), and Tampere (Finland).

The next section (Section 2) describes the overarching research framework where this study originates, showing the multi-method and multi-city-region approach to data collection that drives interlinking comparative and specific analysis respectively at cross-city and in-city levels. The procedure designed for the in-city specific analysis is then detailed, articulating the stages and the novelty features that define it (Section 3). The application in Genoa (Italy) as a research case study is subsequently elucidated through an overview of the local empirical dataset (Section 4), a record of each analytical step taken, (Section 5), and a comprehensive summary of results (Section 6). In particular, Section 6 presents the main points of interest, relevance, critique, or concern around climate change and its associated education as expressed by recruited participants, distilling those elements that an adaptation lens could positively influence particularly when embraced operationally. By identifying GI–CCE mechanisms, these elements are situated, interpreted, and discussed within a broader question of integration between urban environmental and education system domains in the context of climate change adaptation and mitigation. The paper concludes with charting pathways for future developments in these interrelated research, policy, and practice domains that need to be explored to promote GI as an operational tool in CCE (Section 7).

2. Overarching research framework

This section illustrates the overarching research framework of the empirical phase undertaken within the CCC-CATAPULT project. Fig. 1 schematises the flow chart of this framework, beginning with the research design (a) where the method and the corresponding target (i.e. young people, YP; educator, ED; or, policymakers and stakeholders, P) are defined by means of protocols, followed by the case study development per city-region (b) including participant engagement, data collection, and data formalisation. The final process focuses on data analysis performed at the cross-city level (c1) and in-city level (c2), with the latter (c2) corresponding to the analytical process adopted in this research study.

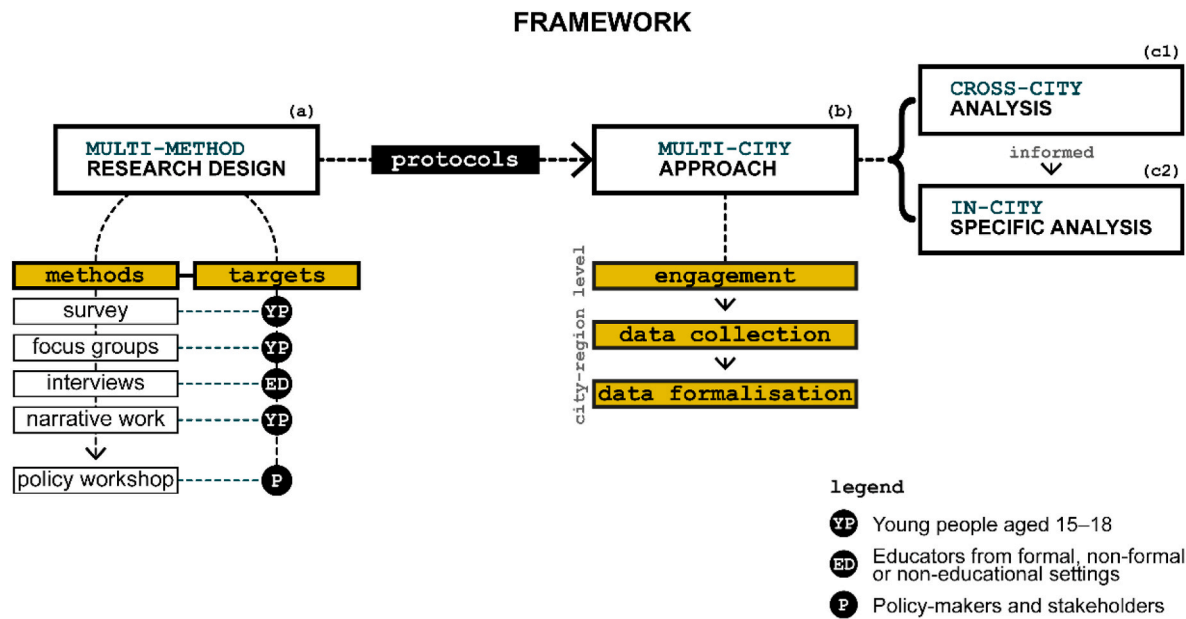


Fig. 1. Flow chart of the overarching research framework showing the process from method identification (a) to case study development (b) following protocols and guidelines, to data analysis (c1, c2) at interlinked levels.

2.1. Multi-method research design (a)

Table 1 shows the research methods adopted across the overall CCC-CATAPULT project and for each selected method or empirical activity, a description in terms of objective and main topics, along with core features and general organising principles is provided. Protocols are defined with respect to each method in order to guarantee the consistency of data collected at the in-city level and to compare the empirical datasets in the cross-city analysis. These protocols include the principles and the guidelines for running each empirical activity: the minimum and

maximum number of participants, the recruitment criteria as well as the detailed layout of the activity including the timing and the supporting materials. Furthermore, protocols comprise analysis forms (templates) designed to capture different typologies of qualitative data generated in the different activities.

2.2. Multi-city-region approach (b)

Starting from the overall project guidance outlined in Table 1, the specific protocols concerning the engagement, data collection and data

Table 1
Empirical research methods with corresponding objective and main topics, core features, and organising principles.

Research Method ^a	Objective and main topics	Core features	General organising principles
Survey (YP)	Investigation of youth perspectives, experiences, beliefs, norms, values, and actions in relation to climate change along with a broader spectrum of socio-environmental issues.	Online, implemented in Qualtrics software, administrated through a QR-code; collected data are fed into a single database for all in-city cases and subsequently processed for descriptive and advanced statistical analysis (see, Rissanen et al., 2024).	Minimum of 400 young people involving different school typologies according to the characteristics of the education system in the city-region.
Focus groups (YP)	Discussion of themes concerning the spheres of trust, intergenerational influence and learning, climate values and actions, experiences of, and desired transformation in climate change education (see, Reilly et al., 2024).	Semi-structured discussions based on a set of questions. Emerging survey findings form a basis for identifying focus group thematic areas for examination in further depth.	Minimum of five focus groups, involving six to eight young people in each.
Interviews (ED)	Examination of educator teaching and professional experiences related to climate change themes and topics, including perspectives on education practices and educational transformation.	As for the focus group method, semi-structured discussions based on a set of questions. Emerging survey findings form a basis for identifying interview thematic areas for examination in further depth.	Minimum of eight interviewees with four schoolteachers representing a diversity of subject areas and four other supporters of learning (e.g., non-profit environmental organisation leaders).
Narrative work (YP)	Exploration of youth connectedness to “significant places” (Phase I) and “learning places” (Phase II) and how this can contribute to modelling transformative spaces and places for climate-focused education.	Storytelling approach based on a two-phase process, with a participatory ethos. It combines different tools such as drawing and deep mapping in a sequence of activities: a preliminary discussion; individual drawings; provision of adaptive suggestions (seeding) and last drawing and storyboarding.	Minimum of two narrative workshops for each phase, involving ideally six to ten people in a group.
Policy workshop (P)	Engagement of stakeholders and policymakers to feedback research findings, produce a collective vision for transformative climate and worldview education in the city-region, and explore opportunities to support its development.	Facilitated discussion based on main findings from the project. Flexible format adjusted according to the specific needs and interests of the city-regions.	One workshop per city-region. Minimum number of participants not required. Involvement of sectors relevant to address the themes in focus.

^a Target participant is shown in parentheses. Abbreviations: young people, YP; educator, ED; policymaker or other stakeholder, P.

formalisations phases are defined at the local city-scale thus accounting and enhancing the specificities of the city context. In addition, the informed consent and ethical guidelines are compiled and addressed for each city-region complying with both the European and national regulation in force. Young people are recruited primarily, although not exclusively, through schools according to the profiles of national education systems; while educators, stakeholders, and policymakers are recruited based on a list of subjects/organisations/authorities depending on context and potential to be involved. As with participant engagement, data collection and data formalisation are locally organised and managed, with the corresponding analysis forms compiled by each project partner on activity completion.

