

Sustainability in selected design strategies in architectural education

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ABSTRACT: In response to today's societal expectations, architects and engineers are required to apply innovative design strategies that are based on sustainable development elements in order to create spaces that meet the requirements of all users, while minimising environmental impact and preserving aesthetic aspects. As part of this approach, architectural and urban design projects are created in accordance with the principles of sustainable development, emphasising the minimisation of environmental impact, the conservation and use of natural resources, and the creation of ecological and functional spaces. Introducing sustainable design strategies into architectural schools' curricula as a permanent feature is important as it creates awareness among future architects, and enables them to acquire the appropriate skills to create ecological, energy-efficient and user-friendly designs for all user groups.

INTRODUCTION

Nowadays, environmental aspects are among the main design guidelines regardless of their field and form. Common concern for the environment, climate change and limited natural resources are central to the creation of buildings and spaces that have to meet the needs of society while protecting or enhancing the quality of the environment [1][2]. In response to the design challenges posed by environmental aspects, the term sustainability has been introduced into the field of architecture and urbanism, which is conditioned and formulated by sustainable design principles. Sustainable design in the field of architecture is a holistic approach whose main objective is the harmony between people, economics and ecology [1].

By safeguarding the harmony between these aspects, architects have the opportunity to create timeless buildings and spaces that are friendly to all user groups and the environment. To this end, an increasing number of new and improved design strategies are being developed as design tools and as opportunities to create innovative and sustainable entities in the architectural and construction fields.

Due to the large subject spectrum of sustainability, it is important to introduce the definitions and education of sustainable design as permanent features into the curriculum of architectural studies. This will enable to build a greater awareness of future architects who can contribute to the creation of aesthetic and functional spaces that fit into the definition of sustainability. In consequence, a significantly greater impact will be made on the creation of a new quality of the environment and social life [3-6].

Purpose, Scope and Method of Research

The aim of this article is to attempt to describe the possibilities of using sustainable design on the basis of selected design strategies in architectural education and to determine their impact on the design process, as well as presenting the results (design works). The research includes the analysis, interpretation and description of selected design approaches in the context of sustainable development and the analysis of the use of their potential on the basis of design entities, such as students' works and existing architectural realisations. The results presented in this article have been obtained through the use of a qualitative method, literature research and comparative analyses.

SUSTAINABILITY IN ARCHITECTURE

Sustainable development was first mentioned in the 1960s and was an attempt to create an idea to promote the protection of the environment from the population-based pollution. Less than 30 years later, the concept of sustainable development was officially defined in the Report of the UN World Commission on Environment and Development

(the Brundtland Report) [7]. The report explains and identifies the threats to future human development caused by meeting community needs at the expense of the environment [7]. This has become the basis for the creation of the three main pillars of sustainable development which are the ecological, economic and socio-cultural aspects closely related to each other.

References to sustainable development in architecture can be traced back to the emergence of the definition itself. Many researchers and sustainability enthusiasts began to look for opportunities to implement sustainable guidelines into design processes to enhance the value of architecture itself. In order to meet the needs of the community and to create architecture that meets global standards, the term sustainable architecture has been defined, which is the result of applying sustainable design principles into the field of architecture [1].

Over the years, many architects and researchers have tried to systematise the principles of sustainable design by looking for new possibilities and finding elements of sustainability in other design methods. The results of these studies have proved inconclusive due to the possibility of subjective interpretations of sustainable architecture, but they have nevertheless been based on the three fundamental aspects of sustainability mentioned above. Definitions of sustainable architecture by architects, engineers and experts in the fields of ecological, economic and social sciences have been written up in Cordero's book *Sustainability in Architecture* and are evidence of the flexibility of sustainable architecture terminology [8].

