Developing specialized coursework for smart architecture: A focus on emerging and re-emerging technologies

Aida AL HOSNI,
Ion Mincu University, Bucharest, Romania
a.s.hosni2020@gmail.com

Abstract
Discussing smart cities means having an understanding of smart technologies revolving around making the cities more smart, sustainable, economical, and ecological, following that train of thought and understanding those desires and the present problems makes it more important to understand the technologies used in the architecture used around the label that makes cities smart and adhere to the specific characteristics following the change and advancements of the moment. To gain a better understanding of emerging technologies, we need to develop specialized coursework focused on analyzing, comprehending, integrating, and utilizing these advancements in smart architecture. This article will explore how both emerging and re-emerging technologies can be integrated into a smart architectural curriculum. It will highlight the application of each technology, its integration into architectural projects, its role in the development of smart cities, and provide details on the advantages and disadvantages associated with each one. One of the prime examples of re-emerging architectural advancements discussed in this article is Biomimetic Architecture. This approach is inspired by nature, using its designs and resources to solve human problems. While it has faced criticism for creating a perceived distance between humans and nature—suggesting that nature's solutions are superior to those created by humans—it also represents a blend of natural design and human innovation, Architectural courses will focus on technologies as complex as biomimetic architecture, providing clarity on current advancements.

Keywords: technological roadmap, Smart Architecture Coursework, student needs.

1. Introduction

The architectural landscape is experiencing a profound transformation fueled by the rapid advancement of technology. To gain a deeper understanding of these innovations, it is essential to stay informed about recent developments that can enhance our architectural practices and expand our knowledge in related fields that address today's needs. Over the past decade, we have observed significant changes in how technology integrates with the fundamental aspects of construction and architecture [1]. Many smart cities and futuristic conceptual designs have emerged, grounded in technological advancements that originate from new research, discoveries, or even the revival of older concepts now adapted to contemporary demands[2]. Keeping pace with technological innovations in architecture can be challenging, as the desire for a better and more comfortable life shows no signs of slowing down.

A coursework program specializing in smart architecture will provide detailed information focused on advancements in architectural technology [3]. It will cover the history and specialization of these advancements, as well as a core curriculum that includes fundamental principles of building science and engineering, core concepts and their feasibility, advanced digital design tools and techniques, and programming and data analysis.

Elective courses will explore specific areas of specialization such as the Internet of Things (IoT) [4], artificial intelligence, robotics, virtual and augmented reality, sustainable design, construction development, and biomimicry.This comprehensive approach will provide students with an understanding of recent advancements and future developments in these fields. Additionally, students will learn essential guidelines for integrating these technologies into modern buildings, particularly concerning the roles of architects in the construction and design of new smart cities

This article explores the necessity for specialized coursework in smart architecture that integrates emerging technologies such as the Internet of Things (IoT), artificial intelligence (AI), and virtual/augmented reality (VR/AR), along with re-emerging concepts like biomimicry and green building practices. In this discussion, biomimicry serves as a key example, as it involves mimicking nature's designs to address contemporary architectural challenges. By examining how various organisms thrive, architects can develop sustainable and energy-efficient buildings. For instance, inspiration can be drawn from termite mounds for natural ventilation, while lotus leaves may lead to the creation of self-cleaning facades.

Through literature reviews and case studies, this research highlights the crucial components of a smart architecture curriculum and aims to identify both challenges and opportunities in its development. The insights gained will be valuable to academic institutions, industry professionals, and policymakers who seek to innovate and advance the field of smart architecture.

2. Core curriculum

2.1. Fundamental knowledge and typologies for the curriculum

When developing a core curriculum for architecture, it's essential to include Science and Engineering Fundamentals, as they form the backbone of architectural practice. Key subjects like Structural Engineering, Building Physics, and Building Services are vital.

Structural Engineering gives architects a solid grasp of structural analysis, materials science, and compliance with building codes, ensuring designs are both aesthetically pleasing and structurally sound. Building Physics covers heat transfer, airflow, and moisture management, enabling architects to create energy-efficient spaces that enhance comfort and sustainability [5, 2].

A thorough understanding of Building Services—encompassing HVAC, plumbing, electrical, and fire protection systems—ensures functionality and safety in designs. Integrating these scientific principles enhances sustainability, efficiency, and project quality.

Additionally, architecture students must become skilled in Digital Design Tools. Proficiency in Building Information Modeling (BIM) facilitates collaboration and analysis, while computational design and Virtual/Augmented Reality technologies offer innovative design solutions and immersive visualizations.

Finally, programming and data analysis are increasingly important in architecture. Learning Python enhances skills in data analysis and automation, allowing architects to make informed decisions and optimize building performance through data-driven insights.

