

Bibliometric Analysis for Healthy School Buildings

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ABSTRACT

People spend most of their time indoors, so designing healthy buildings significantly impacts human health. The "sick building syndrome," identified in the 1970s and mentioned in a 1984 World Health Organization (WHO) report, highlights the negative effects that buildings can have on health. Given that children comprise a significant portion of building users, ensuring health and comfort in school buildings is crucial for both efficiency and public health. This study aims to provide a comprehensive overview and in-depth analysis on "healthy school buildings." Using the VOSviewer program, a bibliometric analysis was conducted on articles published between 1987 and 2024 in the Web of Science database. The analysis includes author keyword analysis, keyword distribution by years, country citation analysis and country citation tie distribution by years, to convey the subject's conceptual framework, boundaries, topicality and regional trends. The study systematically summarizes the literature, highlighting the topic's boundaries, trends and gaps. The results indicate that the most cited countries are the United States, China and Australia, with "built environment," "thermal comfort," and "health" as the most frequently used keywords. The distribution of author keywords and citation ties by country over the years shows that the topic is current, with an increase in research activity since the onset of the COVID-19 pandemic. This study outlines the scope and boundaries of healthy school buildings, emphasizes its importance, helps researchers generate new ideas, and encourages studies addressing research gaps.

KEYWORDS

Healthy buildings, Healthy school buildings, Bibliometric analysis, VOSviewer, Web of Science

INTRODUCTION

In the 21st Century, the green building concept, which emerged in the US and the UK, aims to design "healthy housing" and "user-oriented architecture." It focuses on creating workspaces and interior and exterior spaces that are interactive with the user, compatible with nature, and promote health. In today's conditions, the fact that spaces are entitled to receive certificates by reaching certain standards is also evaluated in terms of the interaction of human health and nature (Dikbaş, 2016). Buildings that can respond to the biological, psychological, and sociological needs of their users to a certain extent are important because they are the places where users spend most of their time. In this sense, the science of building biology should be utilized to the maximum extent in order to take precautions before health problems arise and to encourage designers to design user-oriented buildings. The fact that buildings are not designed in accordance with the criteria of building biology or that existing buildings are not improved in line with these criteria paves the way for the formation of symptoms called "sick building syndrome" in users. However, it is thought that studies on healthy buildings and user satisfaction are insufficient in our country (Akgün, 2019). Especially when the past studies on healthy school design are examined, it is evident that there have been quite limited studies on this topic.

The bibliometric analyses in the study are produced with the VOSviewer program utilizing the Web of Science database. The VOSviewer program offers us multidimensional analysis by shedding light on the

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literature (Artsin, 2020). The study's objective is to determine and visually represent the existing literature on healthy school buildings by using bibliometric procedures. Studies on healthy school buildings, which are crucial to the improvement and development of communities, will be classified according to their focus areas and research topics. This approach will reveal the research trends and gaps in the design of healthy schools.

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

In this section, definitions and related concepts related to healthy buildings are briefly mentioned. Then, national and international studies on healthy buildings and healthy school buildings are examined in the historical process, and a summary of the literature is presented. The aim is to convey the boundaries within which the subject has been dealt with in the historical process to the researchers interested in the subject and contributing to their insights.

HEALTHY BUILDING DESIGN

The physical environment is the artificial environment where living things fulfill their vital activities and needs. The social environment is the environment formed by living things that connect with each other through the physical environment (Güteryüz, 2014). Buildings are artificial environments constructed to meet the vital needs of people, to provide security, and to protect building users from the harmful effects of the external environment (Yazıcı, 2022). Nowadays, people have moved away from the natural environment and started to live their lives in the built environment. The built environment, which does not provide appropriate conditions, has led to the formation of health problems defined as Sick Building Syndrome (SBS) (Aydın, 2017). In the constitution of the World Health Organization: «Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity» (URL-3). Health problems arising from the negative interaction between humans and buildings are studied by the branch of science called "building biology" (Baker-Laporte et al., 2008). The original purpose of building biology is to prevent health problems that may arise in users due to the building before they occur (Sarp, 2007). Consequently, various parameters should be taken into consideration in building design, and these parameters should maintain their quality throughout the lifetime of the building.

The concept of healthy building was first defined by Levin (1995): «A healthy building is one that neither adversely affects the health of the user nor the wider environment». User structure is classified in terms of biological, psychological, and sociological characteristics, and various needs arise in users depending on these structural characteristics. Apart from the needs arising from the structural characteristics of the user, needs arise due to natural and built environment factors. Meeting the requirements is the responsibility of the designer, producer, and operator groups who make decisions at the design stages of the building and/or built environment (Ölmez, 2019). Balanlı (1997) stated that the function of buildings and building elements is to respond to user needs. Churchill (1943) said: «We shape our buildings and afterwards our buildings shape us» (URL-1). Architects, interior architects, landscape architects, urban and regional planners, and all those involved in the design and creation of spaces have a great responsibility in this respect.

When designing spaces, many factors influence the health and comfort of users. The form and size of the land, as well as factors that affect the building's orientation are key considerations. Other important factors include maximizing natural light and air, ensuring thermal comfort, and assessing the impact of building materials on human health. Therefore, designers must take all these factors into account. The WELL Building Standard is the first standard created with a focus on user health and comfort. The concepts of well-being and efficiency are the elements that support the state of being healthy (Ölmez, 2019). An overview of the reviewed literature on healthy buildings is given in Table 1.

