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Passive action strategies in schools: A scientific mapping towards eco-efficiency in educational buildings

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ABSTRACT

The research field on passive intervention strategies in schools is broad, complex, and fragmented due to the great diversity of disciplines, climates, and approaches. This article applies the scientific mapping software SciMAT to analyse research trends and developments from 1982 to 2020 of 537 papers and identifies the best available 24 passive intervention strategies in schools in 42 countries. The results show that, in the early years, research focused on natural ventilation, especially in arid climates. From 2010 onwards, and coinciding with the rise of energy efficiency regulations, green roofs increased as an alternative to declining urban forests and as a solution for urban heat island mitigation. In recent years, growing concerns about climate change, sustainable development, and numerical measurement methods have driven work on occupant comfort and IAQ, while research on cost overruns and payback of passive versus active design. The need for passive, climate-resilient design techniques is highlighted, building on the progress already made. It identifies the most optimised measures to promote guidelines to serve for future regulations. This study is a valuable contribution because it provides a detailed understanding of the status quo for researchers, practitioners, and policymakers and predicts the dynamic directions of the field.

1. Introduction

Buildings and their built environment constitute a complex organisational system that contributes to any country's social, economic, and environmental development [1]. Public buildings, in particular school buildings, represent about 18% of non-residential buildings in Europe. These buildings are ageing and deteriorating; as more than 50% of the educational establishments in Europe today were built before 1990, 60% of them in Mediterranean countries [2]. In addition, the increasing obsolescence of schools is evidence that the climatic considerations of each location were not considered in their early design phases, so that today most of these projects require proposals for action at different levels [3], both in outdoor and indoor spaces.

Schools are buildings located in established neighbourhoods, facilities that cannot be replaced or relocated to other city areas [4,5]. Consequently, the refurbishment and renovation of schools and their built environment can improve indoor comfort while improving the energy efficiency of the building [6,7]. Several studies reported significant deficiencies in classrooms, namely inadequate indoor

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air quality (IAQ) and high energy consumption [8–10], poor hygrothermal comfort [11,12], among others. Studies on representative samples of schools are needed to diagnose their state of repair, energy performance and indoor/outdoor environmental quality after many years of use to promote viable and effective strategies [13].

In this context, countries worldwide emphasise the need to address active and passive design strategies with a high potential for reduced implementation costs and high architectural design performance [14]. The European Commission (EC) presented The European Union (EU) Directive 2018/844 [2] and The European Green Deal [15], which set out a new and more ambitious EU strategy on climate change adaptation. Thus, EU countries must establish long-term strategies to support the renovation of their buildings to nearly zero-energy buildings (nZEB) by 2050 at the latest [16]. In particular, the EU has paid special attention to regulating the construction practices of public buildings, especially in educational establishments in countries with a Mediterranean climate due to global warming.

In this sense, passive intervention strategies offer opportunities to optimise decision-making by directing design interests towards climate issues [17–19]. Passive strategies can be incorporated within building elements [20]; or by integrating external elements [20,21]. However, current building trends often focus energy cost reductions on efficient thermal systems, ignoring proper passive architectural design [22]. It is due to the complexity of the design task, which requires a particular set of skills and abilities, inspiration and creativity inappropriately combining and modifying architectural parameters [23]. According to Rahm et al. [18], the aim is to achieve a deprogrammed architecture, free of formal and functional pre-determinations and open to the weather and seasonal changes,

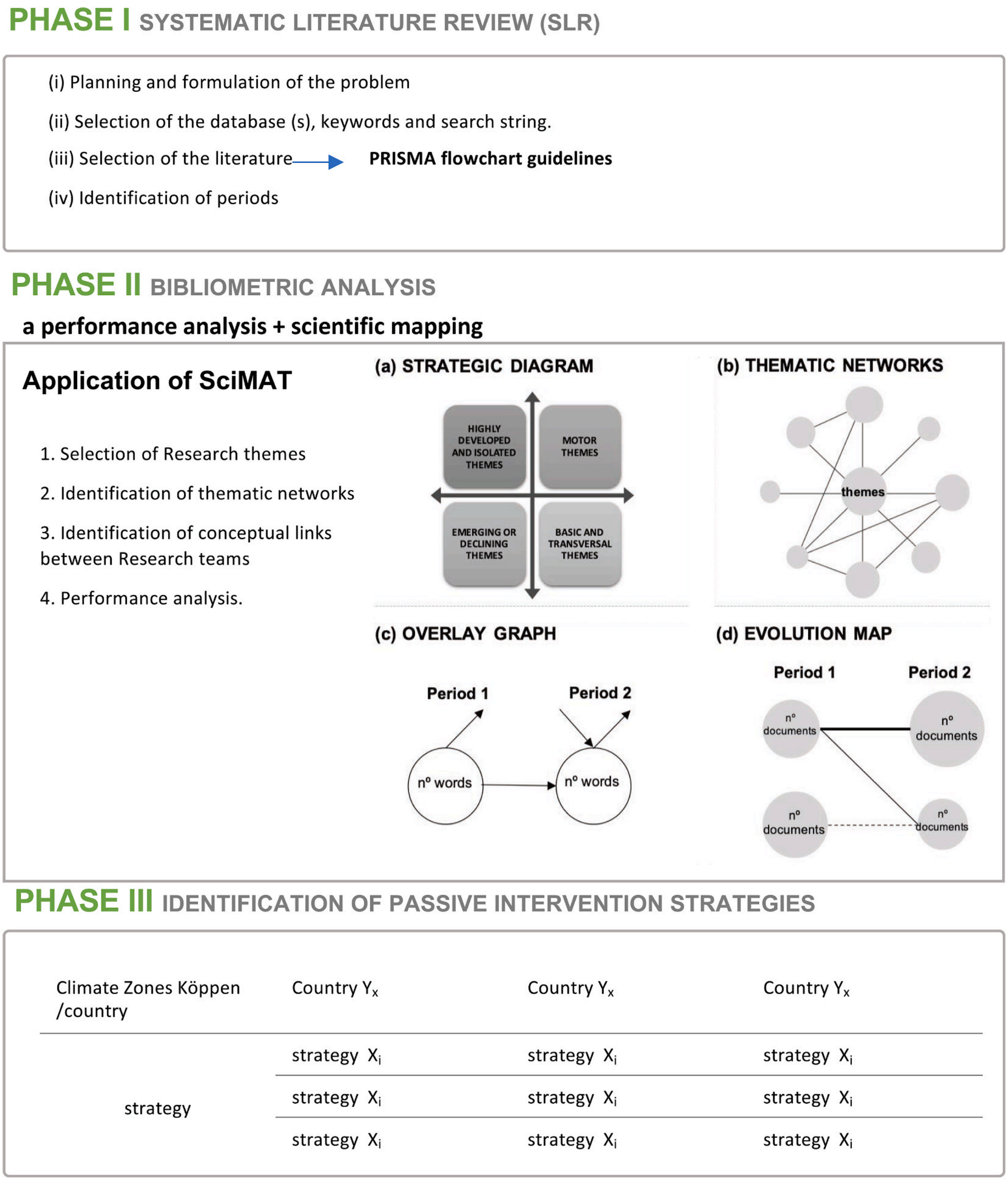

Fig. 1. Materials and methods and examples of a strategic diagram (a); thematic networks (a); overlay graph (c); and evolution map (d).

to the alternation of day and night, to the passage of time and the emergence of ignored functions or unexpected forms.

Adaptation of educational facilities to climate change (CC) [24,25] and reduction of the urban heat island (UHI) are considered essential. These urgent needs have led to many efforts aiming to improve the performance of educational buildings for different climates, occupant profiles and building constructions [26,27]. Studies on the analysis of active and passive techniques on a limited number of school buildings and climatic regions [28,29] have been widely presented in the literature. However, these focus on analysing, evaluating, and monitoring specific strategies on a limited number of educational buildings and do not entirely diagnose the existing developments and demands at a global level.

Consequently, due to the complexity of these interrelationships and the wide range of disciplines involved, it is impossible to get a unique starting point for accessing this topic. The context of not having a broad overview of the research area and the evolution of problems in the field makes it difficult to obtain valuable and unbiased information for future research. Therefore, comprehensive reviews are needed that facilitate the integration of these contributions and provide a critical perspective. In this sense, a bibliometric analysis provides objective criteria for evaluating the work done by researchers [30] and a macroscopic view of a large amount of academic literature [31]. The concept of bibliometric analysis was introduced by Alan Pritchard in 1969 [32] and consists of a double integrated analysis, performance evaluation and scientific mapping.

This investigation aims to contribute to the knowledge on passive intervention strategies in schools and identify strategies used in different climate regions. To meet this goal, the following specific objectives were established: (i) a quantitative analysis based on a systematic literature review; (ii) a qualitative review based on performance analysis and scientific mapping; and finally (iii) detection of strategies of passive intervention in schools in different climate regions of Köppen.

The main scientific contribution of this work consists of highlighting current trends, patterns, and future lines of research in passive design for school buildings. It enables the identification of future school design strategies to optimise their environmental and economic performance towards low carbon climate-responsive school buildings. This work can serve as a basis for the future research development and implementation of regulations, plans or strategies to improve the quality performance of school buildings.

2. Materials and method

The following methodology has been developed to meet the objective of this research (Fig. 1): (i) a systematic literature review (SLR) of bibliographic records on passive intervention design strategies in schools; (ii) a bibliometric analysis of the identified documents; and (iii) detention of strategies of passive intervention in schools in different Köppen climate regions.

2.1. Systematic literature review

The first section of the methodology consists of an SRL [33]. In this work, the SLR is based on the guidelines contained in Kitchenham et al. [34] (Fig. 1), which consist of the following stages: (i) planning and problem formulation; (ii) database selection, keywords, and search string; (iii) literature selection according to the PRISMA flowchart guidelines [35]; (iv) and (iv) period identification.

The Web of Science (WoS) and SCOPUS databases were selected for this study. This review addressed two concepts, passive intervention strategies and schools. For each database, two search strings were used, and the following keywords were set for each concept (Table 1).

2.2. Bibliometric analysis: science mapping and performance analysis

A double bibliometric analysis, a scientific mapping and a performance analysis are carried out. The scientific mapping shows the research's conceptual, social, intellectual structure, evolution, and dynamic aspects. Performance analysis evaluates the impact of citations. In this work, Science Mapping Analysis Software Tool (SciMAT v1.1.04) [36] was used, which is based on the analysis of common words [37] and the *h-index* [38], and consists of the following phases:

(i) Selection of Research themes. The tool generates the equivalence index [39], uses the unicentric algorithm [40] to detect the most relevant themes, and generates one strategic diagram per set period. The strategy diagrams have been generated by the SciMAT v1.1.04 tool. The diagrams are centrality and density based [39]. Centrality is the level of interaction of a research theme with other research themes. Density gives an idea of the level of development of that topic, measuring the internal cohesion of all the links between the keywords describing the topic [41,42]. The diagrams are divided into four quadrants showing the following four types of research topics (Fig. 1a):

a) Motors. These are in the upper right quadrant, well-developed and essential themes in the field. They have a high density and a heavy centrality.

b) Highly developed and isolated. These are in the upper left quadrant, highly developed inside but isolated from the themes. These are specialised topics in outlying areas of the research field.

Table 1
Keywords related to the research concept.

Concept	Keywords Related
passive intervention strategies	passive systems; bioclimatic architecture; passive architecture; passive strategies; passive design strategy; passive measures; passive design
school	educational centres; education centre; high school; colleges; secondary school; grammar school; educational institution; centre of learning; institute; kindergarten; nursery school building

c) They are emerging or declining. These are in the lower-left quadrant and lack development and relevance, although they may evolve and be relevant or disappear.
d) Basic. These topics located in the lower right quadrant are transversal to the scientific field.

(ii) Identification of thematic networks. The thematic networks are generated by the SciMAT v1.1.04. tool and show the relationship of each theme with the keywords and their interconnections. Fig. 1b shows an example of a thematic network where several keywords are interconnected. The size of the circle is proportional to the number of documents corresponding to each keyword, and the thickness of the link between two circles is proportional within the equivalence index.
(iii) Identification of conceptual links between Research themes. The SciMAT v1.1.04 tool generates through the inclusion index, conceptual links between themes in different periods are detected [43]. The strength of association between themes generates an overlay graph (Fig. 1c) and a thematic evolution map (Fig. 1d).
(iv) Performance analysis. The relative contribution of the topics is measured quantitatively and qualitatively. The most outstanding, productive, and high-impact subfields are established using bibliometric indicators, such as the number of most cited articles, journals, and authors.

2.3. Identification of strategies of passive intervention in schools

Based on analyses of relevant documents from the SLR, different strategies of passive intervention in schools in different climatic regions of Köppen are detected. Köppen was selected because of its popularity, easy application. Furthermore, this classification is based on the implicit premise that natural vegetation is an indicator of climate, and some of its categories are supported by the climatic boundaries of certain vegetation formations [44]. These combined strategies are created by introducing energy improvement actions that can be applied generically to a base scheme [45]. It will serve as a basis for establishing optimised eco-efficient strategies that will be of great use to designers, architects, and urban policymakers for future renovation policies.

3. Results and discussion

Once applied the steps of the previous section, the results are analysed in Figs. 2–8 and Tables 2–6.