These fundamentals are essential for gaining a deeper understanding of smart architectural technologies, their design, and their integration into contemporary architecture. They provide a structured foundation for coursework, equipping students with the necessary tools to utilize, create, design, and integrate technological advancements into projects. This approach takes into consideration current needs and aligns with the trends in smart city development.

2.2. Construction of references

Smart architecture courses will be categorized into four distinct typologies based on the level of technological advancement being studied. This differentiation allows for a clearer understanding of the intended development, its purpose, its applications, and its operational modes, which may vary according to the primary function of the technology discussed in each course. The typologies will include:

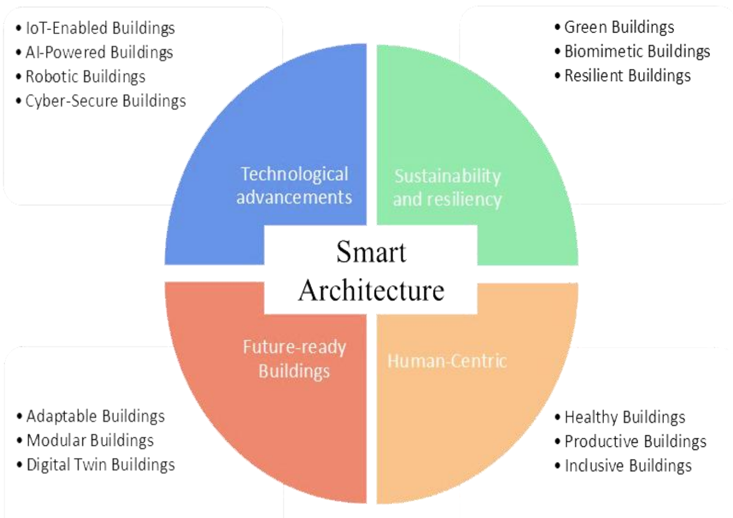

Fig. 1. Diagram illustrating the structure of the coursework

- Technologically Advanced Buildings

Technology has transformed building design and operation. IoT-enabled buildings use sensors and actuators to optimize energy efficiency, security, and occupant comfort. AI-powered systems automate tasks and enhance decision-making, while robotics improve construction, maintenance, and cleaning. To safeguard against cyber threats, cyber-secure buildings implement strong security measures to protect both physical structures and sensitive information.

- Sustainable and Resilient Buildings

Sustainability is at the center of contemporary architecture, with eco-friendly buildings emphasizing energy conservation, water efficiency, and the use of sustainable materials [6]. By taking cues from nature, biomimetic structures are designed to be energy-efficient, robust, and adaptable to evolving environments [7]. Additionally, the idea of resilient buildings is vital in confronting the challenges posed by climate change and natural disasters. These constructions are designed to endure harsh conditions, ensuring the safety and durability of their inhabitants.

- Human-Centric Buildings

Human-centric buildings enhance occupant well-being by prioritizing indoor air quality, natural light, and ergonomic design for better health and productivity. Productive buildings optimize spaces for creativity and include features like flexible workspaces and quiet zones. Inclusive buildings ensure accessibility for individuals of all abilities, removing barriers to navigation and use.

- Future-Ready Buildings

As we look to the future, buildings designed for adaptability are crucial in an ever-evolving environment. These constructions can be easily altered to meet changing demands and advancements in technology. By using prefabricated components, modular structures provide a quick assembly process along with customizable features to address particular needs. Additionally, the emergence of digital twin buildings — virtual representations of actual structures—allows for real-time oversight, simulation, and predictive upkeep, fostering a proactive strategy for building management and efficiency.

By categorizing and understanding the specific applications of each new architectural technology, we can more effectively identify the best fit for a given project or problem. This clarity helps us grasp the core function and intended use of these technologies, making their integration into architectural practices smoother and more efficient.

3. Emerging technologies in smart architecture

The rapid advancement of technology is fundamentally reshaping the field of architecture. Emerging technologies are redefining the way we design, construct, and manage buildings [8]. This chapter explores the key technologies driving the future of smart architecture, focusing on the most prominent trends: the Internet of Things, artificial intelligence, robotics, virtual and augmented reality, and cybersecurity.

- Internet of Things (IoT)

The Internet of Things (IoT) has revolutionized the way we interact with buildings [4]. By connecting devices and systems, IoT enables intelligent buildings that can monitor and control various aspects of their operation. IoT-enabled sensors can monitor temperature, humidity, and air quality, allowing for automated control of HVAC systems. Additionally, by collecting data on energy consumption, IoT can help optimize energy usage and reduce costs. IoT devices can also enhance security by detecting intruders, monitoring access control, and triggering alarms.

- Artificial Intelligence (AI) and Machine Learning

Artificial Intelligence (AI) and Machine Learning have the potential to transform the architectural design and construction process [9]. AI algorithms can analyze sensor data to predict equipment failures and schedule maintenance proactively. AI-powered design tools can generate innovative and optimized building designs. Furthermore, AI can be used to create personalized spaces that adapt to the needs and preferences of occupants.