Table 1. Summary of the literature review on healthy buildings.

Type	Description
Article	Maslow stated that people are driven to fulfill specific wants and that these demands are prioritized (Maslow, 1943).
Article	He presented user requirements as a five-stage pyramid model. He argued that users' requirements should be met starting from the most basic requirements at the lower level towards the higher level requirements (Maslow, 1987).
Article	The aim was to compare underground environments with aboveground environments. The study focused on the effect of daily and seasonal variations on sensory stimulation for people working underground (Küller & Wetterberg, 1996).
Doctoral Thesis	"Healthy building" is defined. A model proposal was presented to examine healthy/unhealthy buildings that maintain their healthy status as long as they meet all the needs of the user and as a result of user changes (Sarp, 2007).
Book	He examined the relationship between natural light in buildings and human health from both psychological and physiological perspectives and brought together various research in this field. He documented medical research findings linking light quality and health (Boubekri, 2008).
Article	It examines through the LEED example whether the set of features that make a building "green" can often correspond to the "healthy" feature (Sentman, 2009).
Article	It includes a literature review on the effects of various factors on indoor occupant comfort. It is found that giving residents control over their interior environment improves their happiness with indoor air quality as well as their thermal and visual comfort. The article argues that thermal comfort is the most influential of these factors on occupant comfort (Frontczak & Wargocki, 2011).
Article	It is stated that by providing indoor environments designed in ideal conditions, individual health is protected and public health is protected by reducing air pollutants that cause premature deaths. It was concluded that LEED certified buildings should also be evaluated according to healthy building criteria, and LEED is insufficient to evaluate healthy building criteria (Allen et al., 2015).
Review Article	He argued that the characteristics of physical and social environmental elements such as social equity, physical safety, air quality, community cohesion, transportation options, access to healthy food, traffic accidents, water quality, physical activity levels, access to nature, and daylight levels directly affect community health (Heidari et al., 2016).
Article	It focused on issues such as human health, satisfaction, and efficiency and evaluated indoor air quality, ventilation, temperature and thermal comfort, water quality, humidity, safety, lighting and visibility, and noise (Cedeño-Laurent et al., 2018).
Master Thesis	She talked about the factors that affect human health biologically, psychologically, and sociologically in an indoor climate. The effects of gases such as carbon dioxide and carbon monoxide in the indoor climate on human health were reported. It has been shown that materials play a major role in the formation of these gases and indoor pollutants (Kokulu, 2019).
Master Thesis	Within the scope of the research, environmental factors originating from the user and the natural and built environment were examined; the requirements arising from these factors were determined, and design principles were established to meet these requirements. The WELL Building Standard Certification System is also included in this study (Ölmez, 2019).
Master Thesis	The effects of spatial features and building materials on the health of the users in buildings with residential functions were specified. "Healthy Housing Checklist" was developed (Yazıcı, 2022).
Master Thesis	Human-oriented design proposals to ensure the health and well-being of users in post-pandemic office buildings were examined. Post-pandemic healthy office building evaluation criteria were determined with reference to existing recommendations (Alankuş, 2023).
Article	It aims to examine and recommend an indoor lighting environment assessment methodology for human well-being using quantitative and qualitative assessments of light, health, and environment (Kim et al., 2024).
Article	It demonstrates how the importance of health and well-being is permeating other fields, like engineering and architecture. There has been a paradigm change in the definition of health and well-being suggested by new working definitions (Christoforou et al., 2024).

USER HEALTH AND COMFORT IN BUILDINGS WITH EDUCATIONAL FUNCTIONS

Communities and individuals in good health make major contributions to sustainability. In order to promote health and well-being and avoid sickness, healthy settings are crucial (Mundo-Hernandez et al., 2018). Educational buildings, like other types of buildings, should meet the biological, psychological, and sociological needs of their users and provide them with a comfortable and healthy environment. Since schools are educational institutions, they fulfill functions such as socialization of individuals, transfer of cultural heritage, and ensuring solidarity and unity in society. The general aim of education and training is to ensure that children grow up in an efficient and healthy manner in terms of skill, science, and behavior (Tösten & Han, 2015).

Schools represent a regional composition of ages, daily academic programs, and building designs. School buildings, where the majority of the day passes for students, teachers, and staff, who are the users of educational buildings, require a good and accurate analysis of the user profile in order to be designed according to the characteristics of the building users, such as age, gender, school type and function, etc. (as well as to ensure user health and comfort) (Mundo-Hernandez et al., 2018).

The architectural environment's design is very important when it comes to schooling. Better social interactions, lower absenteeism, more productivity from both students and instructors, and improved cognitive experiences can all be attributed to providing a safe and comfortable learning environment for students (Mundo-Hernandez et al., 2018). A summary of the literature review on healthy educational buildings is presented in Table 2. Research shows that healthy school buildings have an impact on the academic performance of students and teachers. It is known that educational buildings where health and comfort conditions are provided have a positive impact on academic success.

Table 2. Summary of the literature review on healthy educational buildings.