3.1. Research trends

According to the PRISMA flowchart guidelines, 1320 bibliographic records were retrieved from the two selected databases. After removing 706 duplicates, 53 of the remaining 614 records were excluded. The remaining 561 records were then screened for title, abstract and keywords, and 21 additional records were excluded as they did not fall within the scope of this review. After a final exclusion phase, 537 relevant papers were selected for the study (Fig. 2).

The time horizon used was 1982–2020 and was subdivided into the following three periods, considering the number of papers selected, as well as relevant milestones to analyse trends in publication patterns:

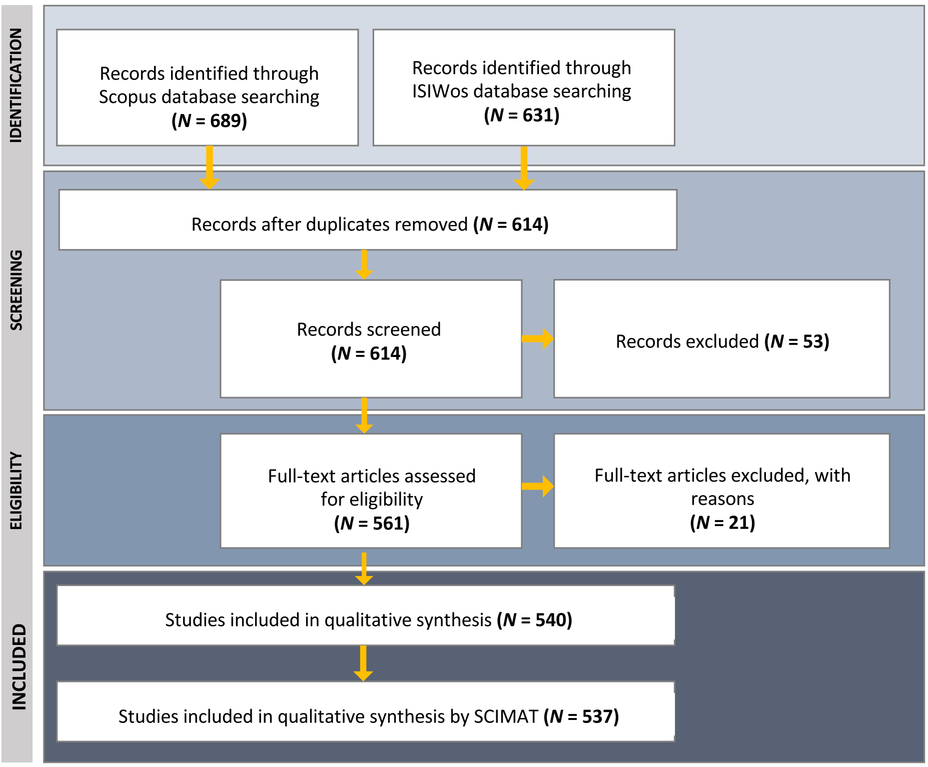

Fig. 2. PRISMA flowchart.

- First period (1982–2010): 155 papers. The first selected records date from the 1980s, where the foundations were laid for introducing strategies of passive intervention in schools.
- Second period (2011–2015): 158 documents. The European Parliament Directive 2010/31/EU on the energy performance of buildings [46] coincides with this period. It led to a notable increase due to the concern for sustainable construction, reflected in increased research in this field.
- Third period (2016–2020): 224 papers. The last period begins with consolidating the establishment of the 17 Sustainable Development Goals (SDGs). The SDGs coincided with another historic agreement concluded in 2015, the Paris Agreement adopted at the Climate Change Conference (COP21) [47].

Fig. 3 shows the distribution of the 537 documents by year. As can be seen, until 2006 the number of documents was low. In 2011 a significant increase of interest in the research field can be observed. Since 2015, when the 2030 Agenda for Sustainable Development was discussed at the Rio+20 Conference, a significant expansion in published works can be observed. Most of the articles in this SLR were published between 2016 and 2020, which is a clear indication of growing interest in the research, and the projection of this analysis indicates that this number will continue to increase.

3.2. Bibliometric analysis: science mapping and performance analysis

In this section, strategy diagrams, thematic networks of the relevant themes, overlay graph and thematic evolution map are analysed and discussed. In addition, the most cited documents and publications are commented.

3.2.1. Strategic diagrams

Three strategy diagrams were generated, one for each period (Fig. 4–6). Table 2 shows the performance measures obtained for each topic in terms of number of documents, *h-index*, number of citations, and centrality and density values. An analysis of the results obtained is shown below.

In the first period (1982–2010), the strategy diagram presented in Fig. 4a shows ten relevant themes in the 155 documents selected for this period, where the size of the balls depends on the average citations of each topic. Of these, four are motor themes (ranked by an average number of citations), wind catchers (51.4), field measurement (33.5), sustainable building (24.6), and thermal insulation (14.78); three are emerging or declining, cooling strategy (41.33), energy-saving (33.75), and passive design (0); one is highly developed and isolated, air flow rates (9.17); and one is considered a transversal theme, school (22.46). Based on performance measures (Table 2), the themes with the highest number of citations are wind catchers, school, and sustainable building. These research topics are present in the most significant number of papers and have a high *h-index*, except thermal insulation. Although it is present in fewer documents, it has an *h-index* of 9, which indicates that it will become a core topic in the coming years.

In the early years of the research field, particular interest was given to passive cooling systems, such as natural ventilation. These

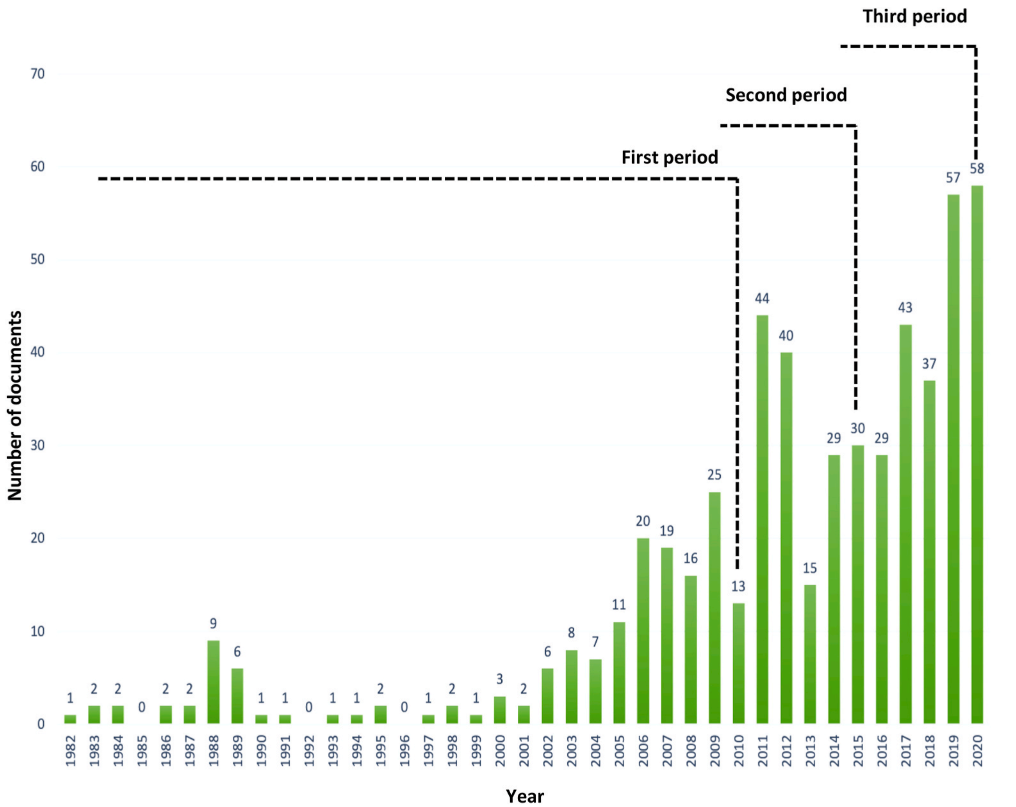

Fig. 3. Documents per years.

systems have been around for well over fifty years. For example, wind towers have been traditionally used in Middle Eastern architecture for many centuries [48]. Also, in cold climates like the United Kingdom (UK), work on natural ventilation principles using both stack effect and wind-driven ventilation has been ongoing for over 30 years [49]. Although the development of field measurements such as analytical [50], numerical [51] or experimental methods [52], and the increased awareness of sustainability in buildings in the last decades, have increased the interest in natural ventilation design [53].

The energy performance of natural ventilation shows economic, environmental, and social benefits over mechanical methods in temperate conditions [54]. Examples include wind catchers that can reduce building energy use, improve the IAQ of classrooms, provide natural ventilation and occupant comfort, particularly in hot and dry regions [55,56]. Wind collectors' construction, operation and maintenance costs are offset by energy cost savings over an average period of 20 years [57].

In the second period (2011–2015), the strategic diagram presented in Fig. 4b shows eight relevant research themes in the 158 papers selected for this period. Of these, three motor themes, green roofs (GRS) (15.88), numerical models (12.2), and classroom (9.75); two emerging or declining themes, air exchange rates (2.44), and low energies (0.33); two highly developed and isolated themes, human activities (25), and fresh air (19.5); and one transversal theme, sustainable building (16.26). By performance measures (Table 2), the themes with the highest number of citations are human activities, sustainable building, and GRS. These research topics are present in the most significant number of papers and have a high *h-index*.

Coinciding with the rise of energy efficiency and climate change regulations, from 2010 onwards, GRS in educational institutions increased as an alternative to shrinking urban forests. Japan, for example, enacted regulations making GRS mandatory as of April 2001 for newly constructed, renovated and expanded buildings whose land area is more significant than 1000 m^2 [58]. Similarly, South Korea is implementing the Green School Project, which is implementing the repair and renovation of severely deteriorated primary and

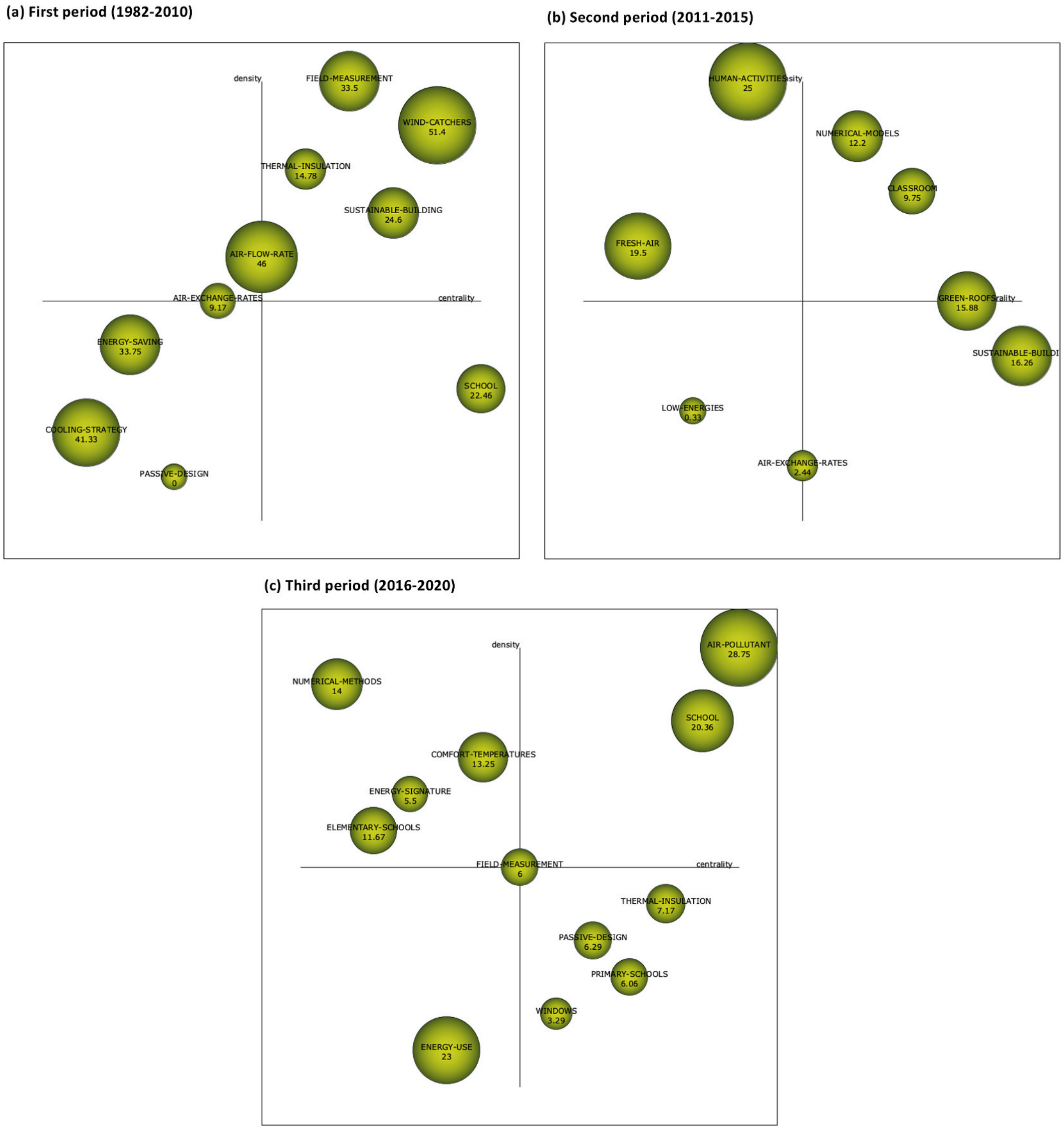

Fig. 4. Strategic diagrams by (a) first period (1982–2010); (b) second period (2011–2015); and (b) third period (2016–2020).