- Robotics and Automation

Robotics and automation technologies are increasing efficiency and productivity in the construction industry. Robots can perform tasks such as bricklaying, concrete pouring, and welding, reducing labor costs and improving accuracy. Automated systems can transport materials and equipment around construction sites, increasing efficiency and safety. 3D printing technology can be used to create complex building components, reducing waste and accelerating construction time.

- Virtual and Augmented Reality (VR/AR)

Virtual and Augmented Reality (VR/AR) technologies are transforming the way architects design, visualize, and communicate their ideas. VR and AR can be used to create immersive experiences that allow clients to visualize building designs in detail. Additionally, VR and AR can be used to simulate construction processes, identify potential issues, and optimize workflows. Remote collaboration between architects, engineers, and contractors can also be facilitated through VR and AR.

These are only some of the emerging advancements focused on the technological part of the field, making architecture more contemporary response to the smart city demands and help integrate architects in the present architectural needs.

4. Re-emerging technologies and biomimicry

4.1. Biomimicry: Learning from nature

Biomimicry serves as an excellent illustration of the overlooked ideas that stem from advancements in architectural technology. This practice of imitating the designs and processes found in nature provides a sustainable and innovative perspective on architecture [10, 11]. By examining the complex strategies that organisms use to survive and flourish, architects can create buildings that are energy-efficient, resilient, and in harmony with the natural environment. Some of the technologies derived from biomimetic architectural concepts have led to:

- Eastgate Centre, Harare, Zimbabwe

This innovative building takes cues from nature, specifically termite mounds. Its design incorporates a passive cooling system that works like the way termites ventilate their homes. Thanks to this clever architecture, natural airflow is optimized, significantly lessening the need for mechanical cooling systems. It’s a brilliant example of how nature can inspire sustainable design [12, 13].

- The Lotus Effect

Have you ever noticed how raindrops bead up and roll off a lotus leaf? This unique self-cleaning property has influenced architects to design building facades that do the same. By imitating the microscopic structure of the lotus leaf, they’re able to create surfaces that repel both water and dirt. This not only cuts down on maintenance costs but also keeps buildings looking fresh and appealing.

- The Kingfisher's Beak

The sleek design of the kingfisher’s beak has had a fascinating impact on engineering, specifically with the Shinkansen bullet train in Japan. By mimicking the bird’s streamlined shape, engineers were able to significantly reduce air resistance, allowing the train to travel faster and more efficiently [11, 14].

a b

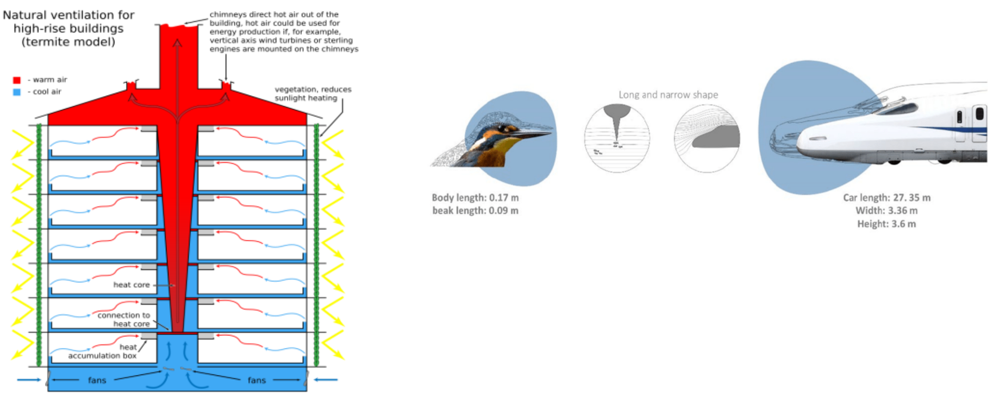

Fig. 2. (a) Natural ventilation high-rise buildings; (b) High Speed Train Inspired by the Kingfisher
Source: (a) Natural_ventilation_high-rise_buildings.JPG: KVDPVector version: Fred the Oyster, via Wikimedia Commons; (b) Organismal Design and Biomimetics: A Problem of Scale - Scientific Figure on ResearchGate

Each of these discoveries stemming from biomimicry provides a new understanding of the limits imposed on designs and projects. These technologies redefine the foundation of what is possible and give a new meaning to architecture. Biomimicry is, of course, just one of many advancements that simply need to be learned and understood.

4.2. Re-emerging technologies

On another note, several recent technological advancements have re-emerged in the architectural and construction fields [15, 8]. One significant example is modular construction, which involves the prefabrication of building components in a factory that are later assembled on-site. This method shortens construction time, enhances quality control, and reduces waste. Prefabricated building systems allow for the quick assembly of standardized components to create various structures, such as apartments and schools, while modular housing provides affordable and portable solutions for remote areas [16].