Type	Description
Review Article	The literature on ventilation, indoor air quality, and health issues associated to schools was examined, and symptoms of building-related illnesses that were often reported in schools up until 1999 were noted (Daisey et al., 2003).
Review Article	It has been found that poor indoor environmental quality is prevalent in schools and that primarily indoor pollutants negatively affect students' performance and engagement through their health (Mendell & Heath, 2005).
Article	Since it was found that the indoor classroom environment significantly affects the academic achievement of students, it was concluded that planning should be made for indoor sound insulation, maintenance of a comfortable thermal environment, and equal light distribution (Park et al., 2011).
Article	There has been a claim made that children cannot learn, play, or develop in a healthy school setting. This study suggests a connection between improved academic achievement and more trees on campuses (Kweon et al., 2017).
Article	It focuses on the vital importance of human-centered building design and the study of symptoms related to the sick building syndrome, which has become widespread since the 1970s, especially in office and school buildings (Ghaffarianhoseini et al., 2018).
Article	There is a claim that the quality of indoor air in schools directly affects the health and performance of the kids (Gil-Baez et al., 2021).
Article	It presents a method for estimating the probability of infection from CO2 concentration monitoring applied to university classrooms (Fantozzi et al., 2022).
Article	With thermal comfort, lighting, acoustics, and indoor air quality conditions, the significance of establishing and preserving ideal indoor environmental quality circumstances in order to enhance the caliber of instruction and learning for school users has been emphasized (Brink et al., 2024).

METHOD

Bibliometric analyses are produced with the VOSviewer program using the Web of Science database on healthy school buildings. Relationship networks are visualized by focusing on national/international awareness of the subject, keywords used by authors, and citation analysis of countries. As a result of the bibliometric analyses on the design of "healthy school buildings" as a result of quantitative data and numerical measurement indicators, it is aimed to present the existing studies in the literature to the information of researchers.

Bibliometric analysis is the numerical examination of data generated within a specific field and time frame or provided by a specific publishing house during a specific time frame (Al & Coştur, 2007). Bibliometric analysis is a useful tool for literature reviews as it can indicate the development course of a field or publishing organization by identifying inadequacies and determining the situation. It is also crucial for enabling information access and directing future research (Keçeli Erciyas, 2022). In the literature, many bibliometric analysis tools are employed (Dirik & Eryılmaz, 2023). Examples of these tools are; VOSviewer, CiteSpace, Gephi, Biblioshiny, BibExcel, and HistCite. These tools have various advantages and disadvantages. VOSviewer, however, is optimized for analyzing large amounts of data. It differs from other tools in that it visualizes big data in a very simple way, has a user-friendly interface, does not require any programming knowledge, and can accept files from different databases. Furthermore, it is free of charge and compatible with widely used databases such as Web of Science and Scopus. As a result, VOSviewer is an ideal choice, especially for researchers who want to perform visual-oriented analysis (Dereli, 2024).

In this study, VOSviewer was preferred due to its strengths in terms of functionality. The VOSviewer program offers great convenience to researchers in order to reveal new concepts, describe relationships and transformations between concepts. VOSviewer enables multidimensional analysis of data through network mapping and visualization. The Web of Science database is important in terms of ensuring the reliability of research. This database has advanced search indicators and uses different control mechanisms to perform advanced data analysis. It also includes reliable and qualified studies in terms of publication ethics and offers access to a wide range of data reserves from various disciplines (Dirik & Eryılmaz, 2023).

On 03.03.2024, 1908 results were accessed in the Web of Science search with the keyword "healthy school buildings" by selecting eleven Web of Science categories including "environmental sciences, engineering civil, construction building technology, environmental studies, engineering environmental, green sustainable science technology, urban studies, architecture, regional urban planning, ecology, acoustics". In this period, including the years 1987-2024, from various disciplines; 1501 journal articles, 417 early access papers, 257 proceeding papers, 140 review articles, 42 book chapters, 21 editorial content, 1 art exhibition review, 1 news item, and 1 retracted publication type work were reached. In terms of disciplines, it is seen that the majority of the studies belong to environmental sciences (814), followed by construction building technology (508), public environment occupational health (403), engineering civil (373), green sustainable science technology (344), environmental studies (317), engineering environmental (310), urban studies (158), architecture (144), energy fuels (113), regional urban planning (105), ecology (88), and acoustics (32). The data were analyzed by all fields, research words, and keywords. The database was based on data indexed in Web of Science. Access was provided to 16 sources from the most recent 2024 and 1 source from the earliest 1987. The most resources were accessed in 2022, with 282 resources.

FINDINGS

This section includes author keyword analysis and citation analysis of countries. These analyses are included in the study due to the emerging nature of the topic and the limited number of existing studies. The primary aim is to draw attention to the study topic, to raise the necessary awareness, to reveal the gaps in the study topic and to show which research areas and countries that have been the focus of previous studies. Author keyword analysis was conducted to determine the scope and boundaries of the study areas by identifying the keywords used in the literature. The citation analysis of the countries provides information about which countries are prominent within the scope of this study topic and which countries are conducting more than academic studies.

CO-OCCURRENCE OF AUTHOR KEYWORDS ANALYSIS GENERAL FRAMEWORK

The aim of the analysis, in which author keywords were selected as the analysis unit and co-occurrence was selected as the analysis type is to reveal the scope of the keywords in existing studies on the topic and to determine the emphasis placed in the studies conducted on this subject by inferring from the keywords in the documents reviewed. Since the concept of "healthy school" is a relatively new area of study, the literature primarily consists of recent sources. The keywords will provide researchers with crucial insights about the scope of the topic.