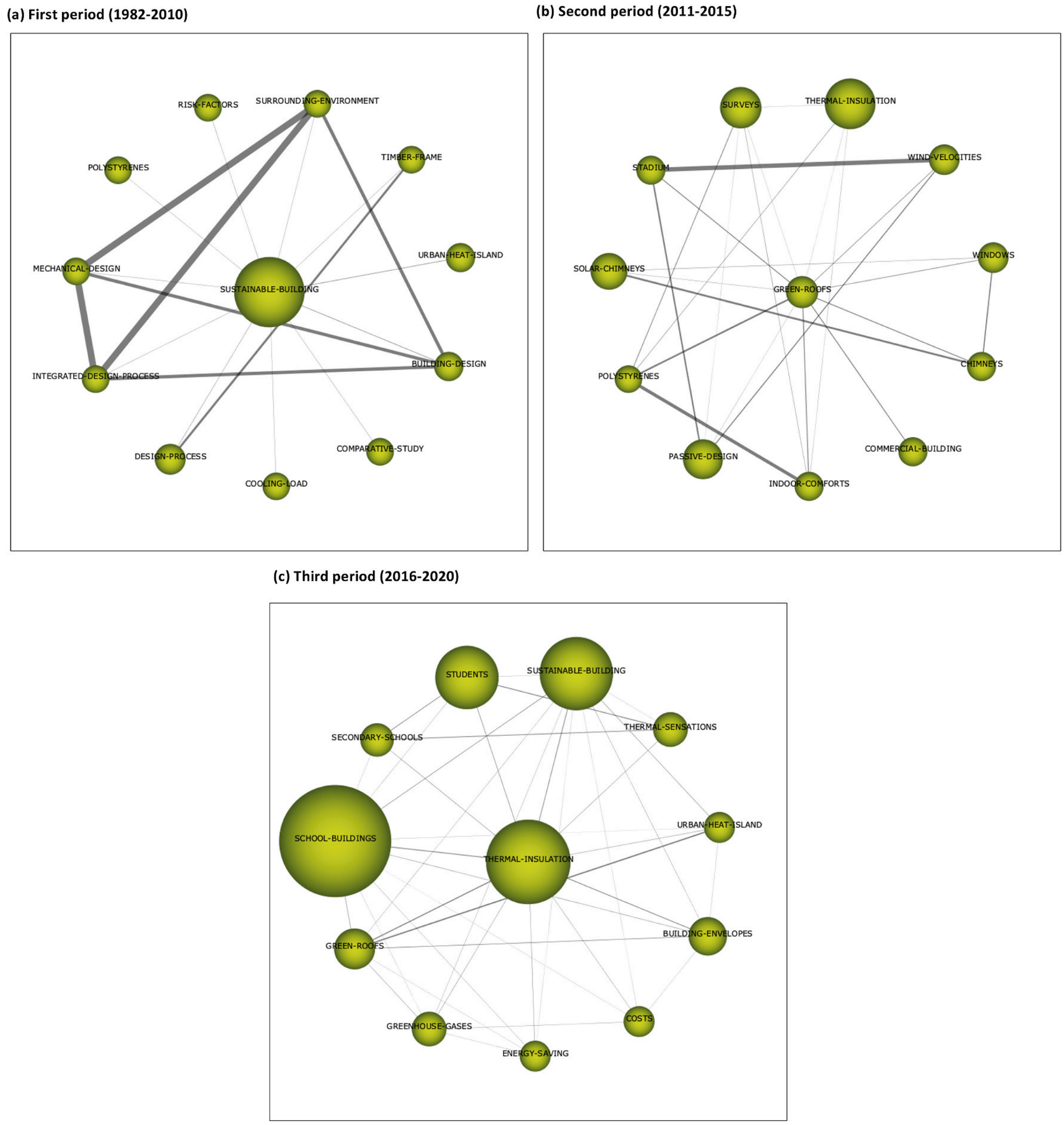

Fig. 5. Thematic networks by (a) first period (1982–2010); (b) second period (2011–2015); and (b) third period (2016–2020).

secondary school facilities using environmentally friendly techniques, including GRS [59].

It is believed that plants can reduce CO_2 concentration in nearby regions by up to 2% [58], reduce the urban heat island effect, provide open recreational spaces for building occupants, provide opportunities for recycling and composting, and function as habitats that support local species [60]. The application of GRS has increased the use of field measurement and numerical simulation techniques [61]. Despite these policy efforts and the multiple benefits, they provide, GRS is not rapidly implemented due to difficulties such as limited budgets, higher construction costs, and difficulties in the repair and maintenance aspect, among others.

In the third period (2016–2020), the strategic diagram presented in Fig. 4c shows twelve research themes in the 224 papers selected for this period. Of these, there are two motor themes, air pollutant (28.75) and school (20.36); two emerging or declining themes, energy use (23), and field measurement (6); four highly developed and isolated themes, numerical methods (14), comfort temperatures (13.25), elementary schools (11.67), and energy signature (5.5); and four primary themes, thermal insulation (7.17), passive design (6.29), primary schools (6.06), and windows (3.29). The topics with the highest citations (Table 2) are air pollutants, school, and thermal insulation. These research topics are present in the most significant number of papers and have a high *h-index*, except air-pollutant, which, although it has a high-performance measure, is present in only four papers, implying that this topic has very high relevance in the field and will become a core topic.

Indoor thermal comfort and IAQ in school classrooms are currently of interest worldwide. Mainly due to their potential impacts on

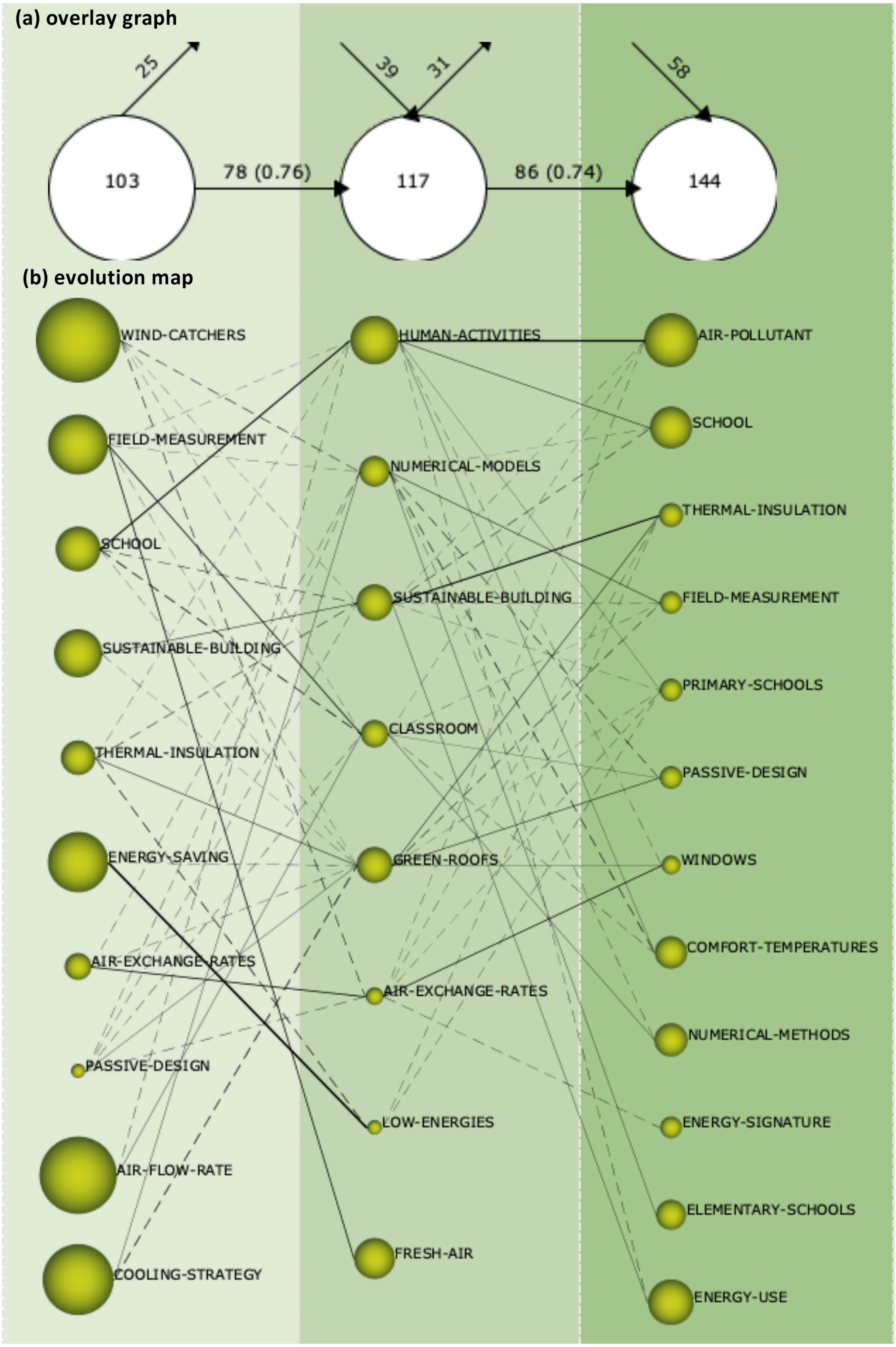

Fig. 6. (a) Overlay graph and (b) thematic evolution map.

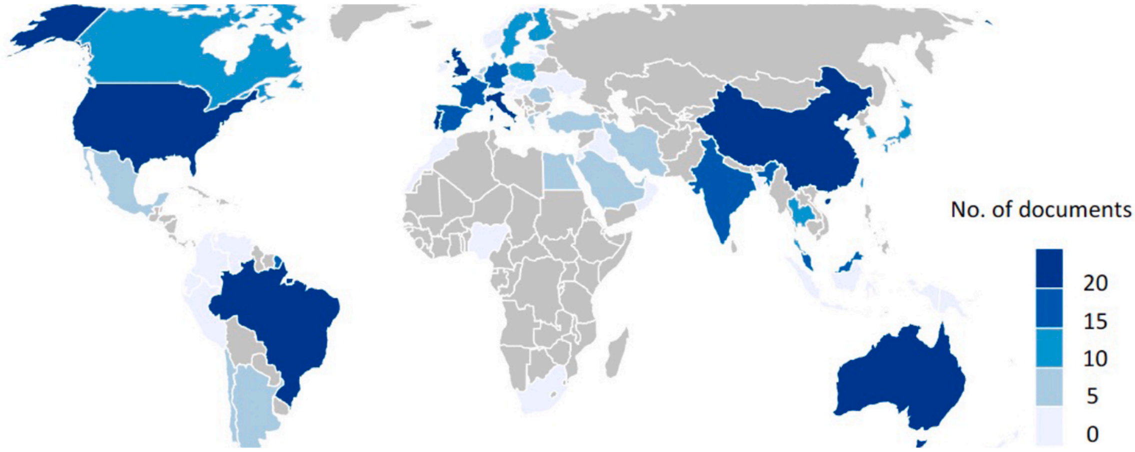

Fig. 7. Documents by country.

health, learning performance and student productivity [62]. In addition, growing concerns about climate change, Covid-19, and the development of numerical measurement methods have spurred research. Ruiz et al. [63] assessed metabolic rate and IAQ with passive environmental sensors in a classroom at Arizona State University in Tempe. Pierpaoli and Fava [64] evaluated the effects of a passive adsorbent surface on the deposition rate of pollutants to improve air quality in a classroom in Piacenza, Italy. They determined that