2.3. Multidimensional analysis (c)

The cross-city analysis aims to identify common patterns and significant divergences between project locations in order to deploy common strategies and or to improving and supporting CCE at an international level. On the other hand, the in-city analysis aims to examine local data in depth, through more specific research questions of particular interest in the local context thus improving the understanding of the involved processes and developing specific actions. The interrelationship between these two dimensions of investigation is mainly from the cross-city to the in-city analysis according to the informed/common protocols even if other forms of inter-relationship are not inhibited. It is important to note that this multi-dimensional analysis is underpinned by collaborative efforts between project partners who first collated interpretations derived from data formalisation and subsequently produced internal common reporting and public executive summaries. These documents form a shared basis of understanding which benefits from the use of different disciplinary lenses and serves as a reference for consistent elaboration on emerging questions of interest both across cases and in a single case study. Direct involvement or consultation of researchers who collated and formalised data is ensured across analysis performed.

2.4. Principles of co-production

All the empirical research activities are premised on principles of co-

production with young people, as previously reported in [Portus et al. \(2024\)](#). Co-production is realised through Youth Action Partnerships (YAPs) consisting of groups of young people invited, as co-researchers being provided with research skills training, to discuss the methodological development and to actively engage with the interpreting the research outputs. Decisions about, for example, which topics to include in focus group and interview guides, interpretations of data to further clarify, or findings to prioritise in communications with policymakers and stakeholders derive from reflections developed in association with YAPs.

3. In-city specific analysis: materials and methods

3.1. Workflow and structure

This section concerns the establishment of an appropriate analytical framework to organise, scrutinise, and relate data deriving from the multi-method research through thematic analysis ([Braun and Clarke, 2006, 2023](#)). [Fig. 2](#) shows the staged procedure for understanding the perspectives of young participants through combined analysis of focus groups and narrative work and bringing these perspectives together with those of educators involved in CCE through parallel interview analysis.

This framework stems from the objectives of systematically progressing data coding ([Saldaña, 2013](#)), articulating themes in a way that documents the interpretative process, and developing a set of analytic outputs (i.e., databases, categorisations, and narratives) that aims as a whole to deliver intelligibility, interoperability, and further exploitation across varied disciplinary fields for cross-cutting research.

3.2. Stages in the process

The analytical framework is structured around three sequential stages. The first stage (stage 1) is defined as the organisation of the empirical dataset through database building. Data gathered by focus groups with young participants and those collated by educator interviews provide distinct databases yet following shared criteria of arrangement. Answers gained are registered in order of appearance, represented with a quote, and summarised through key points contained. Each answer is thus associated with the (anonymised)

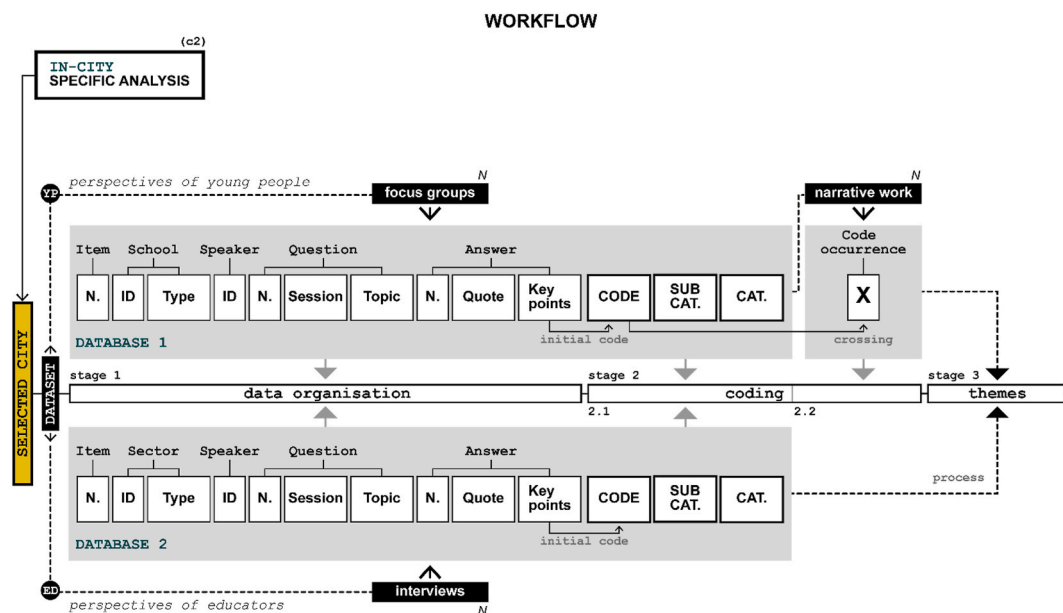


Fig. 2. Details of the workflow designed for the in-city specific analysis (c2). Data collected through focus groups, narrative work, and interviews are organised and coded through databases (stages 1 to 2) to identify themes (stage 3). Note: ID = participant identifier to ensure anonymity; N = number; Cat = category; and Sub-cat = sub-category.

respondent who formulated it; the itemised focus group/interview within which it was produced; the typified school/sector of the respondent; and the question answered, including its overarching thematic session and the topic inquired. This is to ensure that in the subsequent stage (stage 2), coding of answers and refinements can account the question posed and the discussions surrounding it. Each answer is then coded, and eventually categorised, to form a code system (stage 2.1). Coding within focus groups undergoes a further sub-stage (stage 2.2) to determine whether and which identified codes can be applied to data deriving from the narrative work when exploring similar topics with same or other participants. This additional process is aimed at triangulating evidence from multiple methods (Patton, 1999; Turner et al., 2017) and supplementing thematic analysis with longitudinal insights. The last stage (stage 3) encompasses the identification of themes (Ryan and Bernard, 2003) representing and describing the perspectives of young people or educators involved, and areas of synergies between them.

The procedure is tested on the Genoa case study, as illustrated in the following sections.

4. Genoa case study: case design and research implementation

4.1. Collected dataset

The case study is developed in Genoa, which is a Mediterranean city located in Liguria Region (northwestern Italy). Further details are reported in Section 1.1 of the Supplementary materials. Primary data that contributed to the overarching research process (illustrated in Section 2.1) were collected from February 2022 to November 2023. Table 2 provides a summary of the gathered dataset, including per method: a count of study participants, schools involved (where relevant), and meetings per participant with average length; a reference to the time-scale of data collection; finally, an indication of those dataset segments that are instrumental in framing the in-city analytic process, as defined by this study (Section 3).

4.2. Operationalisation of research methods

Participant recruitment within the 15–18 age group was realised locally through establishing connections with multiple schools from the State-run five-year upper secondary education. The sample design ensured that participating schools represented both the general and the vocational pathways, a range of school types within general and technical areas, and diversity of urban and socio-economic contexts within the metropolitan area. Furthermore, the operational method of engagement was based on the specific subsets of schools (and student groups) involved across the different research methods (see also Table S2 in the Supplementary materials).