In our analysis, the minimum number of repetitions of a keyword has been set as 1, resulting in the identification of 6270 keywords. Since there were 4990 links between 4990 keywords out of 6270 keywords, the analysis was performed on these words. A total of 123 clusters, 19509 links, and 20233 total link strengths were found. The first three most frequently used keywords in publications related to "healthy school buildings" are *built environment* (77 times), *thermal comfort* (73 times), and *health* (50 times). In terms of total link strength, the strongest phrases were *built environment* (409), *thermal comfort* (331), and *health* (262) (Figure 1).

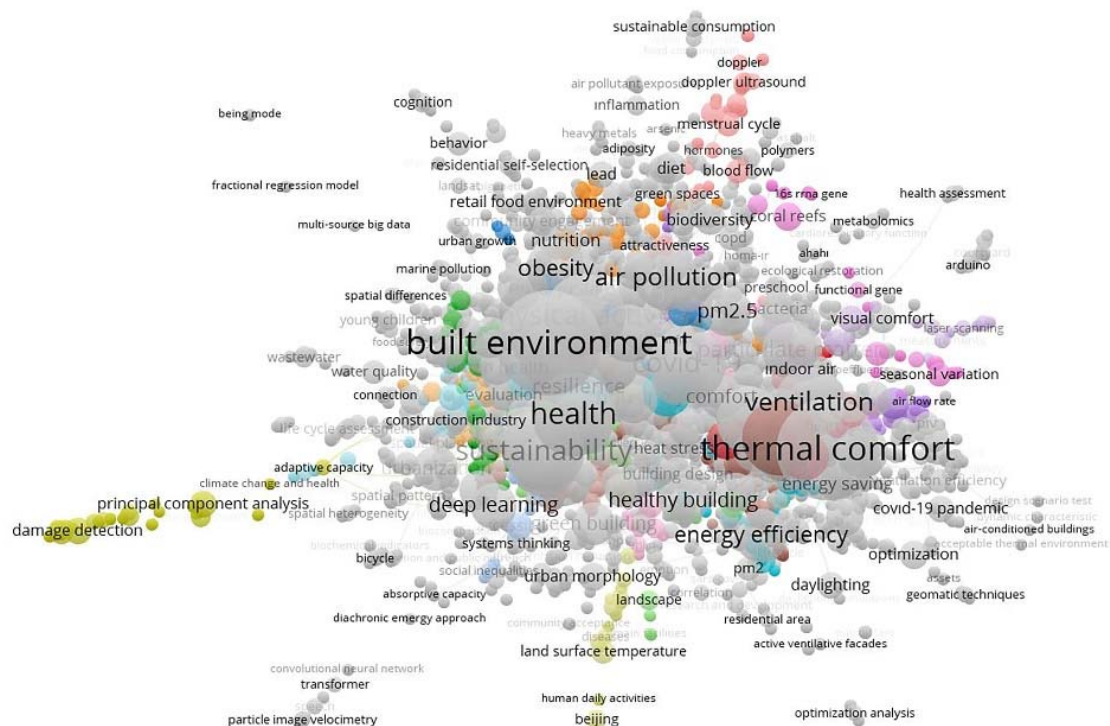


Figure 1. Authors' most frequently used keyword links.

According to the author’s keyword analysis, the top 20 keywords related to the subject and the number of uses are given in Table 3. Concepts such as indoor air quality, thermal comfort, well-being, ventilation, daylight, air pollution, and healthy environment are prominent in the analysis. In addition, educational buildings, which constitute the sample of the study, are also present in the literature in relation to the subject with words such as schools, preschools, kindergartens, classrooms, and children.

Table 3. Prominent author keywords and frequency of use.

No	Author Keywords	Frequency	No	Author Keywords	Frequency
1	Built environment	77	11	Sustainable development	27
2	Thermal comfort	73	12	Climate change	25
3	Health	50	13	Mental health	23
4	Physical activity	46	14	Children	23
5	Sustainability	45	15	Particulate matter	22
6	COVID-19	41	16	Energy efficiency	20
7	Indoor air quality	40	17	Computational Fluid Dynamics (CFD)	19
8	Ventilation	35	18	Urban design	19
9	Public health	34	19	Resilience	19
10	Air pollution	30	20	Policy	19

The distribution analysis of author keywords according to years is given in Figure 2. Upon the retrieved data, it can be observed that the subject has gained significant popularity since 2014, with most studies being published in recent years.