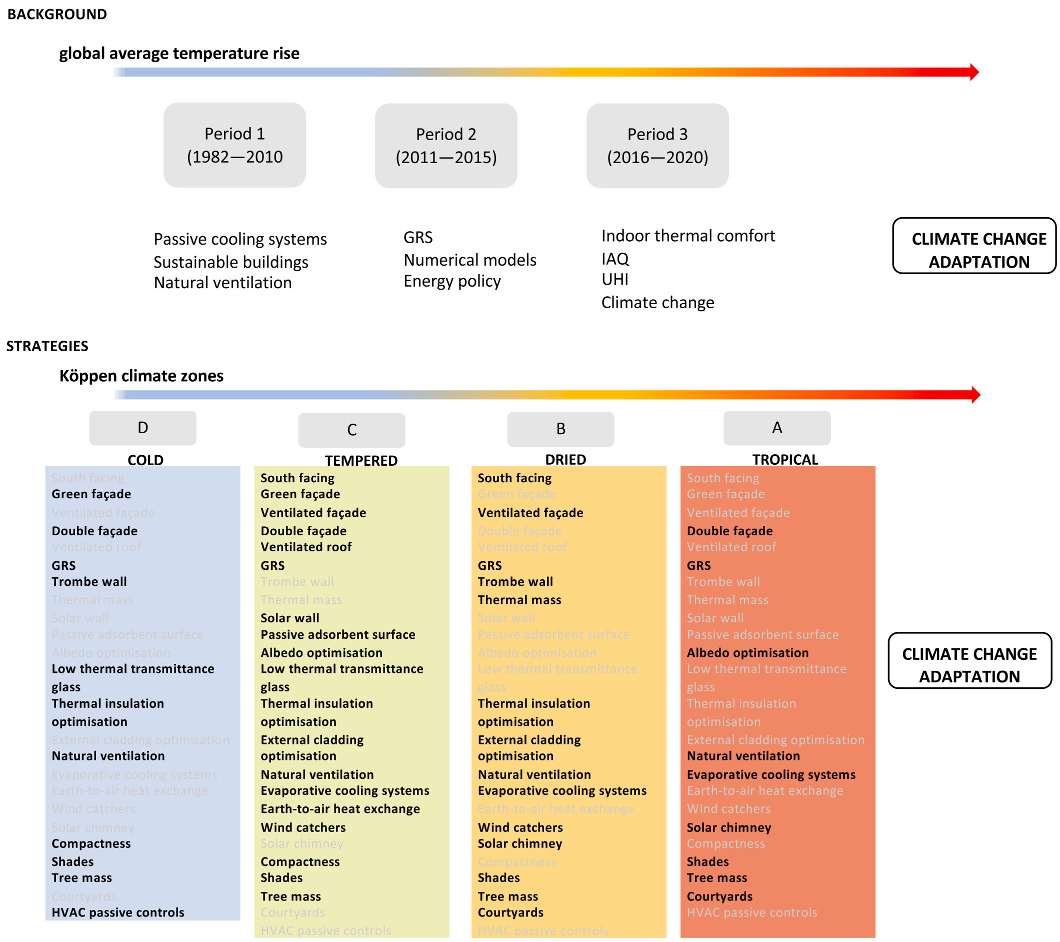

Fig. 8. Roadmap of the research field.

Table 2
Performance measures of the themes.

Name	No. of documents	No. of citations	h-Index	Centrality	Density
Period 1 (1982–2010)					
Wind catchers	5	257	5	89.19	79.17
Field measurement	4	134	3	49.74	97.84
School	37	831	27	115.04	28.08
Sustainable building	10	246	8	83.86	44.39
Thermal insulation	9	133	9	37.55	57.8
Energy saving	4	135	4	19.6	30.65
Air Exchange rates	6	55	3	33.95	32.67
Passive design	3	0	0	30.37	14.95
Air flow rate	2	92	1	36.57	40.62
Cooling strategy	3	124	2	10.06	27.78
Period 2 (2011–2015)					
Human activities	7	175	6	30.43	85.25
Numerical models	5	61	2	37.85	81.42
Sustainable building	35	569	13	97.14	21.6
Classroom	4	39	3	43.14	70.84
Green roofs	8	127	3	53.83	27.81
Air Exchange rates	9	22	3	31.5	16.13
Low energies	3	1	1	21.65	16.39
Fresh air	2	39	1	19.44	37.5
Period 3 (2016–2020)					
Air pollutant	4	115	3	134.97	125.08
School	11	224	7	97.37	53.55
Thermal insulation	66	473	12	75.42	16.97
Field measurement	10	60	5	25.3	20.37
Primary schools	18	109	6	73.55	11.97
Passive design	7	44	3	51.7	12.09
Windows	7	23	2	34.81	5.31
Comfort temperatures	4	53	3	25.1	53.47
Numerical methods	2	28	2	4.47	89.58
Energy signature	2	11	2	11.24	36.67
Elementary schools	3	35	2	6.35	20.83
Energy use	3	69	3	15.88	4.69

furnishing the classroom wall with adsorbent fabric surfaces decreases the levels of pollutants generated indoors.

3.2.2. Thematic networks

For more information on relevant topics and future trends in this section, three thematic networks were selected, one per period. In Fig. 5a, the first-period sustainable buildings are linked to other satellite themes such as building design, cooling load, polystyrenes, risk factors, and the surrounding environment. In Fig. 5b, the second-period GRS theme is linked to other satellite themes such as indoor comforts, passive-design, polystyrenes, solar chimneys, and thermal insulation. In Fig. 5c, the last period theme thermal-insulation is linked to other satellite themes such as costs, energy-saving, greenhouse gases, thermal sensations, and urban heat island.

From the graphs, the applicability of passive building design strategies is influenced by the surrounding environment, the integral effect of outdoor weather conditions and indoor thermal comfort criteria since the early years. Passive design involves changing the environment using specific architectural measures to expand the thermal comfort zone to a broader range. Over the years, researchers have raised concerns regarding CC and UHI, which increase the environmental footprint and adverse effects on human health and reduced occupant comfort. Akkose et al. [60] analysed an existing secondary school in Ankara, Turkey, and determined that total

Table 3
Main journals contributing to the research field.

Journal	No. of documents	No. of citation indexes of the total documents	Most cited document in the journal	No. of citations in the document[a]
Building and Environment	26	1046*	[72]	122
Energy and Buildings	22	894*	[73]	119
Energies	18	88	[74]	11
International Journal of Ventilation	17	173	[75]	24
Building Research and Information	6	106	[76]	45
Sustainability (Switzerland)	5	25	[77]	9
Architectural Science Review	5	18	[78]	9
Atmospheric Environment	5	362	[79]	168
Renewable Energy	5	177	[80]	95
Buildings	4	55	[81]	24

[a] number of citations as of August 15, 2021.

Table 4
Main documents are contributing to the research field.

Research study	Ref.	Keywords	No. of citations	Contributions/or gaps
(Santamouris et al., 2007)	[86]	green roof system; energy performance of buildings; passive cooling of buildings	226	Experimental investigation and analysis of the energy and environmental performance of a green roof system installed in a nursery school building in Athens
(Almeida et al., 2011)	[79]	indoor air; school; atmospheric particles; natural ventilation	167	Measurement of the levels and composition of PM 2.5 and PM 2.5–10 elements in three primary schools located in Lisbon. Study of the relationship between indoor and outdoor concentrations of atmospheric particulate matter. Identification of sources of high aerosol concentrations in classrooms.
(Mumovic et al., 2009)	[72]	indoor air quality; thermal comfort; acoustics; schools; operational performance; classroom	121	Description of a series of field measurements investigating the indoor air quality, thermal comfort, and acoustic performance of nine newly built secondary schools in England.
(Lomas, 2007)	[83]	low energy buildings; advanced natural ventilation; ventilation areas; case studies; downdraught cooling	105	Description of environmental design considerations and ventilation considerations shape the architecture of advanced naturally ventilated buildings.
(Becker et al., 2007)	[87]	school buildings; IAQ; energy performance; thermal comfort; ventilation; thermal insulation; shading	103	Analysis of successful design solutions that address the EE-TC-IAQ dilemma for a performance-based code. Distinction between improving building design variables and improving ventilation schemes.
(Montazeri et al., 2010)	[80]	two-sided wind catcher; natural ventilation; wind tunnel; analytical model; flow visualisation	95	Experimental investigation using an open-loop wind tunnel. Measurement of the volumetric airflow induced in the building and the pressure coefficients around all surfaces of the wind receiver model at various wind angles.
(Montazeri and Azizian, 2008)	[88]	windcatcher; ventilation; pressure coefficient; flow rate; experiment	92	Analysis of the hydrodynamic performance of a unilateral wind collector using experimental smoke visualisation and wind tunnel tests. Estimation of theoretical values of ventilation airflow to assess the capability of simplified models in natural ventilation studies.
(Butala and Novak, 1999)	[89]	energy audit; school buildings; energy number; energy saving	90	Energy and indoor environmental audits of energy consumption and indoor air quality in 24 school buildings in Slovenia
(Tippayawong et al., 2009)	[90]	classroom; I/O ratios; natural ventilation; particle number: size-dependent	88	Monitoring the indoor and outdoor concentrations of resolved size particles in a naturally ventilated classroom and investigating the factors influencing their levels and relationships.

[a]number of citations as of August 15, 2021.

energy consumption can be reduced by 50%. At the same time, potential reductions in indoor discomfort are even more pronounced, highlighting the importance of selecting the optimal combination of passive strategies for maximum impact towards adapting existing educational buildings to changing climatic conditions.

Another critical issue in the field is the cost of passive strategies that generally have a more extended payback period than active ones [65]. Nevertheless, passive strategies have a low additional capital investment cost compared to the potential benefit in energy savings [66,67]. However, passive solutions, such as natural lighting and ventilation, are sensitive to weather and outdoor conditions and therefore have application limitations [68–71].

3.2.3. Overlay graph and thematic evolution map

The evolution of topics over time, Fig. 6ab represents the number of keywords per period and their evolution, the number of incoming and outgoing keywords, and the number and percentage of keywords retained from one period to the next. The horizontal

Table 5
The main authors are contributing to the research field.

Author	Affiliation	h-index	Document		
			No.	Citations[a]	Most cited
Luca Stabile	Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Italy	37	7	212	[82]
Eusébio Z. E. Conceição	Faculty of Sciences and Technology, University of Algarve, Portugal	16	7	94	[85]
Azadeh Montazami	London Metropolitan University, United Kingdom	9	5	54	[91]
Dejan Mumovic	The Bartlett School of Graduate Studies, University College, UK	20	5	135	[72]
Jimin Kim	Department of Public Health Science, Graduate School of Korea University, Republic of Korea	4	5	52	[92]
Jiying Liu	School of Thermal Engineering, Shandong Jianzhu University, Jinan, China	13	5	84	[93]
Angelamaria Massimo	Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Italy	6	5	146	[82]
Ma Manuela J.R. Lúcio	Vertical Grouping of Schools Professor Paula Nogueira, Portugal	15	5	66	[85]
Kevin J. Lomas	Institute of Energy and Sustainable Development, De Montfort University, UK	34	5	232	[83]
Cook, M.	Short and Associates Chartered Architects, Borough, UK	21	4	32	[84]

[a] number of citations as of August 15, 2021.

Table 6
Passive intervention strategies in different Köppen climate zones.

Köppen climate zones/country country	South facing	Green façade	Ventilated façade	Double façade	Ventilated roof	GRS	Trombe wall	Thermal mass	Solar wall	Passive adsorbent surface	Albedo optimisation
A EE. UU. (Miami)						✓					✓
B EE. UU. (Las Vegas)						✓					
B EE. UU. (Kansas)	✓							✓			
B EE. UU. (Phoenix)						✓					
C EE.UU. (Texas)											
D EE.UU. (Boston)											
C Canada (Vancouver)						✓					✓
C La Pampa			✓	✓							
A Ecuador (Guayaquil)				✓							
C Chile (Santiago)				✓	✓						
B Turkey			✓						✓		
C China (Whuan)						✓					
D China (Beijing)						✓					
C China (Nanjing)						✓					
B China (Lanzhou)							✓				
B India (Delhi)											
C Taiwan (Taipei)						✓					
D South Korea (Seul)						✓					
A Thailand											
D Serbia (Niš)		✓		✓		✓	✓				
B Cyprus						✓					
D Sweden											
C Spain (Seville)	✓	✓									✓
B Spain (Melilla)			✓								
C (France) Aquitaine			✓								
C UK (Liverpool, Londres)	✓										
D Czech Republic											
C Italy		✓				✓				✓	
C Suiza				✓							
C Portugal (Algarve)		✓				✓					
C Dinamarca											
C Greece (Athens)						✓					
B Egypt (El Cairo)											
C Lebanon	✓										
B Iran (Yazd)											
B Sudan (Khartoum)			✓								
B United Arab Emirates		✓									
B Kuwait											
C Palestine									✓		
B Israel (Jerusalem)	✓										
B Saudi Arabia											
C Australia (New South Wales)					✓						✓

arrow represents the number of words shared by both periods. The top incoming arrow represents the number of new words in period two, and the top outgoing arrow represents the words that disappear in period 2.

As Fig. 6a shows, the number of keywords increases over the years, parallel to the number of documents. The number of keywords increases from 103 to 144 between the first and the last period, a growth rate of 140%. Specifically, of 103 keywords that appeared in the first period, 76% remain in the second period, and 39 new words are added, giving a total of 117 words. Finally, 86 (74%) keywords remain from the second period in the third period, and 58 new keywords appear, resulting in 144. These results indicate that the number of new and transitional keywords is high and that the number of keywords shared by successive periods has increased. Thus, the increasing thematic diversity of the research field and the fact that keywords are coming back more strongly in the following periods could indicate that this research field is gradually consolidating.

Fig. 6b shows the research field's thematic evolution by analysing the themes' origins and interrelationships. For the second period, the school theme appeared with the highest number of essential documents and evolved into human activities, sustainable buildings, classrooms, and GRS. In the second period, the sustainable building theme evolves towards air pollutants, thermal insulation, field measurement, primary school, and energy use by 2020.