Participants engaged in the narrative work ($n = 27$) were selected from the focus group participants ($n = 39$), who were initially involved as survey respondents ($n = 408$). The first activity was conducted in schools ($n = 8$) that agreed to distribute the survey. The two latter

activities, held in lecture rooms of the University of Genoa, were administered through traineeship agreements (Paths for transversal skills and guidance–PCTO) with schools and teachers interested in pursuing involvement in the project and where integration of didactic and research needs, with their respective timetables, was feasible. Contrary to the survey, these activities were performed in the sole presence of local researchers, including one acting as facilitator and another as observer and note taker. In relation to schools ($n = 3$) that advanced in the process five focus groups were formed, each with seven to eight participants attending the same class or school. Four of the groups proceeded to the narrative research stage, representing schools ($n = 2$) of diverse types. Part-way through this process, attention was given to seeding ideas for climate adaptation that embedded the use of GI, drawing on illustrative cases of implementation both in the Italian context and globally. Furthermore, projected climate change scenarios in the Mediterranean region and across the western and eastern sections of the Ligurian territory were highlighted.

Interviewees, recruited from practitioners in formal education, consisted of selected schoolteachers ($n = 4$) previously active in one or more of the empirical stages and invited directly due to their diverse relationships with aspects of CCE. They taught in distinct schools and school types and represented both the subject areas of humanities (including German language and culture, English language and culture) and science-technology (including applied math, and science). Furthermore, a second group, facilitators of learning ($n = 4$) were engaged and interviewed from organisations, movements, and associations encompassing the critical fields of environmental education, educational assistance, youth-led climate activism, and student-led promotion of sustainable behaviours, all specifically targeted at youth groups across regional or local scales.

As a final stage, a policy workshop was conducted to debate the emergent research findings from earlier stages with relevant sectors. Participants ($n = 14$) included members from formal and non-formal education systems, local government, research institutions, cultural organisations, and youth associations active in the city and the wider region to stimulate learning for environment and sustainability. Their input was deemed significant to steer for a territorial vision of CCE, also fostered by adaptation learning around GI. Further details related to the operationalisation of research methods are provided in Sections 1.2 and 1.3 of the Supplementary Materials.

4.3. Co-production

In the Genoa case study, co-production with young people was achieved through a phased process. In the early to narrative stages of the research, a participatory approach ensured representatives of youth tested, evaluated, and advised elements in the methods prior to delivery. This involvement was task-oriented, temporary, and prioritised the multiplicity of opinions from diverse individuals or small groups. A YAP group of nine contributors was formed following these stages, and thus their observations were integrated in the research process from interpretation of core findings to facilitation of policy action planning and

Table 2

Collected dataset for Genoa case study in the multi-city-region approach as related to the multi-method research design and further processing for the in-city specific analysis.

Multi-method Research (a)	Multi-city-region Approach (b): Genoa Case Study					In-city Specific Analysis (c2)
	Study Participants ^a [n]	Schools Involved [n]	Meetings per Participant [n]	Meetings Avg. Length [min]	Data Collection Timescale	Parts of Dataset Processed
Survey	408	8	2	60	Feb–April 2022	
Focus groups	39 (5)	3	1	90	May 2022	•
Interviews	8	–	1	40	May–Oct 2022	•
Narrative work	27 (4)	2	2	120	June–Nov 2022	•
Policy workshop	14	–	1	180	Nov 2023	

^a Groups involved in the study are shown in parentheses.

knowledge exchange. This involvement was process-oriented, systematic, and prioritised continuity of engagement. These two modes of involvement reflected contextual factors of youth recruitment to the role of co-producers: in this instance, this was made effective through of intensified longitudinal cooperation with schools.

5. Genoa in-city specific analysis: case application

In implementing the in-city specific analysis within the Genoa case study, it is essential to further elaborate on research data that were originated, collated, and scrutinised in the context of primary data collection and formalisation (see Section 2.1). This includes verbatim transcripts, notes, and detailed analysis forms. The approach employed is to perform multiple iterations of coding to determine the appropriate

FOCUS GROUP CODE SYSTEM									
A GENERATIONAL ASPECTS	COUNT CODE PART.				D YOUTH ACTION	COUNT CODE PART.			
	A1 Perceived intergenerational differences					D1 Experiences of environmental/climate action			
	1	Younger generations perceived as having greater knowledge of climate change than predecessors	18	13		34	Individual climate-friendly actions	13	12
	2	Younger generations perceived as having greater climate concern than predecessors	18	13*		34.1	reducing, reusing, recycling		
B SOCIETY AND CLIMATE CHANGE	3	Perceived pressure on younger generations for a resolution of the climate crisis	5	4	34.2	water/energy saving			
	A2 Intergenerational influence				34.3	choice of public transport options			
	4	Feeling of confidence in talking with adults about climate change issues	2	2	35	Participation in clean-up activities through formal or informal education	8	6*	
	5	Experienced or perceived challenges in informing older generations on the theme of climate change	23	15*	36	Participation in a climate strike (FridaysForFuture)	5	3*	
	5.1	lack of in-depth knowledge			D2 Attitude towards youth climate movements				
	5.2	lack of discussion, listening or influence			37	Perceived importance of youth climate movements	12	11	
	6	Feeling a role in informing the youngest	5	5	38	Perceived obstacles affecting participation	21	11*	
	A3 Generations and trust to tackle climate change				38.1	lack of influence on governments			
	7	Distrust in older generations	12	9	38.2	unsupportive peers or school			
	8	Trust in young people or future generations	5	4*	D3 Factors perceived to influence youth action				
C POLITICAL ISSUES	COUNT CODE PART.				39	Feeling limited in action as a result of young age	12	8	
	B1 Perceived needs in the individual dimension				40	Climate change seen as a distant phenomenon	6	5*	
	9	Change in mindset, behaviours, lifestyles	9	7	41	Need for increased climate activities (including by the school), resources, or guidance for action	37	15*	
	10	Small-scale actions	12	10	42	Need for dialogue, listening, promotion of youth ideas and potential in coping with climate change	15	12*	
	11	Personal willingness to act	4	4	COUNT CODE PART.				
	B2 Perceived needs in the collective dimension				E1 Experiences of formal CCE	43	Climate change topics in primary school	13	12
	12	Action and effort from every member of society to achieve large-scale change	9	7	44	Climate change topics in lower secondary school	25	21*	
	13	Cooperation, dialogue, knowledge exchange	20	15*	45	Climate change topics in upper secondary school	21	18*	
	13.1	intergenerational/social cohesion			46	Climate change in humanities disciplines	15	12	
	13.2	cross-national cooperation for mutual learning			47	Climate change in science-technology disciplines	11	9	
	14	Collective/global awareness	19	11*	48	Climate change in Civic Education	6	5	
	15	People involvement in environmental actions	5	4	49	Perceived importance of teachers' sensitivity to climate change issues	8	6*	
	B3 Perceived needs across sectors/systems				50	Perceived lack, discontinuity, or unexploited opportunities of teaching time for CCE	10	7	
	16	Environmental protection	8	8	51	Perceived lack of discussion/in-depth exploration	30	16*	
	17	Sustainable productions	4	4	52	Perceived predominance of traditional lecture and assessment methods	18	13	
	18	Sustainable mobility	12	8	E2 Experiences of informal CCE				
	19	Increase in renewable energy/water technology	5	5	53	Information from social media or the Internet	5	4*	
	20	Waste management and circular economy	7	7	54	Engagement in discussion with adults or family	5	3	
	21	Climate change communication/education	12	9	55	Learning opportunities during sports activities	2	2	
	B4 Perceived barriers to change				56	Learning opportunities through climate activists or environmental groups	2	2	
	22	Perceived high cost of sustainable alternatives	5	4	E3 Confidence in knowledge of climate change				
	23	Perceived infrastructural barriers	6	6	57	High confidence in own knowledge	1	1	
	B5 Society and trust to tackle climate change				58	Enough confidence in own knowledge	5	5	
	24	Distrust in multinational corporations	1	1	59	Low confidence in own knowledge	6	4*	
	25	Trust in scientists, research and innovation	6	5	E4 Desired changes in approaches to CCE				
	26	Trust in social potential for change	7	7	60	School as a driver	37	21*	
	27	Trust in the Pope	1	1	61	CCE to start at an early age	14	9	
COUNT CODE PART.				62	Curriculum changes to provide space for CCE	15	11*		
C1 Perception of government role and action				63	Potential involvement of a diversity of disciplines	25	14*		
28	Critical role of government and those in position of power in solving the climate crisis	7	6*	63.1	humanities disciplines				
29	Need for government to enable good practices	11	7*	63.2	science-technology disciplines				
29.1	supportive regulatory and financial framework			64	Teacher/Educator support to CCE	19	10*		
29.2	economic incentives for climate-friendly options			E5 Desired changes in methods of CCE					
29.3	support for a sustainable transition globally			65	Solution-oriented communication and learning	25	12*		
30	Political inaction and unwillingness for change	10	6	66	Thematic lessons, discussions, or critical analysis	20	15		
31	Old political class	1	1	67	Engagement through projects and activities	25	16*		
C2 Government and trust to tackle climate change				68	Direct observation/experiential learning	7	4		
32	Distrust in governments	10	7*	69	Learning outdoor or outside the school building	9	7		
33	Trust in governments under certain conditions	2	2	70	Teamwork, competitiveness, play	20	13*		
33.1	commitment to combat climate change			71	Involvement of family/friends	8	6*		
33.2	openness to youth and expert advice			72	Guest experts in the classroom	7	6		
				73	Digital tools	2	1		