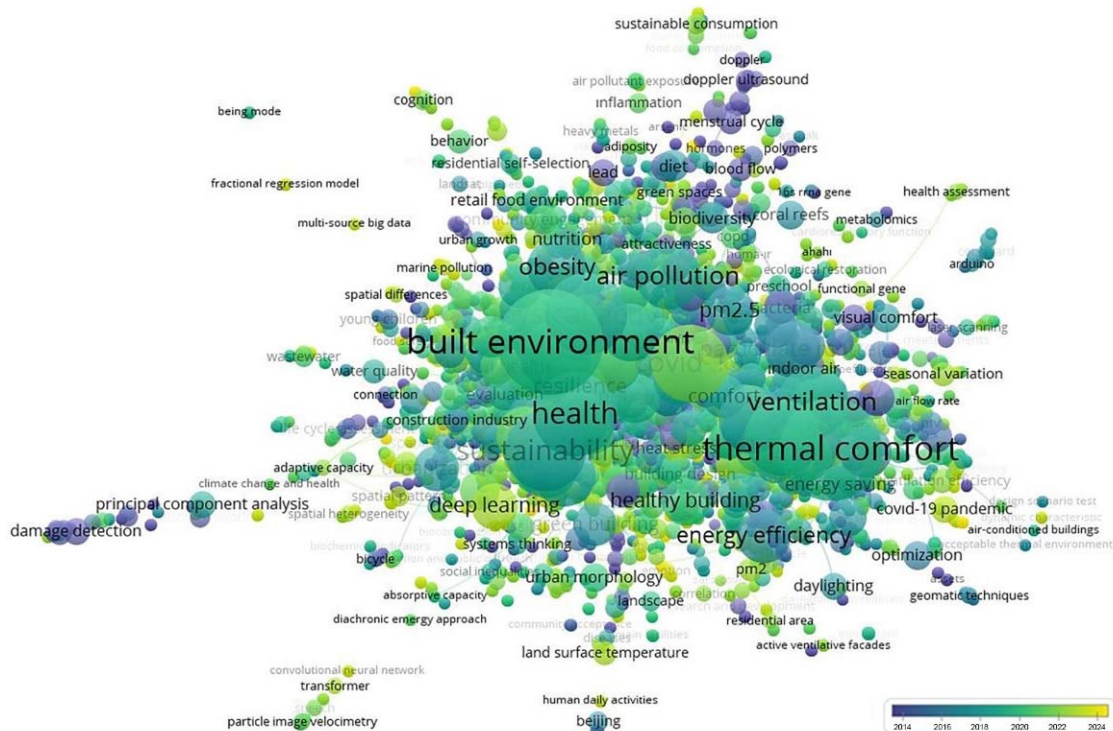


Figure 2. Distribution of authors' most frequently used keyword links by year.

With 77 times, the most frequently used author keyword, "built environment," is expressed by Cluster 1 and shown in Figure 3 (a). The prominent keywords in Cluster 1 are: *built environment, health, physical activity, air pollution, housing, children, older adults, public health, well-being, China, active living, academic performance, urban environmental health, risk assessment, biophilia, mental health, active*

community to school, obesity, air quality, and safety. The keywords in this cluster emphasize the interdisciplinary nature of research in this field. The keywords “built environment” and “housing” can be related to “health, public health, well-being, urban environmental health, and mental health.” The WELL Building Standard, which focuses on user health and comfort, supports this relationship. The WELL Building Standard argues that the built environment has an impact on human health and comfort (URL-2). This standard positively affects the productivity of building users and reduces personnel costs by making appropriate decisions during the design and implementation phase (Ölmez, 2019). According to a study conducted in the USA, it is estimated that 30 to 170 billion dollars of profit can be achieved in ten years as user health and productivity will increase by improving interior spaces (Fisk, 2000). This supports the relationship between improvements in the built environment and housing and increased “academic performance” and “active community to school” and is important for both “children” and “older adults.”

The importance of movement and physical activity for improving and promoting health is well recognized (King & Powell, 2018). Therefore, for movement to be part of our lives, cities and buildings need to be developed to support physical activity (URL-2). A study has proven that the environment has an impact on movement and physical activity (Humpel et al., 2002). In this respect, a relationship can be established between keywords such as “built environment, housing, health, public health, well-being, urban environmental health, mental health” and “physical activity, active living, obesity”. Pedestrian paths, bicycle paths, and green areas should be designed at the urban scale to encourage physical activity. At a smaller scale, i.e., building scale, it is important to make stairs visible and attractive to ensure that they are preferred (Active Design Guidelines, 2010). One study found that a dedicated bicycle lane separated from pedestrian and vehicular paths would maximize the impact on cycling (Wardman et al., 2007). This shows that physical activity can be increased with design decisions to be taken at the building scale and urban scale. At the same time, the provision of a dedicated bicycle lane can be associated with keywords such as “risk assessment” and “safety”.

Thermal comfort, the second most used keyword with 73 times, is expressed by Cluster 2 and shown in Figure 3 (b). The prominent keywords in Cluster 2 are: *thermal comfort, energy efficiency, ventilation, health, indoor air quality, carbon dioxide, school buildings, schools, skin temperature, mixing ventilation, visual comfort, space heating, adaptation, acceptable thermal environment, elderly, urban climate, overheating, clothing insulation, energy conservation, acoustic comfort, cognitive performance, physiological response and indoor temperature.* As indicated in Table 1 and Table 2, various factors have an impact on indoor user health and comfort. There are various studies on these issues. Zhang et al. (2006) conducted a study on indoor air quality in classrooms. Sookchaiya et al. (2010) examined the effects of temperature and humidity on occupant health in air-conditioned buildings in Thailand. According to Frontczak and Wargocki (2011), thermal comfort is more influential on occupant comfort than other factors. This is evidenced by the fact that the keywords in Cluster 2 are mostly associated with thermal comfort. It is known that HVAC (Heating, Ventilating, and Air Conditioning) systems, which are preferred to provide appropriate thermal comfort and indoor environmental conditions, have a large share of the energy consumption in the building (Pérez-Lombard et al., 2008).