Glass a with low thermal transmittance	Thermal insulation optimisation	external cladding optimisation	Natural ventilation	Evaporative cooling systems	earth-to-air heat exchange	Wind catchers	Solar chimney	Compact ness	Shades	Tree mass	Courtyards	HVAC passive controls	Ref.
													[94]
	✓												[94]
		✓							✓				[95]
									✓	✓			[96,97]
									✓	✓			[98]
									✓	✓			[99]
	✓								✓	✓			[94,100]
					✓			✓					[101,102]
			✓				✓			✓	✓		[103]
	✓												[102,104]
	✓						✓			✓			[60, 105–107]
													[108]
													[109]
													[110]
													[111]
			✓										[112]
													[113]
	✓		✓					✓					[59,92, 114,115]
			✓	✓					✓				[90,116]
									✓				[117]
													[118]
✓	✓							✓				✓	[119]
											✓		[120,121]
		✓											[122]
		✓											[123]
			✓	✓		✓		✓					[72,83,84, 124–126]
✓	✓		✓										[114,127, 128]
													[64,129]
			✓										[130]
	✓												[85, 131–133]
			✓										[134]
	✓						✓			✓	✓		[86, 135–138]
									✓	✓			[139,140]
													[140,141]
						✓	✓				✓		[80,141]
				✓									[102]
	✓		✓										[142,143]
						✓							[144]
			✓						✓				[107,145]
✓								✓					[146]
✓	✓	✓											[147,148]
										✓			[149]

3.2.4. Performance analysis

537 relevant papers and 308 journals were selected for the study. Table 3 shows the top ten journals in descending order of the number of papers published. These journals account for 21% of the 537 documents. Most of these are research journals focusing on building science, urban physics, human interaction with the indoor and outdoor built environment, energy demand and consumption in existing and future buildings, indoor environmental quality, solar and other renewable energy sources in buildings.

Table 3 also includes the total number of citations of the papers in each journal. As can be seen, the number of articles and citations are not closely related, as only two of the top two journals (identified in Table 2 with an *), in terms of multiple articles, are also among the top five in multiple citations. In other terms, the most prolific sources have not necessarily been those with the highest research impact.

The 537 documents analysed received a total of 4873 citations. Table 4 lists the ten papers with the highest number of citations, a total of 1165, accounting for 24%. The most cited papers focus on different aspects of the research field analysed, revealing its diversity. These papers deal with the measurement of atmospheric particle concentration levels inside classrooms, analysis of the relationship between the opening of windows and the indoor-outdoor temperature difference, application of questionnaires to obtain the natural thermal sensation, among others.

The ten authors with the highest number of papers were identified (Table 5). In the case of the *h-index*, Luca Stabile has the highest *h-index* (h = 37), followed by Kevin J. Lomas, with an h-index = 22. Luca Stabile focuses on the evaluation of air permeability and ventilation rate in Italian classrooms [82]. Kevin J. Lomas discussed Advanced buildings with chimney ventilation have the potential to consume much less energy for space conditioning than typical buildings with mechanical ventilation or air conditioning [83]. Table 5 shows that although Malcolm Cook ranks last in published papers, his *h-index* is higher than most (h = 21). Malcolm Cook analyzed report on the commissioning and monitoring of the School of Slavonic and East European Studies, London, with passive cooling and downdraft [84]. Eusébio Z. E. Conceição applied an adaptive model and evaluated thermal comfort in ventilated spaces occupied by nursery schools, through a study, carried out in real conditions, in a Mediterranean environment for cold and warm thermal conditions [85].

Fig. 7 shows the scientific production by country. In Seventy-two countries that generate documents on the field of research, the UK accounts for 15.7% of the documents, followed by the USA, China, Italy, and Portugal with 10.8%, 10.2%, 6.14% and 5.6%. Most of the scientific production is in developed countries, with Europe and North America generating most research. However, these papers are not only focused on their countries of origin but also analyse passive intervention strategies in different countries around the world, with those with warmer climates prevailing.

3.3. Identification de strategies of passive intervention in school

Finally, after reviewing the 67 most relevant SLR documents, Table 6 identifies 24 passive design intervention strategies in schools in 42 different countries and Köppen climate zones.

3.3.1. Green roofs

The most prevalent passive strategy is GRS, followed by optimisation of thermal insulation, present in 14 and 12 of the identified countries. These measures are applied in schools in various climatic zones, from classification A, regions with hot, humid tropical climates, to D, regions with cold climates. The work of Mahmoodzadeh et al. [94], who conducted A parametric analysis, was conducted to evaluate the influence of green roof design parameters on the thermal and energy performance of a school building in different climate zones in North America. Optimal green roof parameters were found to be functionally related to the weather conditions in each city.

3.3.2. Natural ventilation, thermal insulation optimisation and IAQ

It is observed that the optimisation of thermal insulation occurs in areas with colder climates to reduce heating consumption. The work of Englund et al. [119] analyses a high school in Sweden and indicates that the best potential renovation measures are shifting to efficient windows, better enclosure tightness, new HVAC system controls, and increased thermal insulation of external walls.

Natural ventilation is also present in all climate zones, and 9 of the countries identified, from cold regions such as Seoul (climate zone D) to more tropical climates such as Guayaquil (climate zone A). Beltran et al. [103] studied four ventilation strategies in Guayaquil, Ecuador, one-sided ventilation, cross ventilation, solar chimney, and double façade. The results show that the exclusive use of natural ventilation is inefficient to guarantee hygrothermal comfort in a building with high thermal loads in a hot-humid climate. However, by using a hybrid system (natural ventilation/dehumidification and cooling), the cooling energy consumption can be reduced by up to 10.6% without compromising the hygrothermal comfort of the occupants.

Becker et al. [146] analysed the energy efficiency-thermal comfort-IAQ dilemma. They concluded that the effective ventilation rates required in crowded spaces to provide adequate indoor air quality could cause significant energy losses in school buildings. They established a set of design variables for schools that are energy efficient while providing IAQ levels as well as thermal and visual comfort; and (a set of preferred ventilation schemes that improve energy efficiency without reducing other performance levels.

While such strategies are controversial due to heat loss in cold climates, where compactness and airtightness are the primary passive design strategies [130], the energy-efficient design of classrooms in school buildings should be primarily concerned with providing optimal solutions to cope with the above dilemma.

3.3.3. Tree mass and shade

Trees and plants can provide solar protection and reduce urban temperatures through evapotranspiration; they mitigate the greenhouse effect, filter pollutants, mask noise, prevent soil erosion and calm human observers [150]. The study by Vanos et al. [98] assessed the thermal comfort of children (aged 9–13 years) due to changes in incident radiation and metabolism when children were outdoors in the sun and shade when warm weather prevailed. The model adequately predicted the children's thermal sensation and simulated the biophysical energy flows modified by activity and urban design interventions (metabolic heat and radiation, respectively).

Schulman and Peters [99] applied Geographic Information System software to classify and compare land cover in 75 schoolyards in Baltimore, Boston and Detroit, USA. The schoolyards were dominated primarily by turf and impervious surfaces. Tree canopy occupied the ground cover in 13% of schoolyards, 24% and 28% of schoolyards had no fine or coarse vegetation, respectively, while 11% of schoolyards had no green space at all. Schoolyards in Boston were characterised by very high levels of impervious surface cover and low levels of green space, with 30% of schoolyards having no tree cover and more than 10% having no green space at all. Another study conducted in a school located in Cairo, Egypt [140], concludes that specific patterns and types of trees, among other landscape elements, enormously improve the microclimate within the size of schoolyards. They significantly attenuate direct radiation, modify wind speed and direction, significantly reduce temperature, and change humidity.

In the case of France, Paris has started to implement a cooling programme for all schools, starting first with the gradual replacement of its ubiquitous asphalt with vegetation. Paris envisions schoolyards as excellent shelters that welcome people vulnerable to heat-waves during extreme weather events. Paris also wants to design schoolyards to support urban agriculture to improve the resilience of the city's food systems. With broad stakeholder participation, the greening of the "Oasis" schoolyard started in 2018 in 3 schools and is expected to finish covering all schools by 2040 [151].

Previous studies show that when hot weather, intense solar radiation and UHI prevail, Physiologically Equivalent Temperature values can be high, especially in climate change scenarios, which can induce dangerous and unsafe conditions for children [100]. Therefore, increased shade can increase physical activity and protect children from hot surfaces, thermal discomfort, and ultraviolet radiation [97]. However, the maintenance of these green masses (staffing, technical infrastructure, budget, low water availability, inadequate space for root systems and soil compaction due to high impermeability) means that their use is sometimes limited [152]. However, an alternative for maintenance optimisation could be sustainable greywater management in the building, considerably reducing economic and environmental costs. In addition, many countries have started to incorporate passive schoolyard retrofit interventions in national shade guidelines that include the use of shade and good practices adapted to local climates [153,154].

Finally, the above results show and as summarised in the diagram in Fig. 8, research is increasingly being directed towards activities aimed at mitigating and adapting to climate change. This is explained by the acceleration of climate change, where winters will be increasingly milder and summers warmer. Thus, in the future, the demand for heating in schools will decrease, while there will be a very significant increase in the demand for cooling. Furthermore, the roadmap in Fig. 8 highlights the need to apply bioclimatic techniques in school buildings, building on the progress already achieved, identifying the most optimised measures, and promoting the creation of action guidelines to serve as a protocol to be followed in future studies. These guidelines could serve as a standardised procedure for eco-efficient renovation and adaptation of the building stock, based on strategies adopted in different climate zones. It should be noted that the strategies identified by climate zones (Fig. 8) can be extrapolated to other buildings such as dwellings.

4. Conclusions

Research trends in passive intervention strategies in schools were analysed across three periods, 1982–2010; 2011–2015; 2016–2020. The results show a constantly evolving research field that has not yet reached a stage of maturity and an exponential increase in the number of papers, especially in the last five years.

Concerning the strategic diagrams, the thematic networks, the overlay graph, and the thematic evolution map show that, in the early years, research focused on natural ventilation, especially in arid climates. Coinciding with the rise of energy efficiency regulations, from 2010 onwards, GRS increased as an alternative to urban forest decline and as a solution for UHI mitigation. Over the past few years, the growing concern about climate change, sustainable development, Covid-19, and numerical measurement methods have driven work on occupant comfort and IAQ, while research on cost overruns and payback of passive versus active design.

Moreover, strategies have evolved in parallel to regulations and policies and as technologies, especially those related to measurement systems, have become more relevant. It is reflected in the recent period where particular focus is placed on occupant ergonomics and environmental conditions beyond thermal comfort or energy demand reduction.

In terms of performance measures, 5 of the 308 journals accounts for 21% of the analysed papers, focusing on building science, urban physics, human interaction with the indoor and outdoor built environment, energy demand and consumption in existing and future buildings, indoor environmental quality, application of solar and other renewable energy sources in buildings, among others. The 537 analysed papers received a total of 4873 citations, with only ten papers receiving 24% of the total citations. These most cited papers analyse the concentration levels of atmospheric particles inside classrooms, the relationship between the opening of windows and the indoor-outdoor temperature difference, and questionnaires to obtain the natural thermal sensation.

Regarding identifying the identified strategies, after reviewing the 67 most relevant SLR documents, 24 passive design interventions were identified in schools in 42 different locations and climatic zones of Köppen. GRS, natural ventilation, optimisation of thermal insulation, tree masses and shading are highlighted as the most prolific and high performing passive intervention strategies. However, the studies' results emphasise the importance of the balance between these measures to reduce heat gain losses.

The above findings provide a detailed understanding of the status quo for researchers, practitioners, and policymakers and predict the dynamic directions of the field. The results highlighted the need to apply passive design techniques in school buildings to increase their resilience to face climate change.

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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References

[1] R. Alawneh, F. Ghazali, H. Ali, A.F. Sadullah, A Novel framework for integrating United Nations Sustainable Development Goals into sustainable non-residential building assessment and management in Jordan, Sustainable Cities and Society 49 (2019), https://doi.org/10.1016/j.scs.2019.101612.

[2] European Commission, Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. https://eur-lex.europa.eu/eli/dir/2018/844/oj, 2018. (Accessed 2 August 2021).

[3] A. Serrano-Jiménez, P. Femenías, L. Thuvander, Á. Barrios-Padura, A multi-criteria decision support method towards selecting feasible and sustainable housing renovation strategies, J. Clean. Prod. 278 (2021), https://doi.org/10.1016/J.JCLEPRO.2020.123588.

[4] J. Bull, A. Gupta, D. Mumovic, J. Kimpian, Life cycle cost and carbon footprint of energy efficient refurbishments to 20th century UK school buildings, Int. J. Sustain. Built Env. 3 (2014) 1–17, https://doi.org/10.1016/J.IJSBE.2014.07.002.

[5] S. Habibi, O. Pons Valladares, D. Peña, New sustainability assessment model for Intelligent Façade Layers when applied to refurbish school buildings skins, Sustain. Energy Technol. Assess. 42 (2020), 100839, https://doi.org/10.1016/J.SETA.2020.100839.

[6] M. Gil-Baez, Á.B. Padura, M.M. Huelva, Passive actions in the building envelope to enhance sustainability of schools in a Mediterranean climate, Energy 167 (2019) 144–158, https://doi.org/10.1016/J.ENERGY.2018.10.094.

[7] A. Serrano-Jiménez, J. Hiruelo-Pérez, E. Ramírez-Juidias, Á. Barrios-Padura, Identifying design shortcomings and heat-island effects in schools located in warm climates: an outdoor environmental assessment procedure based on remote sensing tools, J. Building Eng. 43 (2021), 103209, https://doi.org/10.1016/J.JOBE.2021.103209.