characterisation and level of granularity of codes. This approach aims at identifying connotations and complexities of themes through a hybrid qualitative-quantitative data analysis. Results of this process are illustrated below, focusing on the code system development that led to themes uncovering nuanced youth perspectives. More details are available in Section 2 of the Supplementary materials.

5.1. Database implementation and coding process

The initial stage consists of organising data associated with focus groups and interviews manually into Excel to construct databases. These are compiled in the English language, with translations of data sources

produced when not previously performed. A sequential number is given to each focus group and each interview, with school type or sector recorded correspondingly. Young participants and interviewees are given progressive identifiers (YP1–YP39; ED1–ED8) to ensure anonymity. Questions posed and answers obtained per participant are extracted rigorously from transcripts, ensuring that digressions and unintelligible fragments of discussions are excluded from databases. Subsequently, extensive direct quotations are excerpted from the included answers and assigned key points, with each point summarising the interpretation of a distinct concept expressed. The key points were primarily identified when compiling the analysis forms. Accuracy and completeness of data analysis is ensured by keeping track of participant

FOCUS GROUP TOP CODES

CODE SYSTEM			CODE COUNT						PART. COUNT
CAT.	SUB CAT.	CODE	TOTAL	count by FG					TOTAL
				FG1	FG2	FG3	FG4	FG5	
E	E4	60	37	4	7	14	5	7	21*
D	D3	41	37	0	6	23	3	5	15*
E	E1	51	30	0	15	9	6	0	16*
E	E1	44	25	9	5	1	4	6	21*
E	E5	67	25	1	8	9	0	7	16*
E	E4	63	25	3	6	7	5	4	14*
E	E5	65	25	2	4	17	0	2	12*
A	A2	5	23	2	7	6	6	2	15*
E	E1	45	21	0	8	2	7	4	18*
D	D2	38	21	1	0	16	4	0	11*
B	B2	13	20	3	6	4	3	4	15*
E	E5	66	20	3	4	3	6	4	15
E	E5	70	20	3	6	9	0	2	13*
B	B2	14	19	2	1	12	4	0	11*
E	E4	64	19	1	1	1	12	4	10*
A	A2	2	18	1	8	1	5	3	13*
A	A1	1	18	0	3	5	9	1	13
E	E1	52	18	0	5	3	5	5	13
D	D3	42	15	5	6	0	1	3	12*
E	E1	46	15	6	1	2	2	4	12
E	E4	62	15	1	2	3	5	4	11*
E	E4	61	14	3	6	0	1	4	9
D	D1	34	13	0	6	0	0	7	12
E	E1	43	13	0	4	4	3	2	12
D	D2	37	12	2	2	7	1	0	11
B	B1	10	12	5	1	1	4	1	10
A	A1	7	12	0	3	5	3	1	9
B	B3	18	12	0	1	9	2	0	8
D	D3	39	12	5	0	2	5	0	8
C	C1	29	11	5	0	2	3	1	7*
C	C1	30	11	4	0	4	2	0	7*
C	C1	32	10	2	0	3	5	0	7*
E	E1	50	10	0	0	4	5	1	7*

Fig. 4. Focus Group Top Codes (FGTC) consist of codes with a count higher than or equal to 10. Listed codes are reported in association with code system, code count (total and broken down by focus group), and participant count. For category, sub-category, and code descriptions, see Fig. 3. Note: * is displayed where other participants voiced a collective agreement (not quantifiable). Abbreviations: Cat = category and Sub-cat = sub-category.

agreements and facilitator usage of prompts to encourage dialogue. These annotations become metrics functional in contextualising results of discussion against its varied dynamics.

A subsequent database implementation occurs at code development. At this stage, answers are assigned one or more initial codes through open coding (Bingham, 2023), with the exception of a limited number of answers assessed as unrelated to the research questions. Initial coding is performed extensively to maximise the record of nuanced meanings across data. Code assignment occurs in parallel with determining code distribution and categorisation, with this process reiterated and refined gradually until a code system is reached that showed internal coherence (e.g., uniform degree of detail), intelligibility, and exhaustiveness. All researchers involved in data collection and interpretations in the case study reviewed the developed code system and agreed on the final version presented here.

5.2. Code system and themes unveiling youth perspectives

Fig. 3 shows the Focus Group Code System (FGCS) resulting from thematic analysis of focus groups answers ($n = 561$), which structures 73 codes into five categories (A-E) and 16 sub-categories (A1-E5). Sub-codes are eventually evidenced in the system where they provide a link with other categories. Fig. 4 lists in descending order the Focus Group Top Codes (FGTC) with a code count higher than or equal to 10.

In the FGCS, next to each code is the total amount of assignments that occurred in the answers, supplemented by the total amount of distinct individuals associated with it, in order to observe whether a high code count reflects the opinion of numerous participants or the reiteration of the opinion by a smaller group. It must be noted that the instance of multiple individuals that agreed synchronously with a respondent statement or a moderator recapitulation and whose number cannot be determined is made equal to 1 in the code count. However, an asterisk is reported next to the participant count to highlight this collective agreement. Categories and sub-categories are originated inductively as they ascribe codes to overarching domains identified across the dataset, as follows:

- **Category A – Generational aspects** encompasses codes addressing how generations relate to climate change issues as reflected in perceived differences (A1), capacity of influencing each other (A2), and feelings of trust in generational groups (A3).
- **Category B – Society and Climate Change** includes codes addressing how societies are implicated in climate change as reflected in changes and actions required of individuals (B1) community (B2), and systems (B3), barriers to achieving change (B4), and feelings of trust in entities of society (B5).
- **Category C – Political Issues** collects codes associated with political aspects of climate change as reflected in the role required of governments, politics, and institutions to solve the climate crisis (C1), and feelings of trust in their commitment (C2).
- **Category D – Youth Action** contains codes with reference to youth participation in climate actions as reflected in subjective experiences of involvement (D1), attitude towards youth movements (D2), and perceived influencing factors of action taking (D3).
- **Category E – Climate Change Education** features codes pointing to practices of CCE as reflected in learning experiences through formal (E1), non-formal and informal education (E2), confidence of knowledge acquired through (E3), and desired changes of approaches (E4) and methods (E5).