Analysing the literature sources, it can be seen that architects and scientists formulate the principles of sustainable design in a similar way and are unanimous in the aspect of characterising the idea [2]. For example, Baranowski describes sustainable design as the harmonisation of development processes and structural changes of space based on the principles of respect for natural resources and the complete integration of ecological, economic and socio-cultural aspects, as well as spatial design processes [9]. Thus, sustainable design encompasses the principles of respect for the site, respect for the user, the 3R principles (reduce, reuse and recycle), energy efficiency, and the use of alternative energy sources [2].

New principles of sustainability have been developed for the needs of different architectural communities, e.g. mentioned by other authors - Seruga's principle of the 6E of the energy-efficient, economical, ecological, flexible, aesthetic and ergonomic house, referring to sustainable architectural and urban design [1]. In essence, sustainable architecture is characterised by factors, such as energy efficiency, use of alternative energy sources, economy of raw materials and materials, rational water management, attention to atmospheric cleanliness, psycho-physical comfort, respect for the site and surroundings, and pro-environmental communication [1].

On the basis of the principles of sustainable design that have already been collected and analysed, in this article, selected principles that represent the highest value for the authors in the context of sustainability, based on the three pillars of sustainability, are highlighted:

- energy efficiency;
- environmental protection;
- material efficiency;
- internal quality and health;
- social and cultural integration;
- spatial planning and mobility.

By applying the above-mentioned principles in a single design process, one can aim to create new design approaches that can be recognised as innovative design strategies.

SELECTED SUSTAINABLE DESIGN APPROACHES

Nowadays, the development and combination of innovative design strategies are at the heart of introducing sustainable solutions in architecture. Many architects, engineers and researchers are constantly searching for innovative design approaches that incorporate closely interlinked ecological, economic and social aspects. Currently, newly developed design methods and approaches themselves contain the potential to perform design processes at a world-class standard. Thanks to these strategies, the designed objects and spaces are not only efficient and functional, but also work in harmony with the environment. Among the innovative design strategies referring to the above-mentioned principles of sustainable design the following ones can be distinguished:

- 1) bioclimatic design;
- 2) modern materials and technologies;
- 3) community design;
- 4) design thinking;
- 5) open-source design.

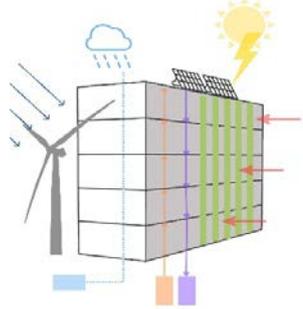
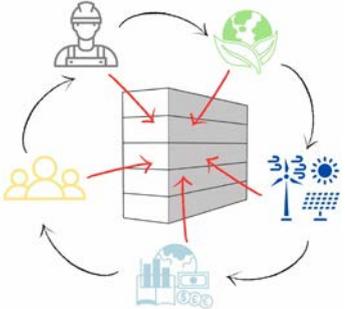
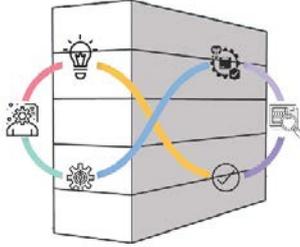
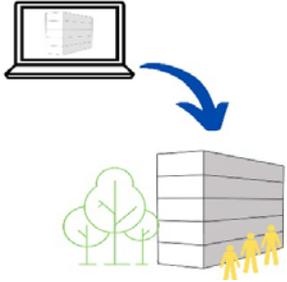
Using and combining strategies or elements of strategies in the design process can contribute to achieving sustainable architecture.