[8] B.J. Wachenfeldt, M. Mysen, P.G. Schild, Air flow rates and energy saving potential in schools with demand-controlled displacement ventilation, Energy Build. 39 (2007) 1073–1079, https://doi.org/10.1016/J.ENBUILD.2006.10.018.

[9] T. Karimipanah, H.B. Awbi, M. Sandberg, C. Blomqvist, Investigation of air quality, comfort parameters and effectiveness for two floor-level air supply systems in classrooms, Build. Environ. 42 (2007) 647–655, https://doi.org/10.1016/J.BUILDENV.2005.10.016.

[10] D.A. Coley, R. Greeves, B.K. Saxby, The effect of low ventilation rates on the cognitive function of a primary school class, Int. J. Vent. 6 (2016) 107–112, https://doi.org/10.1080/14733315.2007.11683770.

[11] H. Feriadi, N.H. Wong, Thermal comfort for naturally ventilated houses in Indonesia, Energy Build. 36 (2004) 614–626, https://doi.org/10.1016/J.ENBUILD.2004.01.011.

[12] S.P. Corgnati, M. Filippi, S. Viazzo, Perception of the thermal environment in high school and university classrooms: subjective preferences and thermal comfort, Build. Environ. 42 (2007) 951–959, https://doi.org/10.1016/J.BUILDENV.2005.10.027.

[13] A. Brás, A. Rocha, P. Faustino, Integrated approach for school buildings rehabilitation in a Portuguese city and analysis of suitable third party financing solutions in EU, J. Build. Eng. 3 (2015) 79–93, https://doi.org/10.1016/J.JOBE.2015.05.003.

[14] W. Wang, H. Rivard, R. Zmeureanu, Floor shape optimization for green building design, Adv. Eng. Inf. 20 (2006) 363–378, https://doi.org/10.1016/J.AEI.2006.07.001.

[15] D. Mulvaney, Innovation, Sustainability, and Environmental Justice, first ed., University of California Press, 2019 https://doi.org/10.2307/j.ctvd1c6zh.

[16] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 2011.

[17] S. Liu, Y.T. Kwok, K.K.L. Lau, W. Ouyang, E. Ng, Effectiveness of passive design strategies in responding to future climate change for residential buildings in hot and humid Hong Kong, Energy Build. 228 (2020), 110469, https://doi.org/10.1016/J.ENBUILD.2020.110469.

[18] P. Rahm, Meteorological Architecture, vol. 79, Architectural Design, 2009, pp. 30–41, https://doi.org/10.1002/AD.885.

[19] C. Díaz-López, M. Carpio, M. Martín-Morales, M. Zamorano, Defining strategies to adopt Level(s) for bringing buildings into the circular economy. A case study of Spain, J. Clean. Prod. 287 (2021), https://doi.org/10.1016/j.jclepro.2020.125048.

[20] T. Ahmad, M.J. Thaheem, A. Anwar, Developing a green-building design approach by selective use of systems and techniques. https://doi.org/10.1080/17452007.2015.1095709, 2015, 12,29,50.

[21] B.A. Maleki, Shading: passive cooling and energy conservation in buildings, Int. J. Technic. Physical Problems of Eng. (IJTPE) 3 (2011) 72–79.

[22] F. Manzano-Agugliaro, F.G. Montoya, A. Sabio-Ortega, A. García-Cruz, Review of bioclimatic architecture strategies for achieving thermal comfort, Renew. Sustain. Energy Rev. 49 (2015) 736–755, https://doi.org/10.1016/J.RSER.2015.04.095.

[23] E. Millán, M.-V. Belmonte, M. Ruiz-Montiel, J. Gavilanes, J.L.P. de-la Cruz, An intelligent tool to assist architecture students in the early stages of design, in: 22nd International Conference on Computers in Education, 2014, pp. 22–31.

[24] C. Díaz-López, J. Jódar, K. Verichev, M. Luis Rodríguez, M. Carpio, M. Zamorano, Dynamics of changes in climate zones and building energy demand, A Case Study in Spain 11 (9) (2021), 4261, https://doi.org/10.3390/app11094261.

[25] J.J. de la Torre Bayo, C. Díaz-López, M.L.M.L. Rodríguez González, E.M.E.M. Ibarra, M. Zamorano, Climate classification and its applicability to buildings, WIT Trans. Ecol. Environ. 238 (2019) 311–318, https://doi.org/10.2495/SC190281.

[26] T. Niemelä, R. Kosonen, J. Jokisalo, Cost-optimal energy performance renovation measures of educational buildings in cold climate, Appl. Energy 183 (2016) 1005–1020, https://doi.org/10.1016/J.APENERGY.2016.09.044.

[27] F. Ascione, N. Bianco, R.F. de Masi, G.M. Mauro, G.P. Vanoli, Energy retrofit of educational buildings: transient energy simulations, model calibration and multi-objective optimization towards nearly zero-energy performance, Energy Build. 144 (2017) 303–319, https://doi.org/10.1016/J.ENBUILD.2017.03.056.

[28] S.S. Herrera-Gomez, A. Quevedo-Nolasco, L. Pérez-Urrestarazu, The role of green roofs in climate change mitigation, A case study in Seville (Spain), Building Environ. 123 (2017) 575–584, https://doi.org/10.1016/J.BUILDENV.2017.07.036.

[29] L. Pierangioli, G. Cellai, R. Ferrise, G. Trombi, M. Bindi, Effectiveness of passive measures against climate change: case studies in Central Italy, Building Simulation 10 (2017) 459–479, https://doi.org/10.1007/S12273-016-0346-8, 2017 10:4.

[30] E.C.M. Noyons, H.F. Moed, M. Luwel, Combining mapping and citation analysis for evaluative bibliometric purposes: a bibliometric study, J. Am. Soc. Inf. Sci. 50 (1999) 115–131, https://doi.org/10.1002/(SICI)1097-4571(1999)50:2<115::AID-ASI3>3.0.CO;2-J.

[31] K. van Nunen, J. Li, G. Reniers, K. Ponnet, Bibliometric analysis of safety culture research, Saf. Sci. 108 (2018) 248–258, https://doi.org/10.1016/J.SSCI.2017.08.011.

[32] A. Pritchard, Statistical bibliography or bibliometrics, J. Doc. 25 (1969) 348–349.

[33] M.D. Martínez-Aires, M. López-Alonso, M. Martínez-Rojas, Building information modeling and safety management: a systematic review, Saf. Sci. 101 (2018) 11–18, https://doi.org/10.1016/J.SSCI.2017.08.015.

[34] B. Kitchenham, S. Charters, Procedures for Performing Systematic Literature Reviews in Software Engineering, Keele University & Durham University, UK, 2007.

[35] A. Liberati, D.G. Altman, J. Tetzlaff, C. Mulrow, P.C. Gøtzsche, J.P.A. Ioannidis, M. Clarke, P.J. Devereaux, J. Kleijnen, D. Moher, The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration, BMJ (Clinical Research Ed. 339 (2009) b2700, https://doi.org/10.1136/bmj.b2700.

[36] SciMAT - science mapping anaylsis tool, n.d. https://sci2s.ugr.es/scimat/. (Accessed 21 October 2021).

[37] M. Callon, J.-P. Courtial, W.A. Turner, S. Bauin, From translations to problematic networks: an introduction to co-word analysis, Soc. Sci. Inf. 22 (1983) 191–235, https://doi.org/10.1177/053901883022002003.

[38] J.E. Hirsch, An index to quantify an individual's scientific research output, Proc. Natl. Acad. Sci. U. S. A. 102 (2005) 16569–16572, https://doi.org/10.1073/pnas.0507655102.

[39] M. Callon, J.P. Courtial, F. Laville, Co-word analysis as a tool for describing the network of interactions between basic and technological research: the case of polymer chemsitry, Scientometrics 22 (1991) 155–205, https://doi.org/10.1007/BF02019280.

[40] N. Coulter, I. Monarch, S. Konda, Software engineering as seen through its research literature: a study in co-word analysis, J. Am. Soc. Inf. Sci. 49 (1998) 1206–1223, https://doi.org/10.1002/(SICI)1097-4571(1998)49:13<1206::AID-ASI7>3.0.CO;2-F.

[41] M.A. Martínez, M.J. Cobo, M. Herrera, E. Herrera-Viedma, Analyzing the scientific evolution of social work using science mapping, Res. Soc. Work. Pract. 25 (2015) 257–277, https://doi.org/10.1177/1049731514522101.