As the last stage, codes of the FGCS are identified within the narrative work dataset through examining its transcripts, drawings, and feedback forms to detect whether and which of these codes re-occurred. Table 3 shows the outcome of this procedure, analysed in the context of theme identification.

Themes are identified based on interpretation of codes falling within

Table 3

List of focus groups codes which re-occurred in the narrative work (stage 2.2).

Category	Sub-category	Codes
B	B3	16, 18, 19, 20
E	E2	53, 55, 56
	E4	60, 62, 64
	E5	65, 66, 67, 68, 69, 70, 71, 72, 73

categories and sub-categories, considering dominance, variety, uniqueness, and interconnectedness of opinions they reflected. In doing so, two themes and related sub-themes are distilled during the analytical process:

- **Theme 1 – How climate change is perceived to affect generations and challenge the role of society and governments:**

- Generational differences in understanding climate change.
- Complexity of building an intergenerational climate dialogue.
- Collaborating and reconciling divides to achieve a multidimensional change in society.
- Mismatch between government role and political will for climate action.
- Decoupling of power and trust to tackle climate change.

- **Theme 2 – Support required of society and transformation of education practices for climate agency:**

- Empowering youth to unlock climate agency.
- School institutions as catalysts and drivers in climate change education.
- Transformation of education practices for novel forms of climate change learning.

6. Genoa in-city cooperation areas: results and discussion

Youth perceptions of climate change and their views on climate agency and educational transformation (Themes 1 and 2), including the main points of convergence with educator views, assume particular significance in defining cooperation areas between GI and CCE for urban adaptation learning. The new research-informed framework described in Fig. 5 is designed to assist urban environmental (in conjunction with urban climate) and education research, policy, and practice in understanding how common ground can be established through GI, for transformative CCE pathways to thrive. Being underpinned by a sophisticated system of codes, categories, and themes, this framework offers a way to operationalise youth perspectives by conceiving GI–CCE mechanisms that maximise expected or desired potentials in climate learning and teaching while also facing perceived obstacles in current practices. Next, Theme 1, Theme 2, and points of convergence are described sequentially, with an explanation of how they intersect to inform development of cooperative GI–CCE areas following thereafter.

6.1. Theme 1: How climate change is perceived to affect generations and challenge the role of society and governments

6.1.1. Generational differences in understanding climate change

Youth who participated in the research study (hereafter young participants) observe a schism between younger and older generations in the way they understand climate change. This schism relates to perceived differences in levels of subject knowledge (code 1) and feelings of concern (code 2) and pressure (code 3) of living and projecting to live in an epoch of climate crisis. Being youth at distinct periods of contemporary society is regarded as a factor shaping such divergences. The younger generations are indeed assumed to have greater knowledge of climate change than their predecessors as a result of increased resonance, documentation, and discussion of the phenomenon, with

GI AS OPERATIONAL TOOL IN CCE

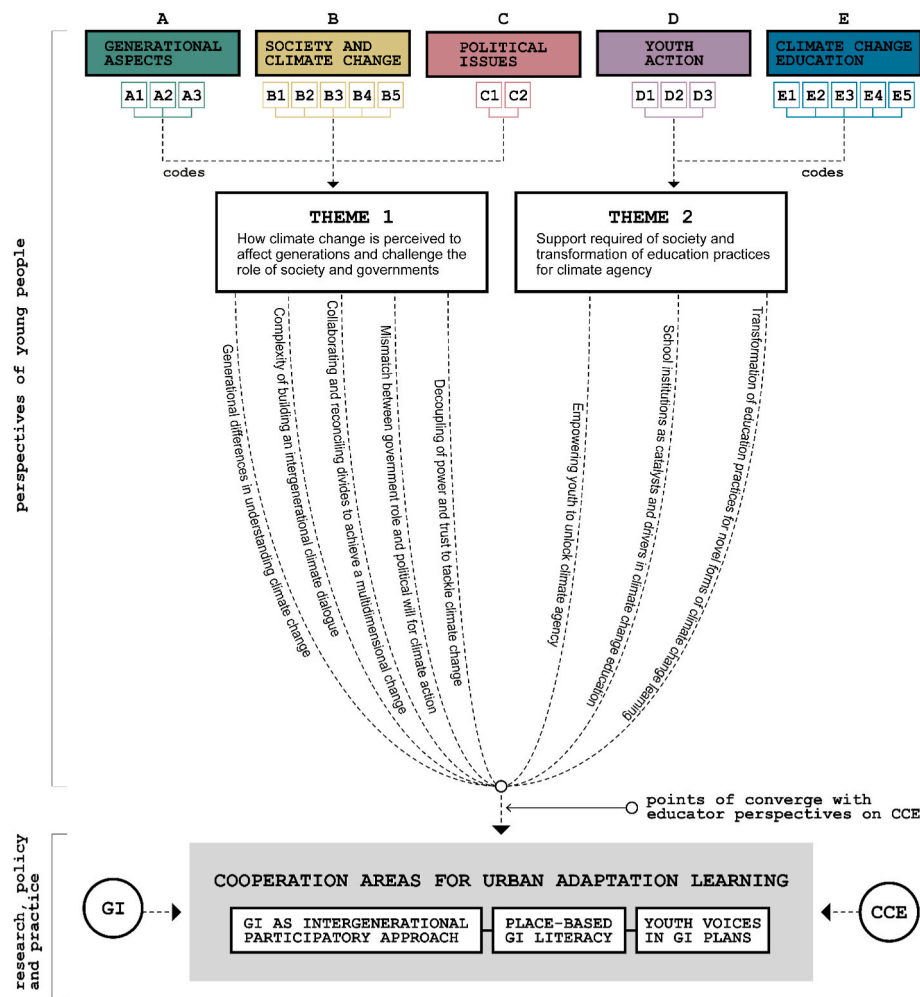


Fig. 5. Framework that operationalises youth and educator perspectives through identification of main cooperation areas between GI and CCE to promote urban adaptation learning.

exposure since childhood to related education that did not exist in the past. In the view of some, the question of knowledge being transmitted to a higher degree represents for older generations the need to “get used” to newly introduced issues (YP-25), which requires them leaving behind prior information that proved to be “incorrect” (YP-28).

Many young participants believe that, albeit not every adult, the majority of them have lower concern for climate change than youth. This is attributed by some to the fact that their predecessors had undergone years of prioritisation of economic growth over nature, the “effects” (YP-38) of which were not as apparent as at the present. Some young participants emphasise that this is reflected in adults appearing less attentive and inclined to environmentally considerate behaviours such as recycling. Others perceive the question of adults understating or lacking interest in climate change issues as related to them feeling less impacted by than younger and future generations will.

Albeit to a lesser extent than knowledge and concern, young participants’ responses unveil pressure for the resolution of the climate crisis as an additional area in which they perceive generational differences. A two-fold form of pressure is referred to: pressure of the climate emergency, whose unprecedented circumstances provoke in younger generations a sense of “urgency” (YP-39) and of being “compelled to do something” (YP-38); and pressure of society, which is home of

expectations on younger generations and their climate leaders “to fix” (YP-22) inherited damages.

6.1.2. Complexity of building an intergenerational climate dialogue

Young participants identify limitations in their capacity and opportunity to inform older generations around aspects of climate change (code 5); yet some believe they can take an influencing role towards the younger children (code 6). The majority of young participants argue that they lack a broad and in-depth knowledge of the topic “to feel able to explain it” to others (YP-12), “engage in discussions” (YP-9) with adults, or to do this effectively. Others face or expect barriers to influencing behaviours of older generations, including when reasoning with adults unconcerned, not heeding their advice, or with entrenched beliefs. In the broader perspective of one young participant, climate change is one amongst several issues where a “communication problem” arises between generations (YP-31). Their younger siblings and grandchildren, on the other hand, are seen by some young participants as a generational group to which they can easily transfer information and towards which they can act as “role models” (YP-36), to inspire and encourage sustainable behaviours “from an early age” (YP-29).