1. **Bioclimatic design:** bioclimatic design is one of the most popular design strategies, which is based on the use of natural climatic and environmental conditions to ensure the highest comfort and energy efficiency. This approach is closely linked to the climate and involves a careful analysis of it in order to adapt the design to specific environmental conditions. It is important to position the building in relation to the sides of the world, which influences natural ventilation and lighting and maximum use of solar energy, as well as preventing heat loss [10]. In addition, appropriate thermal insulation is used to minimise heat loss in winter and cooling loss in summer. In bioclimatic design, it is important to use renewable energy sources to produce clean energy and heat, while reducing greenhouse gas emissions [1][11][12][13].
2. **Modern materials and technologies:** the use of modern materials and technologies is one of the most common approaches in the design process. Innovative technological solutions contribute to minimising energy and resource consumption, which consequently increases the efficiency of buildings. Modern materials in the form of natural fibre composite materials, cross-laminated timber (CLT), low-carbon concrete and recycled plastics have a low carbon footprint, with a significantly lower environmental impact when used in comparison to traditional materials. Sustainable technologies also include the use of renewable energy, intelligent building management systems, such as energy consumption monitoring systems, lighting and ventilation automation and waste management systems that result in maximum resource utilisation and reduced energy consumption. Sustainable design has begun to use materials and technologies capable of purifying the environment (green roofs and façades). In addition, recycling and waste management technologies are being used, which has a positive impact on the environmental aspect [14][15].
3. **Community design:** community design is a design approach that prioritises community participation in the design process. It is considered a holistic approach, incorporating especially the social aspect, but also the economic and ecological aspect, aiming to create socially and environmentally friendly (sustainable) spaces. In the context of sustainable development, community design can be implemented through public participation, i.e. involving the local community in the design phase and giving them the opportunity to influence the shaping of their surroundings. Together with the influence of the community creating their space, there is an increase in the quality of the environment, resulting from the desire to make life more comfortable [16].
4. **Design thinking:** design thinking, at its core, uses the human centre of thinking, meaning that it places a strong emphasis on learning about the perspectives and experiences of the project's users. This approach, like social design, involves users in the research and design processes through observations, interviews and the creation of users' character profiles in order to understand their needs, goals, motivations and challenges [17]. In relation to sustainable design, design thinking fits into the socio-cultural aspect by creating functional spaces with an enhanced standard of living. Using research and striving for the best possible solutions can lead to the discovery of new sustainable solutions. Design thinking enables the combination of perspectives and knowledge from different disciplines, which can lead to a holistic approach in sustainable design [18].
5. **Open-source design:** open-source design is a design approach whose main objective is to share and collaborate openly in the design process, allowing free access to designs, and thus modifying and disseminating them. By making designs openly available, access to design solutions, particularly sustainable ones, is enabled, consequently giving designers and community the chance to learn and use the design with customisation. Open-source design fosters an interdisciplinary approach, encouraging collaboration between experts from different disciplines, which can lead to the development of sustainable designs. This approach also promotes the involvement of the community in the design process, providing the opportunity to take into account unique needs and socio-cultural contexts [19][20].

The main characteristics and principles of selected approaches in sustainable design together with examples are described in Table 1, in order to systematise design strategies in the context of sustainability.

Table 1: Selected design strategies (elaboration: authors).

General characteristics of selected strategies in sustainable design			
Bioclimatic design	<ul style="list-style-type: none"> • Analysis of climate and local conditions • Optimum building layout • Thermal insulation and insulating capacity • Use of natural lighting and ventilation • Use of renewable energy sources 	<ul style="list-style-type: none"> ➤ Geodesic Dome - Expo 67 Pavilion in Montreal, Canada (Richard Buckminster Fuller, 1967) ➤ One Angel Square in Manchester, UK (3DReid, 2013) ➤ Edificio Malecon, Quito, Ecuador (Pablo Pschepiurca, 1999) 	