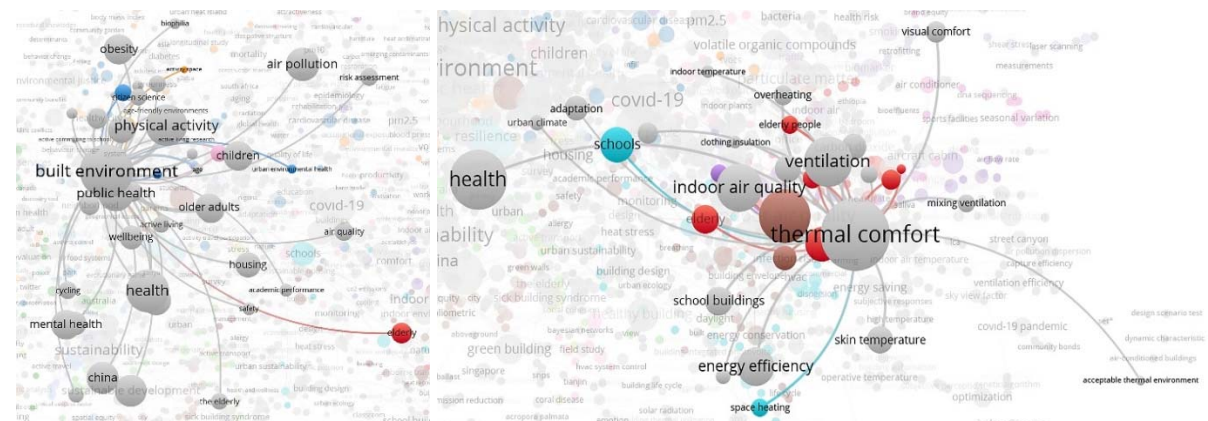


Figure 3 (a) and (b). Highlights from author keyword analysis: Cluster 1 and Cluster 2.

The word "health", which is the third most used word with 50 occurrences, is referred to as Cluster 3 and is shown in Figure 4. The elements of this cluster are: *built environment, health, sustainability, thermal comfort, indoor air quality, ventilation, physical activity, school buildings, indoor environment, workplace, buildings, schools, housing, mobility, China, safety, adaptation, acclimation, risk, children, governance, resilience, activity-friendly, systematic literature review, and urbanization.* Table 2 shows the studies on “indoor air quality” and “ventilation” and their results. Some of these studies show that indoor air quality in schools negatively affects students' academic performance. In addition, there are studies showing that ventilation efficiency depends on the location of air inlet and outlet ducts and the presence of furniture in the environment (Moon et al., 2016).

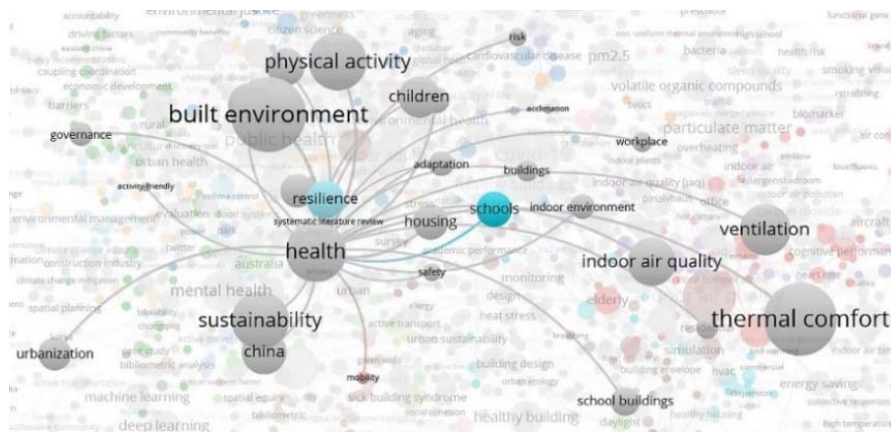


Figure 4. Highlights from author keyword analysis: Cluster 3.

CITATION ANALYSIS OF COUNTRIES

In order to create a network map of the citations received by studies according to their countries of origin, 55 interrelated items were analyzed in the context of the criteria of at least 1 publication and at least 1 citation by a country. A total of 12 clusters, 366 links, and 1403 total link strengths were identified. The most cited countries were the USA with 15883 citations, the People's Republic of China with 11942 citations, and Australia with 6958 citations. These countries also constitute the top three in terms of total link strength. In terms of number of publications, the ranking is China (728), USA (504) and UK (245). Figure 5 shows the citation analysis of countries.