[42] M.J. Cobo, A.G. López-Herrera, E. Herrera-Viedma, F. Herrera, An approach for detecting, quantifying, and visualizing the evolution of a research field: a practical application to the Fuzzy Sets Theory field, Journal of Informetrics 5 (2011) 146–166, https://doi.org/10.1016/j.joi.2010.10.002.
[43] L. Alcaide-Muñoz, M.P. Rodríguez-Bolívar, M.J. Cobo, E. Herrera-Viedma, Analysing the Scientific Evolution of E-Government Using a Science Mapping Approach, vol. 34, Government Information Quarterly, 2017, pp. 545–555, https://doi.org/10.1016/J.GIQ.2017.05.002.
[44] M.E. Hernández Cerda, M. de J. Ordoñez Díaz, J. Giménez de Azcárate, M.E. Hernández Cerda, M. de J. Ordoñez Díaz, J. Giménez de Azcárate, Análisis comparativo de dos sistemas de clasificación bioclimática aplicados en México, Investigaciones Geográficas, 2018, https://doi.org/10.14350/RIG.57451, 0–0.
[45] A. Tejero-González, M. Andrés-Chicote, P. García-Ibáñez, E. Velasco-Gómez, F.J. Rey-Martínez, Assessing the applicability of passive cooling and heating techniques through climate factors: an overview, Renew. Sustain. Energy Rev. 65 (2016) 727–742, https://doi.org/10.1016/J.RSER.2016.06.077.
[46] European Commission, Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings, Official Journal of the European Union, 2010. https://eur-lex.europa.eu/eli/dir/2010/31/oj. (Accessed 9 September 2021).
[47] United Nation, Adoption of the Paris Agreement, 2015. Paris.
[48] N. Khan, Y. Su, S.B. Riffat, A review on wind driven ventilation techniques, Energy Build. 40 (2008) 1586–1604, https://doi.org/10.1016/J.ENBUILD.2008.02.015.
[49] B.M. Jones, R. Kirby, Quantifying the performance of a top-down natural ventilation Windcatcher^{TM}, Build. Environ. 44 (2009) 1925–1934, https://doi.org/10.1016/j.buildenv.2009.01.004.
[50] Z. Hedayat, B. Belmans, M.H. Ayatollahi, I. Wouters, F. Descamps, Performance Assessment of Ancient Wind Catchers - an Experimental and Analytical Study, Energy Procedia, 2015, pp. 2578–2583, https://doi.org/10.1016/j.egypro.2015.11.292.
[51] H. Montazeri, Experimental and numerical study on natural ventilation performance of various multi-opening wind catchers, Build. Environ. 46 (2011) 370–378, https://doi.org/10.1016/J.BUILDENV.2010.07.031.
[52] J.K. Calautit, B.R. Hughes, S.S. Shahzad, CFD and wind tunnel study of the performance of a uni-directional wind catcher with heat transfer devices, Renew. Energy 83 (2015) 85–99, https://doi.org/10.1016/j.renene.2015.04.005.
[53] D. Etheridge, A perspective on fifty years of natural ventilation research, Build. Environ. 91 (2015) 51–60, https://doi.org/10.1016/J.BUILDENV.2015.02.033.
[54] M. Gil-Baez, Á. Barrios-Padura, M. Molina-Huelva, R. Chacartegui, Natural ventilation systems in 21st-century for near zero energy school buildings, Energy 137 (2017) 1186–1200, https://doi.org/10.1016/J.ENERGY.2017.05.188.
[55] S.H. Hosseini, E. Shokry, A.J. Ahmadian Hosseini, G. Ahmadi, J.K. Calautit, Evaluation of Airflow and Thermal Comfort in Buildings Ventilated with Wind Catchers: Simulation of Conditions in Yazd City, Iran, vol. 35, Energy for Sustainable Development, 2016, pp. 7–24, https://doi.org/10.1016/J.ESD.2016.09.005.
[56] M.N. Bahadori, Passive cooling systems in Iranian architecture, Sci. Am. 238 (1978) 144–154, https://doi.org/10.1038/SCIENTIFICAMERICAN0278-144.
[57] H. Goudarzi, A. Mostafaeipour, Energy saving evaluation of passive systems for residential buildings in hot and dry regions, Renew. Sustain. Energy Rev. 68 (2017) 432–446, https://doi.org/10.1016/J.RSER.2016.10.002.
[58] T. Hong, J. Kim, C. Koo, LCC and LCCO2 analysis of green roofs in elementary schools with energy saving measures, Energy Build. 45 (2012) 229–239, https://doi.org/10.1016/J.ENBUILD.2011.11.006.
[59] T.W. Kim, K.G. Lee, W.H. Hong, Energy consumption characteristics of the elementary schools in South Korea, Energy Build. 54 (2012) 480–489, https://doi.org/10.1016/J.ENBUILD.2012.07.015.
[60] G. Akkose, C. Meral Akgul, I.G. Dino, Educational building retrofit under climate change and urban heat island effect, J. Build. Eng. 40 (2021), 102294, https://doi.org/10.1016/J.JOBE.2021.102294.
[61] J.F. Li, O.W.H. Wai, Y.S. Li, J.M. Zhan, Y.A. Ho, J. Li, E. Lam, Effect of green roof on ambient CO2 concentration, Build. Environ. 45 (2010) 2644–2651, https://doi.org/10.1016/J.BUILDENV.2010.05.025.
[62] A. Guais, G. Brand, L. Jacquot, M. Karrer, S. Dukan, G. Grévillot, T.J. Molina, J. Bonte, M. Regnier, L. Schwartz, Toxicity of carbon dioxide: a review, Chem. Res. Toxicol. 24 (2011) 2061–2070, https://doi.org/10.1021/TX200220R.
[63] I. Ruiz, M. Sprowls, Y. Deng, D. Kulick, H. Destaillats, E.S. Forzani, Assessing metabolic rate and indoor air quality with passive environmental sensors, J. Breath Res. 12 (2018), https://doi.org/10.1088/1752-7163/aaaec9.
[64] P. Mattia, F. Gabriele, A passive opportunity for improving air quality in the schools environment: a real-world scale testing, Am. J. Environ. Sci. 12 (2016) 206–212, https://doi.org/10.3844/AJESSP.2016.206.212.
[65] X. Sun, Z. Gou, S.S.Y. Lau, Cost-effectiveness of active and passive design strategies for existing building retrofits in tropical climate: case study of a zero energy building, J. Clean. Prod. 183 (2018) 35–45, https://doi.org/10.1016/J.JCLEPRO.2018.02.137.
[66] A. Jafari, A. Haghighi Poshtiri, Passive solar cooling of single-storey buildings by an adsorption chiller system combined with a solar chimney, J. Clean. Prod. 141 (2017) 662–682, https://doi.org/10.1016/j.jclepro.2016.09.099.
[67] R.S. Abro, Recognition of passive cooling techniques, Renew. Energy 5 (1994) 1143–1146, https://doi.org/10.1016/0960-1481(94)90142-2.
[68] N.K. Khambadkone, R. Jain, A bioclimatic analysis tool for investigation of the potential of passive cooling and heating strategies in a composite Indian climate, Build. Environ. 123 (2017) 469–493, https://doi.org/10.1016/j.buildenv.2017.07.023.
[69] W. Gamage, S. Lau, H. Qin, Z. Gou, Effectiveness of air-well type courtyards on moderating thermal environments in tropical Chinese Shophouse, Architect. Sci. Rev. 60 (2017) 493–506, https://doi.org/10.1080/00038628.2017.1383230.
[70] K.M. Al-Obaidi, M. Ismail, A.M. Abdul Rahman, Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia: a literature review, Front. Architectural Res. 3 (2014) 283–297, https://doi.org/10.1016/j.foar.2014.06.002.
[71] Y. Chen, Z. Tong, A. Malkawi, Investigating natural ventilation potentials across the globe: Regional and climatic variations, Build. Environ. 122 (2017) 386–396, https://doi.org/10.1016/j.buildenv.2017.06.026.
[72] D. Mumovic, J. Palmer, M. Davies, M. Orme, I. Ridley, T. Oreszczyn, C. Judd, R. Critchlow, H.A. Medina, G. Pilmoor, C. Pearson, P. Way, Winter indoor air quality, thermal comfort and acoustic performance of newly built secondary schools in England, Build. Environ. 44 (2009) 1466–1477, https://doi.org/10.1016/J.BUILDENV.2008.06.014.
[73] J. Khedari, B. Boonsri, J. Hirunlabh, Ventilation impact of a solar chimney on indoor temperature fluctuation and air change in a school building, Energy Build. 32 (2000) 89–93, https://doi.org/10.1016/S0378-7788(99)00042-0.
[74] F. Ascione, N. Bianco, R.F. de Masi, M. Mastellone, G.P. Vanoli, Phase change materials for reducing cooling energy demand and improving indoor comfort: a step-by-step retrofit of a mediterranean educational building, Energies 12 (2019) (2019) 3661, https://doi.org/10.3390/EN12193661.
[75] B.M. Jones, R. Kirby, Indoor air quality in U.K. school classrooms ventilated by natural ventilation windcatchers, Int. J. Vent. 10 (2012) 323–338, https://doi.org/10.1080/14733315.2012.11683959.
[76] C.A. Short, K.J. Lomas, A. Woods, Design strategy for low-energy ventilation and cooling within an urban heat island. https://doi.org/10.1080/09613210410001679875, 2007, 32,187,206.
[77] M.Á. Campano, S. Domínguez-Amarillo, J. Fernández-Agüera, J.J. Sendra, Thermal perception in mild climate: adaptive thermal models for schools, Sustainability 11 (2019) (2019) 3948, https://doi.org/10.3390/SU11143948.
[78] D. D'Agostino, L. Daraio, C. Marino, F. Minichiello, Cost-optimal methodology and passive strategies for building energy efficiency: a case-study. https://doi.org/10.1080/00038628.2018.1491826, 2018, 61,400,409.
[79] S.M. Almeida, N. Canha, A. Silva, M. do Carmo Freitas, P. Pegas, C. Alves, M. Evtyugina, C.A. Pio, Children exposure to atmospheric particles in indoor of Lisbon primary schools, Atmos. Environ. 45 (2011) 7594–7599, https://doi.org/10.1016/J.ATMOSENV.2010.11.052.
[80] H. Montazeri, F. Montazeri, R. Azizian, S. Mostafavi, Two-sided wind catcher performance evaluation using experimental, numerical and analytical modeling, Renew. Energy 35 (2010) 1424–1435, https://doi.org/10.1016/J.RENENE.2009.12.003.
[81] B. Hamzah, Z. Gou, R. Mulyadi, S. Amin, Thermal comfort analyses of secondary school students in the tropics, 2018, Buildings 8 (8) (2018) 56, https://doi.org/10.3390/BUILDINGS8040056, 56.

[82] L. Stabile, A. Frattolillo, M. Dell'Isola, A. Massimo, A. Russi, Air permeability of naturally ventilated Italian classrooms, Energy Procedia 78 (2015) 3150–3155, https://doi.org/10.1016/J.EGYPRO.2015.11.772.
[83] K.J. Lomas, Architectural design of an advanced naturally ventilated building form, Energy Build. 39 (2007) 166–181, https://doi.org/10.1016/J.ENBUILD.2006.05.004.
[84] C.A. Short, M. Cook, K.J. Lomas, Delivery and performance of a low-energy ventilation and cooling strategy, Http://Dx.Doi.Org/10.1080/09613210802607841, https://doi.org/10.1080/09613210802607841, 2009, 37,1,30.
[85] E.Z.E. Conceição, J.M.M. Gomes, N.H. Antão, M.M.J.R. Lúcio, Application of a developed adaptive model in the evaluation of thermal comfort in ventilated kindergarten occupied spaces, Build. Environ. 50 (2012) 190–201, https://doi.org/10.1016/J.BUILDENV.2011.10.013.
[86] M. Santamouris, C. Pavlou, P. Doukas, G. Mihalakakou, A. Synnefa, A. Hatzibiros, P. Patargias, Investigating and analysing the energy and environmental performance of an experimental green roof system installed in a nursery school building in Athens, Greece, Energy 32 (2007) 1781–1788, https://doi.org/10.1016/J.ENERGY.2006.11.011.
[87] R. Becker, I. Goldberger, M. Paciuk, Improving energy performance of school buildings while ensuring indoor air quality ventilation, Build. Environ. 42 (2007) 3261–3276, https://doi.org/10.1016/J.BUILDENV.2006.08.016.
[88] H. Montazeri, R. Azizian, Experimental study on natural ventilation performance of one-sided wind catcher, Build. Environ. 43 (2008) 2193–2202, https://doi.org/10.1016/J.BUILDENV.2008.01.005.
[89] V. Butala, P. Novak, Energy consumption and potential energy savings in old school buildings, Energy Build. 29 (1999) 241–246, https://doi.org/10.1016/S0378-7788(98)00062-0.
[90] N. Tippayawong, P. Khuntong, C. Nitatwichit, Y. Khunatorn, C. Tantakitti, Indoor/outdoor relationships of size-resolved particle concentrations in naturally ventilated school environments, Build. Environ. 44 (2009) 188–197, https://doi.org/10.1016/J.BUILDENV.2008.02.007.
[91] A. Montazami, M. Wilson, F. Nicol, Aircraft noise, overheating and poor air quality in classrooms in London primary schools, Build. Environ. 52 (2012) 129–141, https://doi.org/10.1016/J.BUILDENV.2011.11.019.
[92] J. Yang, I. Nam, H. Yun, J. Kim, H.J. Oh, D. Lee, S.M. Jeon, S.H. Yoo, J.R. Sohn, Characteristics of indoor air quality at urban elementary schools in Seoul, Korea: assessment of effect of surrounding environments, Atmospheric Pollution Research 6 (2015) 1113–1122, https://doi.org/10.1016/J.APR.2015.06.009.
[93] Y. Zhao, Y. Zhao, F. An, Z. Zhuang, J. Liu, An experimental study of the effect of intermittent window opening on the thermal comfort of college student in winter, in: 16th Conference of the International Society of Indoor Air Quality and Climate: Creative and Smart Solutions for Better Built Environments, International Society of Indoor Air Quality and Climate, 2020. Indoor Air, https://www.scopus.com/inward/record.uri?eid=2-s2.0-85101598776&partnerID=40&md5=374a61d73604c14d5fe6c3e80edc272b, 2020.
[94] M. Mahmoodzadeh, P. Mukhopadhyaya, C. Valeo, Effects of Extensive Green Roofs on Energy Performance of School Buildings in Four North American Climates, Water (Switzerland), 2020, p. 12, https://doi.org/10.3390/W12010006.
[95] D.I. Norton, Elementary school utilizes solar design techniques and groundwater cooling system for energy efficiency, ASHRAE J. 37 (1995) 50–52. https://www.scopus.com/inward/record.uri?eid=2-s2.0-0029277411&partnerID=40&md5=704f1e094a49c655ab1d4709fb4a6e68.
[96] S. Yuan, D. Rim, Cooling energy saving associated with exterior greenery systems for three US Department of Energy (DOE) standard reference buildings, Building Simulation 11 (2018) 625–631, https://doi.org/10.1007/S12273-018-0427-Y.
[97] J.K. Vanos, A. Middel, G.R. McKercher, E.R. Kuras, B.L. Ruddell, Hot playgrounds and children's health: a multiscale analysis of surface temperatures in Arizona, USA, Landsc. Urban Plann. 146 (2016) 29–42, https://doi.org/10.1016/J.LANDURBPLAN.2015.10.007.
[98] J.K. Vanos, A.J. Herdt, M.R. Lochbaum, Effects of physical activity and shade on the heat balance and thermal perceptions of children in a playground microclimate, Build. Environ. 126 (2017) 119–131, https://doi.org/10.1016/J.BUILDENV.2017.09.026.
[99] A. Schulman, C.A. Peters, GIS analysis of urban schoolyard landcover in three U.S. cities, Urban Ecosyst. 11 (1) (2007) 65–80, https://doi.org/10.1007/S11252-007-0037-4, 2007 11.
[100] E.A. Kennedy, H.A. Olsen, J.K. Vanos, Thermally Comfortable Playgrounds: A Review of Literature and Survey of Experts, Standards Council of Canada, 2020.
[101] C. Filippín, S.F. Larsen, A. Beascochea, Architecture, Thermal Design and Energy Performance of Solar Schools in Argentina, 2011.
[102] S. Mohamed, H. Al-Khatri, J. Calautit, S. Omer, S. Riffat, The impact of a passive wall combining natural ventilation and evaporative cooling on schools' thermal conditions in a hot climate, J. Build. Eng. 44 (2021), https://doi.org/10.1016/j.jobe.2021.102624.
[103] R.D. Beltrán, J. Kastillo, I. Miño-Rodríguez, C. Naranjo-Mendoza, C. Ávila, Assessment of different natural ventilation strategies for an educational building on the warm-humid climate of Guayaquil, Ecuador, in: ASME 2015 9th International Conference on Energy Sustainability, ES 2015, Collocated with the ASME 2015 Power Conference, the ASME 2015 13th International Conference on Fuel Cell Science, Engineering and Technology, and the ASME 2015 Nuclear Forum, 2015, https://doi.org/10.1115/ES2015-49701.
[104] M. Trebilcock, B. Piderit, J. Soto, R. Figueroa, A parametric analysis of simple passive strategies for improving thermal performance of school classrooms in Chile, Architect. Sci. Rev. 59 (2016) 385–399, https://doi.org/10.1080/00038628.2016.1150251.
[105] J.L. Hernández, R. Sanz, Á. Corredera, R. Palomar, I. Lacave, A fuzzy-based building energy management system for energy efficiency, Buildings 8 (2018), https://doi.org/10.3390/BUILDINGS8020014.
[106] E. Cuce, F. Sher, H. Sadiq, P.M. Cuce, T. Guclu, A.B. Besir, Sustainable Ventilation Strategies in Buildings: CFD Research, Sustainable Energy Technologies and Assessments, vol. 36, 2019, https://doi.org/10.1016/j.seta.2019.100540.
[107] B. Ford, G. Pentella, R. Schiano-Phan, J. Vallejo, W. Zhu, A green school for Gaza: design and thermal performance evaluation, in: 30th International PLEA Conference: Sustainable Habitat for Developing Societies: Choosing the Way Forward - Proceedings, 2014, pp. 35–37.
[108] Q. Li, L. Zhang, L. Zhang, X. Wu, Optimizing energy efficiency and thermal comfort in building green retrofit, Energy 237 (2021), 121509, https://doi.org/10.1016/J.ENERGY.2021.121509.
[109] B.J. Liu, S.H. Wang, F. Lu, X.Y. Wang, M.B. Jensen, S.W. Zheng, L. Liu, M.Y. Shan, K.X. Zhao, Roof greening in urban area of Beijing during 2005-2015: development trends, distribution patterns and policy promotion, Chinese J. Ecol. 37 (2018) 1509–1517, https://doi.org/10.13292/J.1000-4890.201805.005.
[110] C. Jiayu, Y. Haiwei, K. Fanhua, Measuring the performance of green roof cooling effects from a multidimensional perspective, Sheng Tai Xue Bao/Acta Ecol. Sin. 40 (2020) 1445–1454, https://doi.org/10.5846/STXB201812032630.
[111] T. Wang, L. Zhu, D. Bai, F. Gao, J. Wang, Measuring study on energy saving performance of the trombe wall in school building, in: IOP Conference Series: Earth and Environmental Science, 2021, https://doi.org/10.1088/1755-1315/719/2/022009.
[112] R. Goyal, M. Khare, Indoor–outdoor concentrations of RSPM in classroom of a naturally ventilated school building near an urban traffic roadway, Atmos. Environ. 43 (2009) 6026–6038, https://doi.org/10.1016/J.ATMOSENV.2009.08.031.
[113] K.T. Lei, J.S. Tang, P.H. Chen, Numerical simulation and experiments with green roofs for increasing indoor thermal comfort, J. Chinese Instit. Eng. Transac. Chinese Instit. Eng. Series A. 42 (2019) 346–356, https://doi.org/10.1080/02533839.2019.1585207.
[114] C. Ji, T. Hong, K. Jeong, J. Kim, C. Koo, M. Lee, S. Han, Y. Kang, Embodied and operational CO2 emissions of the elementary school buildings in different climate zones, KSCE J. Civil Eng. 24 (2020) 1037–1048, https://doi.org/10.1007/S12205-020-2321-2.
[115] S.K. Kim, P. Joosse, M.M. Bennett, T. van Gevelt, Impacts of green infrastructure on flood risk perceptions in Hong Kong, Climatic Change 162 (2020) 2277–2299, https://doi.org/10.1007/s10584-020-02803-5.
[116] S. Chansomsak, B. Vale, The Buddhist approach to education: an alternative approach for sustainable education, Asia Pac. J. Educ. 28 (2008) 35–50, https://doi.org/10.1080/02188790701850063.
[117] D. Randelovic, M. Vasov, M. Ignjatovic, M. Stojiljkovic, V. Bogdanovic, Improving the energy efficiency of school buildings by using passive design systems, in: 2020 5th International Conference on Smart and Sustainable Technologies (SpliTech), 2020, pp. 1–6, https://doi.org/10.23919/SpliTech49282.2020.9243794.
[118] C. Ozburak, M.H. Batirbaygil, S.S. Uzunoğlu, Sustainable environment education in pre-school pupils, Eurasia J. Math. Sci. Technol. Educ. 14 (2018) 3367–3379, https://doi.org/10.29333/EJMSTE/91874.