<p>Modern materials and technologies</p>	<ul style="list-style-type: none"> • Materials with a low carbon footprint • Renewable energy • Intelligent building management systems • Environmentally friendly materials and technologies • Recycling and waste management technologies 	<ul style="list-style-type: none"> ➤ The Edge, Amsterdam, Netherlands (PLP Architecture, 2015) ➤ CopenHill, Copenhagen , Denmark (Bjarke Ingels Group, 2015) ➤ The Line, Neom, Saudi Arabia (Thom Mayne, Peter Cook, and Roger Soto, in progress) 	
<p>Community design</p>	<ul style="list-style-type: none"> • Social participation • Strengthening the local community • Multi-faceted approach • Improvement of the environment • Long-term planning and flexibility 	<ul style="list-style-type: none"> ➤ The High Line in New York, USA (Piet Oudolf, James Corner, Charles Renfro, 2009) ➤ Escalators of Comuna 13, Medellín, Colombia (Carlos Escobar, transformed a Colombian neighborhood in Medellin in Columbia, 2011) ➤ Ilima Primary School in Kenya (MASS Design Group, 2015) 	
<p>Design thinking</p>	<ul style="list-style-type: none"> • Problem definition • Idea generation • Prototyping and testing • User focus accessibility • Empathy, flexibility and creativity 	<ul style="list-style-type: none"> ➤ Masdar City in Abu Dabi (Norman Foster, 2006) ➤ LUMA Arles, Arles, France (Frank Gehry, 2012) ➤ The Shed, Nowy York, USA (Rockwell Group, 2019) 	
<p>Open-source design</p>	<ul style="list-style-type: none"> • Openness and accessibility • Cooperation and participation • Improvement and iteration • Transparency and fairness • Open licence 	<ul style="list-style-type: none"> ➤ Open Building Institute (Web site) ➤ Pavilion OpenStructures (Web site) ➤ WikiHouse Project (Web site) 	

THE URBAN FARM AS A RESPONSE TO SUSTAINABLE DESIGN STRATEGIES

Nowadays, urban farms represent an innovative form of urban agricultural production that is based on the principles of sustainability, while creating a living environment that is closely connected to the urban space. Urban farms are often ecologically and economically autonomous and self-sustaining architectural entities. It is achieved through the use of sustainable design strategies. Urban farms, especially vertical urban farms, are a conglomerate of advanced technologies and the use of modern materials adapted to specific climatic conditions and creating an ideal microclimate for growing food. Urban farms are an interesting and innovative solution combining the aforementioned design strategies, which are in line with the principles of sustainability.

Aspects linking sustainable design and urban farms relate to the optimal use of resources, minimising environmental impact, improving quality of life, involving the local community, and to the possibility of innovation and achieving long-term sustainability. These types of agriculture allow food to be grown in a residential environment, for the local community, which minimises the need for transport while reducing energy consumption. It also uses advanced hydroponics or aeroponics technology, contributing to the optimal use of natural resources.

In order to maintain urban farms to an efficient standard, methods of renewable energy harvesting, rainwater harvesting and CO₂ reduction are being introduced to help protect the environment. Such agricultural facilities not only serve to

provide food, but also provide a social environment. They can be used as places for education, social integration and recreation, enabling residents to have direct access to healthy food, improving their health and therefore their living comfort. They are often designed, developed and managed in collaboration with the local community, involving the community to promote sustainable living. Due to the structure of urban farms and their location, urban farms must be designed using long-term and timeless solutions to counter the problems of climate change and environmental degradation [21]. The introduction of urban farm facilities in response to sustainable design standards can go a long way in creating a symbiotic space between the community and the environment with the main aspects of sustainability in mind.

DISCUSSION AND CONCLUSIONS

In times of rapid development and constant change, it is necessary to educate architects, on a local and global scale, about structures, communities and the environment. The education of architects should be interdisciplinary and involve the exploration of knowledge in different areas of technical, engineering, social and applied science [4].

A contemporary topic discussed within the discipline of architecture is sustainable development. The guidelines of sustainable design in relation to design and construction technologies are complex enough to require professional expertise and experience. Due to the ever-evolving trend of sustainable design, an appropriate educational system, subject to continuous modification, dedicated mainly to the tenets of sustainable architecture is required in architectural faculties. This involves the rapid development of technologies, the emergence of innovative materials and the creation of new design strategies using modern principles [22].