6.1.3. Collaborating and reconciling divides to achieve a multidimensional change in society

Young participants believe climate action should permeate diverse dimensions of society, placing members and sectors of it on centre stage in coping with climate change. In the individual dimension, young participants identify the need for a change in mindset, behaviours, and lifestyles (code 9). This entails people moving away from a current way of living that is “really dangerous for the environment” (YP-9); reversing the way of thinking, by assuming that the environment should not be requiring clean-up operations, as it should be maintained in good health; and “adapting” to re-input what is consumed as this is “what nature does, it is a cycle” (YP-34). The significance and ease of access to individual small-scale actions (code 10) is indeed emphasised by many: these are recognised as the means by which individuals can contribute to climate impact reduction in their “own small way” (YP-29; YP-30; YP-34) and capacity. Especially recycling is described as a “duty” (YP-5), a “simple” (YP-1) and “helpful” (YP-34) act, which is yet hardly or not properly undertaken. Some also highlight that the personal willingness (code 11) of the individual is critical for climate action.

One aspect that emerges strongly from responses is the essential linkage of the individual dimension with a collective scope: the efficacy of individual small-scale actions is perceived by many to be dependent on whether they are performed by all (code 12). However, as climate change is an enormous challenge that “affects everyone” (YP-30), not only effort is required of each individual to achieve a large scale-change, but especially cooperation, dialogue, and knowledge exchange between individuals and groups (code 13) is felt as a necessary condition of climate action. Many young participants indeed discuss that tackling climate change is a shared responsibility between generations, which requires of them “to work together” (YP-34) making advances synergistically. Other responses affirm the importance of fostering collaboration of all members of society and diverse professionals, each having a critical role to play; or, between countries to “learn from each other” (YP-12), as incentive and inspiration to action, given that climate change “concerns everyone, not one country specifically” (YP-12). Besides the need for cooperation, a view held by various young participants, especially of one focus group, is that collective awareness remains a target still to be achieved (code 14), as climate change is “not seen that much as a problem” (YP-19), with this involving people to become “better informed” (YP-20).

Young participants identified the mobilisation of entire sectors required to attain system-wide changes (codes 16–21). Some of the interventions contemplated by young participants pertain, for instance, to the area of environmental management, at scale ranging from “the preservation of glaciers” (YP-12) to protection and increase in “green areas” (YP-35). Other responses point to a decrease in greenhouse gas emissions and environmental pollution caused by industrial, agriculture, mobility, and waste sectors; increase in renewable energy use; and research into innovation technology. Moreover, education and media are seen by young participants as sectors through which climate information should be supplied more widely. Knowledge is believed to contribute not only to increasing awareness (see also code 14), but also to keeping pace with change:

“[t]he less we know the worse it is. Because, anyway, we live in the world, and it keeps changing, so if we are not ready for change, we don't move forward, that is” (YP-12).

6.1.4. Mismatch between government role and political will for climate action

Young participants perceive that the role of government and those in position of power in the climate crisis (code 28), including the responsibility of enabling societal change (code 29), is largely unfulfilled (code 30). State governments and politicians are regarded as those with the power to solve the climate crisis. This is primarily associated with their authority and leadership to intervene on issues requiring both

regulation and support mechanisms for entities of society to contribute their part in sustainability. For instance, demands of young participants are the adoption of supportive regulatory and financial frameworks for green solutions, the allocation of economic incentives for climate-friendly options, as well as policies for a sustainable transition globally. While emphasising the importance of governments, young participants commonly criticise their inaction, the unwillingness for a change in priorities within the politics, and the pretextual interest to the issue often “just used for propaganda, campaigning ...” (YP-21).

6.1.5. Decoupling of power and trust to tackle climate change

Young participants predominantly express a lack of trust in older generations (code 7) and governments (code 32) to tackle climate change; yet some exhibit a sense of trust either in specific groups as younger and future generations (code 8) and scientists (code 25), or in a social unifying effort for change (code 26). It is particularly what young participants perceive to be an intergenerational difference in understanding climate change (previously outlined) that underlies their view of older generations as unequipped or uninterested in addressing it. Another reason includes the “idea that [...] it was a bit the fault of older generations that we find ourselves in this situation” (YP-21). Furthermore, there is a prevailing scepticism regarding the likelihood of governments undertaking action, with especially participants of one focus group discussing that seeing state governments as those with the power to implement changes is distinct from having trust in them. For instance, one young participant argues that:

“[...] if it is actually politicians or states that have the power to change things more immediately, I [...] do not rely much on it but rather on science, on—perhaps just in a utopian way—even some invention that can save us all [...]. I rely more on that rather than thinking that politicians will change [attitude] completely overnight. Because, in the end, it is about shifting the focus [...] to the common good, on saving the planet, and I do not think that will happen” (YP-27).

Young people and experts, including young scientists, are indeed especially trusted to voice the climate emergency and to identify “some way to solve it” (YP-34). Others entrust society as a whole with the responsibility to tackle climate issues or rely on a social potential for change. This is for several reasons, including some young participants reflecting that trust cannot be placed on a single entity or individual and relying on a collective understanding of the need for action, as “in the last few years we have made a lot of progress” (YP-34) as otherwise “problems will not be solved to any great extent” (YP-18).

6.2. Theme 2: Support required of society and transformation of education practices for climate agency

6.2.1. Empowering youth to unlock climate agency

Young participants demonstrate a degree of daily efforts at individual climate related actions, which basically comprise not disposing of waste into the environment, reusing, recycling, water and energy saving, and choice of public transport options (code 34). Participation in collective or group actions mainly consists of engagement in clean-up activities as part of formal education (code 35) and sporadic attendance of climate strikes through the local group of Fridays for Future movement (code 36). Many young participants recognise the importance of youth climate movements, protests, and campaigning (code 37). They mostly acknowledge the role of young climate leaders in drawing attention of politics and the public to climate issues, giving voice and prominence to young people, and motivating their peers to action, as “to see a figure our age so determined to change things can be reassuring and can make us want to do something too” (YP-34). However, participants experience frustration resulting from a decline of political attention after a protest and the failure of governments to follow up and act (see also code 30). Yet, if their involvement in climate strikes was often one-time, this

is due for some to disappointment at seeing that not all attendees were genuine protesters, while for others to perception that schools are unsupportive as “they mark your absence and so nobody goes” (code 38).

Young participants identify factors that they believe impact youth capacity for action. The factor most cited and agreed is the perceived lack of climate activities, resources, and guidance that they feel it limits their agency (code 41). Young participants indeed emphasise the difficulty of undertaking a concrete action “of their own accord” (YP-12) or get it started by their own circle of friends. They argue this necessitates knowledge about what can be enacted and how to get involved, as well as evidence of achievable results and activities (including by the school) offering them “the opportunity to do something” (YP-22). A support factor for youth action involves society valuing and heightening youth potentials in the field of climate change (code 42). Young participants express the need for adults to “hear proposals of young people” (YP-37) and “[t]rust them, because if you don't believe in their ideas then it is useless” (YP-2). What they advocate is valuing, promoting, and accounting of their inventive capacity through the support of education and specific funding. This includes through “dedicated places, where perhaps people can come together” (YP-12) for collective learning and project development.