[119] J.S. Englund, M. Cehlin, J. Akander, B. Moshfegh, Measured and simulated energy use in a secondary school building in Sweden-a case study of validation, airing, and occupancy behaviour, Energies 13 (2020), https://doi.org/10.3390/EN13092325.
[120] E. Crespo Sanchez, J. Ramon Dacosta Diaz, K. Kampouropoulos, Novel architectural strategies to support an nZEB mediterranean school, in: IOP Conference Series: Materials Science and Engineering, 2019, https://doi.org/10.1088/1757-899X/603/4/042012.
[121] E. Diz-Mellado, V.P. López-Cabeza, C. Rivera-Gómez, J. Roa-Fernández, C. Galán-Marín, Improving school transition spaces microclimate to make them liveable in warm climates, Appl. Sci. 10 (2020) 1–13, https://doi.org/10.3390/app10217648.
[122] Verdasco, A ceramic double skin in an educational center in melilla, Construct. Build. Res. (2014) 97–102, https://doi.org/10.1007/978-94-007-7790-3_13.
[123] T. Colinart, M. Bendouma, P. Glouannec, Building renovation with prefabricated ventilated façade element: a case study, Energy Build. 186 (2019) 221–229, https://doi.org/10.1016/J.ENBUILD.2019.01.033.
[124] D.P. Vivian, S. Samuel, M. Dejan, Y. Keqin, M.-M. Dimitris, L. Tom, Performance of a natural ventilation system with heat recovery in UK classrooms: an experimental study, Energy Build. 179 (2018) 278–291, https://doi.org/10.1016/j.enbuild.2018.09.005.
[125] M.G. Davies, The passive solar heated school in wallasey. I foreword and introduction, Int. J. Energy Res. 10 (1986) 101–120, https://doi.org/10.1002/er.4440100202.
[126] B.M. Jones, R. Kirby, Indoor air quality in U.K. school classrooms ventilated by natural ventilation windcatchers, Int. J. Vent. 10 (2012) 323–338, https://doi.org/10.1080/14733315.2012.11683959.
[127] J. Mohelníková, M. Novotný, P. Mocová, Evaluation of school building energy performance and classroom indoor environment, Energies 13 (2020) 2489, https://doi.org/10.3390/EN13102489, 2020.
[128] P. Mocová, J. Mohelníková, Indoor climate performance in a renovated school building, Energies 14 (2021) 2827, https://doi.org/10.3390/EN14102827, 2021.
[129] A. Bonoli, B. Pulvirenti, Urban green technologies for energy saving: numerical simulation of heat transfer between green façades and green roofs and the local outdoor environment, Acta Hortic. 1215 (2018) 11–19, https://doi.org/10.17660/ACTAHORTIC.2018.1215.2.
[130] V. Dorer, A. Weber, Air, contaminant and heat transport models: integration and application, Energy Build. 30 (1999) 97–104, https://doi.org/10.1016/S0378-7788(98)00049-8.
[131] C. Almeida, I. Teotónio, C.M. Silva, C.O. Cruz, Socioeconomic feasibility of green roofs and walls in public buildings: the case study of primary schools in Portugal, Eng. Econ. 66 (2021) 27–50, https://doi.org/10.1080/0013791X.2020.1748255.
[132] A.M. Raimundo, N.B. Saraiva, A.V.M. Oliveira, Thermal insulation cost optimality of opaque constructive solutions of buildings under Portuguese temperate climate, Build. Environ. 182 (2020), 107107, https://doi.org/10.1016/J.BUILDENV.2020.107107.
[133] G. Gómez, B. Frutos, C. Alonso, F. Martín-Consuegra, I. Oteiza, F. de Frutos, M.M. Castellote, J. Muñoz, S. Torre, J. Fermoso, T. Torres, M.A. Antón, T. Batista, N. Morais, Selection of nature-based solutions to improve comfort in schools during heat waves, Int. J. Energy Product. Manag. 6 (2021) 157–169, https://doi.org/10.2495/EQ-V6-N2-157-169.
[134] J. Gao, P. Wargocki, Y. Wang, Ventilation system type, classroom environmental quality and pupils' perceptions and symptoms, Build. Environ. 75 (2014) 46–57, https://doi.org/10.1016/J.BUILDENV.2014.01.015.
[135] G. Kotsiris, A. Androutsopoulos, E. Polychroni, M. Souliotis, A. Kavga, Carbon footprint of green roof installation on school buildings in Greek Mediterranean climatic region, Int. J. Sustain. Energy 38 (2019) 866–883, https://doi.org/10.1080/14786451.2019.1605992.
[136] N. Barmparesos, M.N. Assimakopoulos, V.D. Assimakopoulos, N. Loumos, M.A. Sotiriou, A. Koukoumtzis, Indoor air quality and thermal conditions in a primary school with a green roof system, Atmosphere 9 (2018), https://doi.org/10.3390/ATMOS9020075.
[137] D. Antoniadis, N. Katsoulas, D. Papanastasiou, V. Christidou, C. Kittas, Evaluation of thermal perception in schoolyards under Mediterranean climate conditions, Int. J. Biometeorol. 60 (2016) 319–334, https://doi.org/10.1007/s00484-015-1027-5.
[138] P. Toumpoulidis, A. Dimoudi, P. Kosmopoulos, S. Zoras, The contribution of a solar air heater collector to the cooling load in a building, Int. J. Vent. (2020), https://doi.org/10.1080/14733315.2020.1777654. https://www.tandfonline.com/doi/full/10.1080/14733315.2020.1777654?scroll=top&needAccess=true.
[139] A. Ragab, A. Abdelrady, Impact of green roofs on energy demand for cooling in egyptian buildings, Sustainability 12 (2020) 1–13, https://doi.org/10.3390/SU12145729.
[140] W.M. El-Bardisy, M. Fahmy, G.F. El-Gohary, Climatic sensitive landscape design: towards a better microclimate through plantation in public schools, Cairo, Egypt, Procedia. Social Behav. Sci. 216 (2016) 206–216, https://doi.org/10.1016/J.SBSPRO.2015.12.029.
[141] K.S. Galal, The impact of classroom orientation on daylight and heat-gain performance in the Lebanese Coastal zone, Alexandria Eng. J. 58 (2019) 827–839, https://doi.org/10.1016/J.AEJ.2019.07.003.
[142] M.A. Haggag, S.K. Elmasry, Integrating passive cooling techniques for sustainable building performance in hot climates with reference to the UAE, WIT Trans. Ecol. Environ. 150 (2011) 201–212, https://doi.org/10.2495/SDP110181.
[143] A. Aldawoud, F.E. Hosny, R. Mdkhana, Energy retrofitting of school buildings in UAE, Energy Engineering, J. Assoc. Energy Eng. 117 (2020) 381–395, https://doi.org/10.32604/EE.2020.011863.
[144] J. Saif, A. Wright, S. Khattak, K. Elfadli, Keeping cool in the desert: using wind catchers for improved thermal comfort and indoor air quality at half the energy, Buildings 11 (2021), https://doi.org/10.3390/buildings11030100.
[145] S. Monna, M. Baba, A. Juaidi, A. Barlet, D. Bruneau, Improving thermal environment for school buildings in Palestine, the role of passive design, J. Phys. Conf. 1343 (2019), 012190, https://doi.org/10.1088/1742-6596/1343/1/012190.
[146] R. Becker, I. Goldberger, M. Paciuk, Improving energy performance of school buildings while ensuring indoor air quality ventilation, Build. Environ. 42 (2007) 3261–3276, https://doi.org/10.1016/J.BUILDENV.2006.08.016.
[147] M. Alwetaishi, A. Taki, Investigation into energy performance of a school building in a hot climate: optimum of window-to-wall ratio. https://doi.org/10.1177/1420326X19842313, 2019, 29,24,39.
[148] M.A.M. Alhefnawi, Energy budget in an educational building in KSA: the case of cladding with terracotta and aluminium, Ain Shams Engineering Journal 12 (3) (2021) 3255–3261, https://doi.org/10.1016/J.ASEJ.2021.01.024.
[149] N. Downs, A. Parisi, J. Turner, D. Turnbull, Modelling ultraviolet exposures in a school environment, Photochem. Photobiol. Sci. 7 (2008) 700–710, https://doi.org/10.1039/b801685b.
[150] A. Ferrante, G. Mihalakakou, The influence of water, green and selected passive techniques on the rehabilitation of historical industrial building in urban areas, Sol. Energy 70 (2001) 245–253, https://doi.org/10.1016/S0038-092X(00)00100-6.
[151] France, OASIS - School Yards: Openness, Adaptation, Sensitisation, Innovation and Social Ties: Design and Transformation of Local Urban Areas Adapted to Climate Change, Working Jointly with Users, UIA - Urban Innovative Actions, 2018. https://www.uia-initiative.eu/en/uia-cities/paris-call3. (Accessed 15 September 2021).
[152] A.M. Coutts, E.C. White, N.J. Tapper, J. Beringer, S.J. Livesley, Temperature and human thermal comfort effects of street trees across three contrasting street canyon environments, Theorical Application Climatology 124 (2016) 55, https://doi.org/10.1007/s00704-015-1409-y.
[153] R.D. Brown, R.C. Corry, Evidence-based landscape architecture for human health and well-being, Sustainability 12 (2020) 1360, https://doi.org/10.3390/SU12041360, 1360. 12 (2020).
[154] C. Díaz-López, K. Verichev, J.A. Holgado-Terriza, M. Zamorano, Evolution of climate zones for building in Spain in the face of climate change, Sustainable Cities and Society 74 (2021), https://doi.org/10.1016/j.scs.2021.103223.