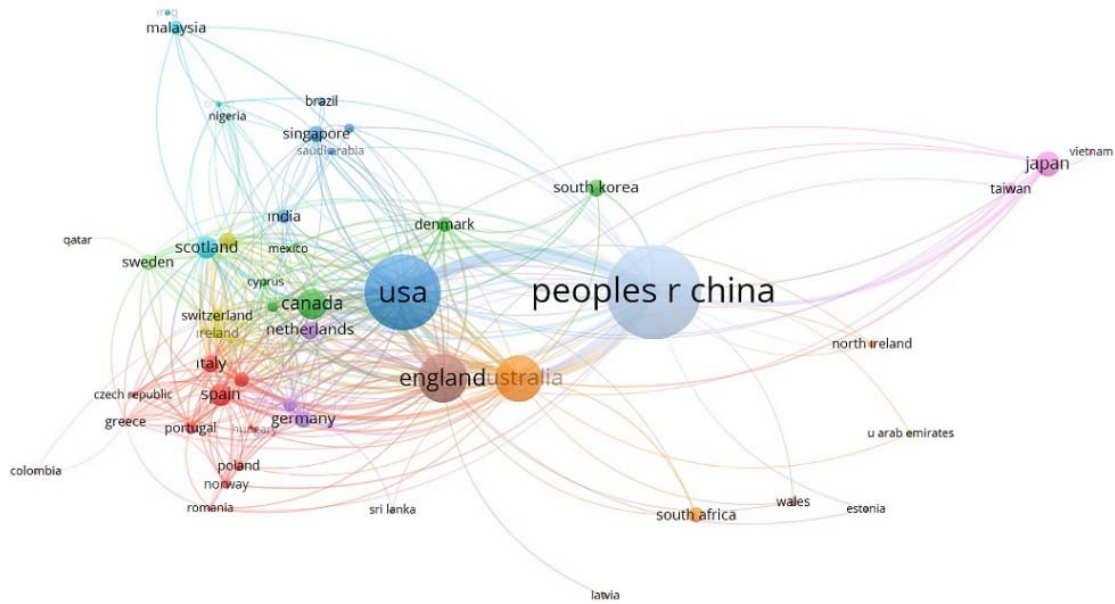


Figure 5. Citation ties of countries.

According to the citation linkage analysis of the countries in Figure 5, the top 20 countries in terms of the number of works are presented in Table 4. It is seen that the list consists of countries from different geographies.

Table 4. Leading nations in terms of the quantity of works.

No	Country	Number of Documents	No	Country	Number of Documents
1	China	728	11	New Zealand	44
2	USA	504	12	Italy	44
3	England	245	13	Germany	42
4	Australia	224	14	Singapore	39
5	Canada	110	15	Sweden	38
6	Japan	79	16	South Africa	36
7	Spain	67	17	Denmark	34
8	Scotland	65	18	Belgium	34
9	Netherlands	47	19	India	31
10	South Korea	44	20	Malaysia	30

The distribution of countries' citation analysis by year is shown in Figure 6. The ties of distribution by year provide information about the time period and where the study topic is concentrated. According to the results, three major time periods can be identified. Investigations in countries such as the USA, England, Scotland, Sweden, Greece, Canada, the Netherlands, Poland, and Japan stood out in 2019 and before. The prominent countries in 2019-2020 are China, Australia, Germany, Spain, Portugal, France, Belgium, and Italy. In 2020 and in the following period, countries such as Norway, Romania, South Africa, Iran, Cyprus, Oman, and Iran participated in the studies on this subject.

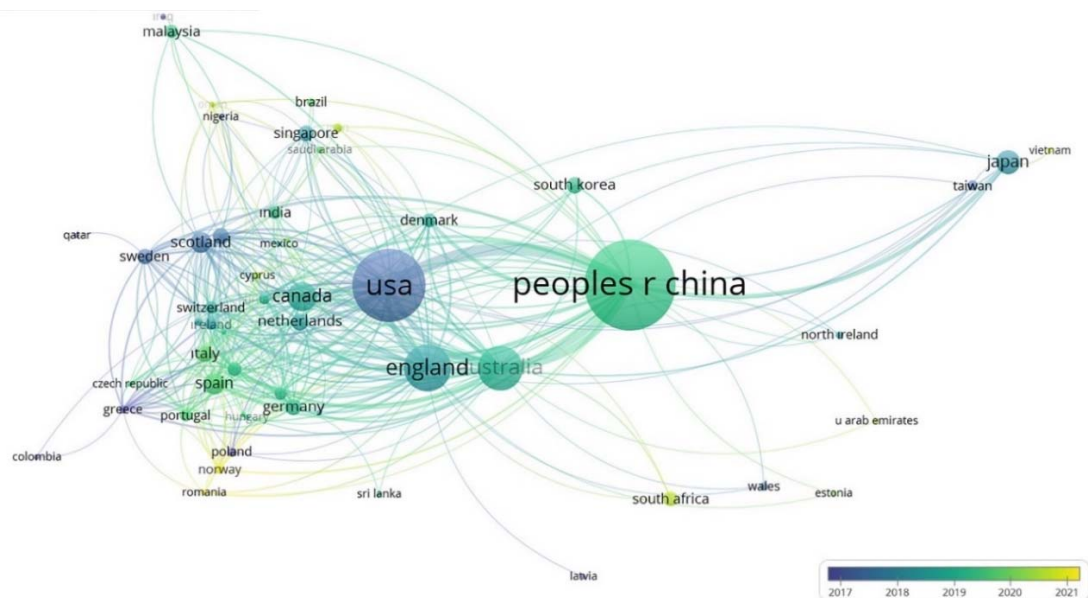


Figure 6. Distribution of countries' citation ties by year.

CONCLUSION AND DISCUSSION

Considering the outcomes of the literature review, it is seen that the concept of healthy building has become popular in recent years and has been examined from various angles. Especially the COVID-19 pandemic, which has significantly affected the whole world, has shown that designing healthy buildings is a need and has led to an increase in studies on this subject.

In this study, the historical development process of the concept of healthy building and the related conceptual framework are briefly explained. By including a detailed literature summary, information about the foci of interest, scope, and boundaries of the subject and the years in which the studies were carried out were provided for researchers interested in the subject. Then, the scope of the subject was narrowed within the school buildings selected as a sample, and the studies on healthy school buildings were examined. The study was supported by the bibliometric analysis method and aimed to examine the literature more comprehensively.

Based on quantitative techniques, author keyword analysis and citation analysis of countries were carried out with the bibliometric analysis method, which provides an unbiased transfer of data. As a result of this analysis; the most frequently used author keywords in the literature, the distribution of these words according to years, the leading countries according to publication outputs, and the distribution of citation links of countries according to years were determined. The aim here is to convey the scope of the subject more accurately and to emphasize its timeliness.