6.2.2. School institutions as catalysts and drivers in climate change education

Young participants unanimously expect school institutions to become the driving force behind CCE (code 60) as shown in Fig. 4. This is linked to a twofold reflection. On the one hand, it is argued that the school is the primary setting “in contact with the new generations [...], the place where the basics are given precisely to people” (YP-32) and climate change begins to be taught. Teaching this topic adequately is considered to be part of its responsibility, as “the school is supposed to be the learning environment, therefore it should precisely teach us to live in the world and to understand that the world, in any case, changes and there are risks to the climate” (YP-12). The school is believed to become increasingly important for CCE; thus it is hoped its future role will be “greater than now, better than now” (YP-21). On the other hand, the school is expected to operate both as the main supplier or catalyst of climate education activities and a pointer to opportunities for engagement beyond the school setting (see also code 41). Some consider that these pivotal roles imply schools need to network with each other and act as role models, for instance by making their learning spaces sustainable, consistently with the principles they promote.

6.2.3. Transformation of education practices for novel forms of climate change learning

Young participants' experiences of CCE mostly relate to formal education. These experiences involve both primary and secondary education (codes 43–45), albeit differently in terms of methods, with a slightly higher number of mentions regarding humanities than science-technology disciplines (codes 46, 47). In instances where explicit reference is made to involved subjects, these especially consisted of Technology and Arts in lower secondary education, as well as Science, Geography, and English in lower and upper secondary education; in some cases, this was as part of the instructional time for civic education teaching (code 48). However, all the young participants are critical of the way this thematic domain was dealt with. The main perceived weakness is the lack of discussion and in-depth exploration (code 51). They feel that climate change is a broad topic of which they were only and repeatedly taught “some basics but nothing in depth” (YP-9), addressed within a few lessons lacking an active debate element. They reflect that they are “kind of limited in knowledge” (YP-12) and believe there is still much to be implemented in terms of education, as “[t]he school says it exists, but this is not enough” (YP-20). Apart from being explained vaguely and in general terms, young participants argue that climate change was approached primarily through traditional lecture and assessment methods (code 52). They highlight that theory-based lessons

were hardly supported by any practical activities and thus perceived as additional study load, given that—except for recycling education—lessons failed to provide knowledge applicable in real life. Many young participants also express dissatisfaction about a perceived discontinuity, lack, or misuse of teaching time (code 50). Their experiences include discontinuous teaching of climate change across stages of education, thematic disconnects due to a change of teachers, occurrence of lessons limited to specific periods of the school year, and the perception that certain lessons overlooked or did not maximise links with related topics. Finally, some young participants consider teacher sensitivity to climate change a factor that influenced not only the frequency of lessons delivered but also the level of preparedness shown and the ability to captivate their attention (code 49).

Hence, young participants' desired transformations of CCE relate to a double sphere. The first sphere includes changes in the formal education system approaches. Many young participants suggest that CCE should start at an early age (code 61). Based on a gradual progression to advanced knowledge, this is believed to make younger generations increasingly more informed than those preceding them, embracing responsible behaviours and environmental care “[a]s if it were just an everyday, natural thing” (YP-12), “something you are used to doing” (YP-36), as “if you have this mindset from an early age, then everything will be easier” (YP-9). Young participants reflect on curriculum changes to provide space for this form of education (code 62) and the importance of inputs from a variety of disciplines (code 63), with a potential involvement of History mentioned across all focus groups and a tendency among respondents to prioritise subject areas specific to their educational pathway. Mentorship of educators, especially school-teachers, appears critical in exploring evolving complexities and vastness of the topic, and thus there is consensus about the benefits of educator training on novel teaching methods (code 64).

The second sphere includes changes in the methods of CCE. In the young participants' view, it is particularly important that education and communication not only supply adequate information about climate change (see code 21), but also that information is solutions-conscious and includes advice about “what everyone can do in practice” (YP-33), “not just the worst situations they might cause” (YP-38). Many indeed highlight the state of uncertainty and anxiety for youth potentially caused by not knowing exactly how to face climate change and advocate to reverse prevailing perspectives for which the phenomenon is explained as a set of inevitable events rather than an issue to be tackled (code 65). This also implies that education needs to expand, diversify, and interconnect learning methods employed. There is a high young participant demand for filling their knowledge gaps innovatively, embodied in the need of teaching modes that combine theory and practice, offering linkages with real life and possibilities of intervening in it. Indeed if, on the one hand, they think lessons should enable a critical understanding of the phenomenon, including through rigorous data analysis and debates (code 66); on the other hand, they particularly call for increased engagement through projects and activities (code 67). These are believed to provide practical knowledge, a way for them to learn by doing and be potentially “encouraged to continue such activities in the future” (YP-38). They emphasise how activities “where you feel involved” (YP-12) can help make the learning process stimulating and enjoyable, especially when they incorporate elements as team-working, competitiveness (among groups, schools, cities), and play (code 70), but also when they allow learning outdoor or outside the school building (code 69). Some young participants also emphasise the importance of observing environmental damages on-site and learn by interacting with the context (code 68). Youth experiences of being involved in clean-up activities are frequently cited as memorable examples that combined many of these aspects (see also code 35). Finally, some underline that transformation of education practices necessitates the school to connect with other supporters of young people's learning representing different forms of knowledge such as activists, associations, and professionals in the field (code 72), as well as with the family, which

they expect to be a complementary player in education (*code 71*).

The relevance of school institutions as catalysts and drivers in CCE and the need of novel forms of climate change learning related to Theme 2 clearly emerge by examining results from the narrative work through re-occurrence of certain codes (Table 3). Collected drawings and stories envision a diversity of formal, non-formal, and informal places, tools, and actors to shape future education. Grounding on personal experiences for effective learning, young participants identify as important characteristics the guidance of educators and thematic experts, visualisation of, and interaction with, climate information and impacts, personal deepening of own areas of interest, and social dialogue. Cultural, recreational, natural, school, and virtual settings become varied and variously interconnected parts of desired future places in which these characteristics are embodied. Proposals include thematic experts entering the classroom or leading educational site-visits to observe environmental changes; students visiting museums and science festivals dedicated to climate change or participating in themed group competitions involving different types of school; media, apps, and the Internet offering dynamic contents to stimulate curiosity and support individual learning; and multiplication of in-person and virtual arenas of discussion. When encouraged to think about more radical transformations, young participants especially give technology a driving role: for instance, museums or schools combine traditional learning tools with virtual reality to simulate climate risks and ways to deal with these; the school becomes a living laboratory which incorporates GI, or an urban park becomes interactive through advanced tools involving users in producing energy.

6.3. Points of convergence between young people and educators' visions for educational transformation

Visions for CCE of educators interviewed present multiple points of convergence with those of participating young people. Hereafter, the main areas are synthesised. One point concerns the perceived importance of delivering education on climate change. There is consensus among interviewees that the topic should be “definitely” (ED-1) discussed in educational settings, and that education associated with it is still insufficient. Many emphasise this is further compounded by the paucity of information in the media, a situation that they believe hampers achievement of broader public awareness.

A second point of convergence relates to the perceived role of educators in CCE. Interviewees recognise educators to have “a great responsibility” (ED-4) in this regard, with their role especially involving enabling *critical* understandings of climate change through offering a spectrum of contents, resources, and activities. An aspect reiterated by many interviewees is the importance of pointing learners to reliable sources, along with teaching how to discern these and navigate through. Educators and educational settings are regarded as having the potential to trigger virtuous processes, setting good examples that young people might transmit to their families and future generations, as young people “will certainly be the ones who will bring about a proactive change in the various spheres of their lives” (ED-1). One facilitator of learning interviewed enlightens that this requires educators being not only competent, but also empathetic. While interviewees expect climate change to become a priority issue for the formal education sector, they also consider CCE a shared responsibility. Educators of any field, even when not specifically working in the environmental sector, are deemed “fundamental in the life development” (ED-5) of young people and thus their role, and that of the family, is believed to be crucial in CCE.