In the field of sustainable design, the education of engineers plays a key role in creating a future in which architecture is integrated with the environment and provides social benefits. The education of engineers is designed to prepare them to understand, design and implement sustainable solutions that contribute to reducing negative environmental impacts, improving energy efficiency and creating people-friendly spaces. Therefore, it is important that engineering education programmes take into account aspects of sustainability and prepare students to work in a dynamic and changing environment [3].

The education of engineers is also intended to develop their critical thinking skills, creativity and innovation. Engineers should be able to identify problems associated with poor design and propose innovative solutions. An important aspect of educating engineers in sustainable design is also learning how to collaborate and communicate. Engineers often work in design teams where collaboration between different professionals, such as architects, environmental engineers, urban planners and sociologists is crucial [3].

As part of the curriculum of the architecture degree programme at University of Technology in Kielce, Poland, there are two subjects in relation to sustainable design - these are *Sustainable Design Fundamentals* for the engineering degree and *Sustainable Design Determinants* for the Master's degree. In regard to these subjects, students carry out projects focusing mainly on sustainable solutions taking into account the scope of energy procurement, modern materials and technologies, accessibility and all relevant aspects in relation to sustainable design. The subjects aim is to prepare students to design in modern times, with the environment in mind, and to sensitise students to the creation of ecological, economic and social spaces to meet the requirements of all users.



Figure 1: ARTS - ecological centre for new art, student project (author: Adrianna Pawlik).

An example of a proposal for sustainable solutions, using the aforementioned design approaches, is the diploma project depicting a model of an urban farm in Kielce, Poland (Figure 2). The solution was to create a living space for the

community of Kielce that would integrate local society and engage it in the communal cultivation of plants and vegetables. This solution has a major impact on economic and environmental aspects.



Figure 2: Diploma project, *City Farm* (author: Bartosz Cecot).

The project incorporated the three basic pillars of sustainable design and principles, such as community design, modern materials and technologies in the form of green roofs, algae façades and renewable energy generation. This indicates that the urban farm can respond to sustainable design standards. Food-growing spaces accessible to all residents have been created, sustaining community ties. Green roofs made of filter mats are designed to collect excess water and direct it to a retention basin, which, using pumps, provides drip irrigation. Organic waste turned into compost is to be a source of biofuel used to provide energy. The whole complex was designed to be a self-sustainable unit with mixed-use buildings. In the design concept, the entire farm is powered by renewable energy from algal panels and photovoltaic materials used in the glazing.

SUMMARY

In conclusion, sustainable development is not only a need, but also an opportunity to create better, more harmonious and ecologically responsible designs. Sustainable design provides the tools and framework to create a future that respects the environment, cultures and the needs of communities, and new design strategies that are constantly being introduced enable new and sustainable ideas to be implemented more quickly and easily into the design process.

The primary role of educating engineers in sustainable design is to provide them with knowledge and skills about sustainable principles and practices and selected design approaches. Students should gain knowledge of the ecological, social and economic aspects of design and be given the tools and techniques to analyse, plan and implement sustainable solutions enabling innovative and novel designs using sustainable design strategies.

All implemented approaches and methods of sustainable design can be applied at the level of architecture, as well as urban planning, creating not only sustainable buildings, but harmonious and environmentally friendly surroundings and communities. It is important to sensitise students to perceiving the context of the environment and the building, so that at the same time the object and the space remain at the same level of sustainability. Incorporating innovative design strategies into the architectural curriculum is crucial to enrich future architects with the knowledge and skills needed to create sustainable spaces. In doing so, the architecture curriculum prepares students for industry challenges, and empowers them to be creators of a sustainable and harmonious future.

Due to the rapidly growing trend of sustainable architecture and emerging new design methods, improvement and evaluation in the field of sustainable design should also take place at the educator level, in order to communicate the latest principles and guidelines, and to point out the tools available to create the highest standard of sustainable architecture.

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