Table 1 summarizes the existing literature studies on healthy buildings, while Table 2 summarizes the existing literature studies on healthy school buildings. Upon analyzing Table 1, it can be observed that the concept of healthy and comfortable building aligns with the rate of meeting user needs. The existing literature focuses on factors such as light and lighting, thermal comfort, indoor air quality, ventilation, visual comfort, acoustic comfort, water quality, humidity, safety, physical activity and access to nature. Additionally, it has been found that buildings focused on user health and comfort make a significant contribution in terms of satisfaction and productivity. Similarly, Table 2 reveals that the performance and academic success of students increase and absenteeism decreases with the provision of compliance in needs such as indoor air quality, ventilation, lighting, indoor sound insulation, and thermal conditions in school buildings. When comparing these overall findings with the results of

bibliometric analysis, it is seen that these concepts match with the most frequently occurring author keywords. Furthermore, the years in which the studies are concentrated align with the temporal trends identified in the analysis.

When the author keyword analysis is analyzed, it is seen that the first three most frequently used words are "built environment", "thermal comfort", and "health". While the words "built environment" and "health" can be evaluated in a general scope, the word "thermal comfort" has a narrower scope. According to the results, it can be said that thermal comfort, which should be realized in order to ensure health and comfort conditions in buildings, is addressed more in studies on healthy school buildings than other conditions such as acoustic comfort, visual comfort, and indoor air quality. In addition, if we evaluate other keywords that stand out with the analysis (in [Table 3](#));

- The words “built environment” and “urban design” can be evaluated at a larger scale (city scale), and in terms of its relationship with healthy school buildings, healthier cities can be achieved through improvements and/or design decisions made at the structural scale,
- Healthy and comfortable school buildings can be associated with ensuring resilience (since the word “resilience” is included in [Table 3](#)),
- Healthy school buildings are not only focused on user health in terms of their relationship with keywords such as “sustainability, air pollution, climate change, sustainable development, and energy efficiency” but can also be associated with environmental sustainability,
- After “thermal comfort”, the most frequently used indoor health and comfort parameter is indoor air quality based on the keywords “indoor air quality, ventilation, and particulate matter”,
- “CFD (Computational Fluid Dynamics)” analysis can be associated with healthy school buildings,
- In terms of the fact that the users of school buildings are mostly children, the word “children” is among the most commonly used words,
- The COVID-19 process and its aftermath can be associated with the keywords “public health” and “COVID-19” in [Table 3](#), with a better understanding of the importance of having healthy structures and the evaluation of healthy structures within the framework of the understanding of “healthy individuals, healthy society”,
- It can be said that healthy school buildings can be associated with the main categories of the WELL certificate, which focus on user health and comfort; Movement (due to the keyword “physical activity”), Air (due to the keywords “indoor air quality”, “ventilation”, and “particulate matter”), and Mind (due to the keyword “mental health”).

As a result of the analysis; when all the keywords used are evaluated, it can be said that the scope of the subject is quite wide. Apart from the parameters that are directly effective on health and comfort conditions, studies have proven that the performance of building users is also affected due to the negative effects of health and comfort. It has also been seen that healthy school buildings can be associated with environmental parameters such as sustainability and sustainable development goals.

When the distribution analysis of the authors' most frequently used keyword links by year is analyzed, it can be said that the topic has been addressed recently and is a new research topic. It is known that the studies were concentrated between 2018 and 2022 and were addressed more after the pandemic.

The highest number of works on the subject was produced in 2022, and these outputs prove the topicality of the subject.

The reason for conducting the citation analysis of countries, which is another analysis, is to determine the countries that produce the most studies and works on this subject. This may guide the resource preferences of researchers interested in the subject. When the analysis is examined; there are different countries belonging to different geographical continents among the top twenty countries. The reason why China is the first country to produce the most works is estimated to be the better understanding of the importance of healthy buildings during the pandemic process, as it is the country where the COVID-19 pandemic emerged and is one of the countries most affected by the pandemic in terms of its population. The second ranking of the United States of America is estimated to be the country where the WELL Building Standard was created and implemented the most. The fact that the United Kingdom ranks third is thought to be the emergence of the first green building certificate, BREEAM (Building Research Establishment Environmental Assessment Method), in this country and taking important steps about healthy and green buildings.

When the distribution of the citation links of the countries by years is analyzed; it is seen that the USA is the oldest, then the UK, and the most recent studies, that is, the most recent studies, were carried out in China. This situation shows that studies on healthy building design in China have increased in 2019 and after (post-pandemic).

In general, this study aims to serve to enlighten those interested in the subject through a detailed scientific summary and to guide future studies. It is of great importance to continue the studies on healthy school buildings and to develop new strategies in this field. In this respect, technical, social, and economic strategies can be developed. Updating building standards, integrating smart building technologies, promoting green building certification systems, insulation and ventilation improvements are examples of technical strategies. Social strategies include raising public awareness, providing healthy building design trainings for professionals, and supporting user participation and feedback. Economic strategies can include incentives and tax reductions, cost-benefit analysis, price regulation of building materials, and public-private partnerships. These strategies can promote healthy building design in terms of both technical requirements and economic viability and can lead to wider adoption of this approach.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interest about this paper.

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