A third point regards changes needed in education practices to nurture climate change learning. Interviewees consider it essential to incorporate instructional activities that are science-informed, yet contemporary, inspirational, and engaging in practical and meaningful ways to offer a valuable and overall varied learning experience. For instance, participatory, interactive, and hands-on learning methods are believed to offer young people platforms where “they learn, they

understand, by doing” (ED-7) and see tangible results of their actions. One interviewee enlightens that “the basis must necessarily be scientific, it must be accessible, it must be understandable to young people. But then the part of active participation, of working in groups, is the one that really brings out needs, demands, ideas in an equal manner and without fears” (ED-5). Drawing from their experiences in delivering CCE, interviewees suggest that climate change themes be addressed comprehensively and from different perspectives “by combining different sciences” (ED-8), disciplines, and expertise, with a focus on both global and local contexts. This includes, among others, examining the approach of various countries to climate change, exploring the topic through alternative lens such as climate justice, providing young people with knowledge of solutions and actions which can be taken part in, and helping them develop technical and soft skills.

A fourth point of convergence concerns adaptation of school curricula and teacher training to respond to the needs of CCE. It is a prevailing opinion among interviewees that implementing CCE in practice, effectively and “systematically” (ED-6), requires increased, deeper, and more explicit integration in school curriculum within and across stages of education, alongside a system that enables teachers to receive specific training “on a continuous cycle” (ED-3) and supports them to adopt innovative teaching methods.

6.4. Synergies in GI–CCE cooperation areas for urban adaptation learning

As a systemic, interdisciplinary, transdisciplinary, place-based, solution-oriented approach (Pauleit et al., 2017) with proven capacity in risk reduction and climate adaptation (EU, 2019), GI embodies many of the principles that the growing literature about effective strategies for CCE (e.g., Monroe et al., 2017) seeks to achieve in teaching practice and curricula. Results of the empirical study presented in Sections 6.2 and 6.3 highlight core areas for cooperation between CCE and GI which can meet demands of young people and educators regarding novel forms of climate change learning capable of supporting action in the climate crisis. This includes a latent demand of learning for adaptation which is apparently still overlooked in the education practices. This is despite the capabilities it contributes to building are increasingly recognised as “crucial for the transformative potential of education for climate change adaptation to be realised” (Hügel and Davies, 2024, p. 3). By promoting GI as an operational tool in CCE that embeds perspectives of young people and educators, GI can aspire to have an important impact on developing adaptive capacity in the youth acting as a main driver of change into—practicing integration across—environmental and education system domains in the context of urban adaptation and mitigation to climate change. The three GI–CCE cooperation areas identified below are intended as a contribution to this aspiration. They are interrelated and need infrastructures, resources, and networks to draw upon, such as modes for cooperative multi-stakeholder nature-based initiatives (Frantzeskaki, 2019; Frantzeskaki et al., 2019; Raška et al., 2022) that involve school institutions as key partners.

6.4.1. GI as an intergenerational participatory approach

Results indicate that young participants recognise the complex origins and impacts of climate change, which they consider a challenge requiring collaboration, awareness, and agency to be tackled effectively and globally. Intergenerational cohesion is seen as a necessary precondition to ensure impact of collective commitment as an input for social change; however, it demands dialogue across different demographic groups by bridging existing communication gaps. The employment of GI in CCE encourages situating youth learning at the core of participatory processes where communities socially construct own interactions with (urban) nature continuously negotiating relevance, acceptance, and legitimacy of nature-based initiatives through deliberation (Nesshöver et al., 2017). The presented study suggests that these participatory processes should seize opportunities to further investigate generational differences in understanding climate change, facilitating the emergence

of intergenerational arenas for co-creation (see, [Gnecco et al., 2024](#)).

6.4.2. Place-based GI literacy

In the view of young participants and interviewed educators, climate change education and the broader communication of climate information in society are expected to operate concurrently for people to attain a clear understanding of climate change, approaching it as a problem which can be intervened upon. In particular, young participants ask that formal education equips them with more specific knowledge and competences than those provided hitherto by using hybrid, diversified, flexible learning methods, as well as tools, tailored to engage with—adapting to—the composite nature of climate change. These methods are envisaged to be dialogic and active while encompassing and connecting to more conventional passive learning through lecturing, thus enabling learning by doing in concert with other teaching strategies. Further advancement of urban environmental education models embracing GI ([Cole et al., 2017](#)) can support research and practice in education areas (pedagogies, curricula, educator training) where intervention is needed to bridge actionable knowledge gaps emerging in CCE. Results suggest that such models should ensure that resources on mitigation and adaptation actions are accessible to all individuals through formal education yet promoting networks across a range of learning places and settings, types of education, and critical actors involved in young people's learning process on climate change. A promising avenue for exploration is whether place-based GI literacy could lead to greater equity in how education establishments and the youth might get involved in GI implementation, favouring upscaling ([Blanc et al., 2025](#)).

6.4.3. Youth voices in GI plans

The prevailing scepticism of young participants about the likelihood of government action, despite acknowledgement of its role and power in solving the climate crisis, is related to a perceived political inertia. This is counterbalanced by trust in youth and scientists and reliance on collective action alongside research and innovation to provide a voice and responses to climate issues. Operating in a spatial planning dimension, the inclusion of GI in CCE could provide means for youth, teachers, other facilitators of learning, and schools to cooperate with professionals and researchers throughout GI development, from planning to design, implementation, and maintenance. These modes of transdisciplinary working and urban governance ([Wickenberg, 2024](#)) could inspire and sustain innovative pedagogies in CCE; for example, forms of indoor-outdoor learning ([Samborska-Goik et al., 2025](#)) combined with digital participatory mapping ([Maurer et al., 2023](#)) and art-based methods. However, results show that transdisciplinary collaboration should consider how feelings of trust and distrust held by youth might influence this process, respectively as leverage points and obstacles. This highlights that defining clear mechanisms of inputting into local GI plans and policy to avoid disengagement ([Samborska-Goik et al., 2025](#)) would be particularly important when involving youth.

7. Conclusions

This paper proposes that developing GI into an operational tool of CCE could facilitate adaptation learning within climate change education to emerge more effectively and robustly across education practices, while supporting a focus on urban adaptation that is largely absent. A systematic analytical process was developed to highlight the perspectives held by youth and educators on diverse aspects of climate change and CCE. The proposed approach was successfully applied to the Genoa case study (Italy) to identify GI–CCE cooperation areas incorporating the perspectives of study participants, both youth and educators. These cooperation areas include GI as an intergenerational participatory approach, place-based GI literacy, and youth voices in GI plans. They should support society in creating conditions, mechanisms, and guidance for youth to develop their roles in climate action. This support should include learning and teaching practices, active listening,

empowerment, intergenerational dialogue, social learning, and participation in decision-making through GI.

Although the present empirical work was conducted in Genoa as a research case study and thus involves a selection of participants in a given context, the developed systematic analytical process allows for replication in the other project locations for cross-city analysis, with potential also for use in other city-regions beyond those included in this research consortium. Such strategic building of GI–CCE cooperation areas has potential to provide valuable new opportunities for urban adaptation learning among youth.

CRedit authorship contribution statement

Sabrina Sposito: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Anna Palla:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Lindsey McEwen:** Writing – review & editing, Methodology, Funding acquisition. **Ilaria Gnecco:** Writing – review & editing, Validation, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Ethics information

In Italy, the Research Ethics Committee (CERA) at the University of Genoa granted ethical approval on the November 18, 2021, reference number 2021/64.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2026.129069>.

Data availability

The data that has been used is confidential.

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