Another important innovation is the Passive House design, which prioritizes energy efficiency through three main strategies: ensuring high insulation levels to minimize heat loss, maintaining an airtight envelope to prevent air leaks, and employing mechanical ventilation with heat recovery to circulate air efficiently while conserving heat [17].

Lastly, the circular economy in construction promotes waste reduction and resource efficiency by designing buildings for deconstruction and recycling [16]. This involves choosing reusable or recyclable materials, implementing designs for disassembly, and minimizing waste during construction and operation.

By integrating these principles into coursework, we can prepare new generational architects to incorporate these technologies into their projects, ultimately creating sustainable and resilient buildings that are ready to face future challenges.

5. Results, interdisciplinary collaboration and project-based learning

Smart architecture is an exciting and intricate field that thrives on teamwork among experts from various areas. When architects collaborate with engineers, computer scientists, urban planners, and other professionals, they can tap into a wealth of knowledge and skills that lead to the creation of innovative and eco-friendly buildings. This kind of teamwork not only elevates the design process but also helps tackle the complex challenges we face in our built environment.

5.1. Knowledge and understanding for the Project-Based coursework

A basic understanding of technology is beneficial, but a deep dive into its intricacies and early integration into project development is crucial. Knowledge transfer is a vital strategy for smart leaders to foster innovation and sustainability in smart cities. By cultivating and promoting knowledge sharing, we can accelerate the development of solutions and ensure the long-term viability of smart city initiatives. To achieve this, we must create communities centered around the concept of smart cities that facilitate growth, application, and stability.

This knowledge-sharing environment can only be realized through leaders who understand and apply knowledge dynamics. Nonaka (1991; 1994) and Takeuchi (1995) made a significant contribution by developing the concept of knowledge dynamics, which involves the transformation of knowledge between different forms. Their model proposes a space for continuous knowledge transformation, outlining four fundamental processes: socialization, externalization, combination, and internalization. This SECI model is widely recognized in academic literature [18].

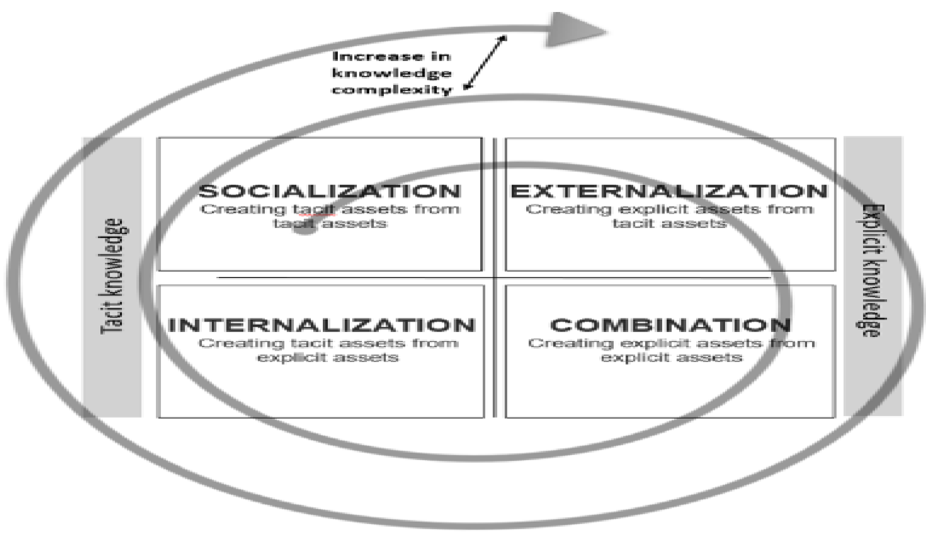

Fig. 3. SECI Model of Dynamic Knowledge Creation. Adapted from: (Nonaka, 1994)
Source: Andreea Bianca CAMARĂ."Knowledge dynamicsfor smart leaders and smart cities".

As time progresses, knowledge grows exponentially, making it increasingly difficult to absorb, recall, and apply. The nature of knowledge itself is constantly evolving to meet current demands and innovations. Keeping up with these changes becomes challenging as information is in a perpetual state of flux.

Nonaka's model emphasizes the importance of a culture of knowledge sharing and the creation of new experiences within organizations. This fosters a departure from traditional work methods and paves the way for innovation and technological advancement, which are intrinsically linked to the dynamics of knowledge [18].
This specialization will delve into technologies that influence the construction process from various angles:

- Internal: Building materials, IoT, robotics, modular construction, etc.;
- External: Window solar panels, green roofs, green facades, etc.;
- Surrounding Environment: Urban developments, smart city integrations, etc.

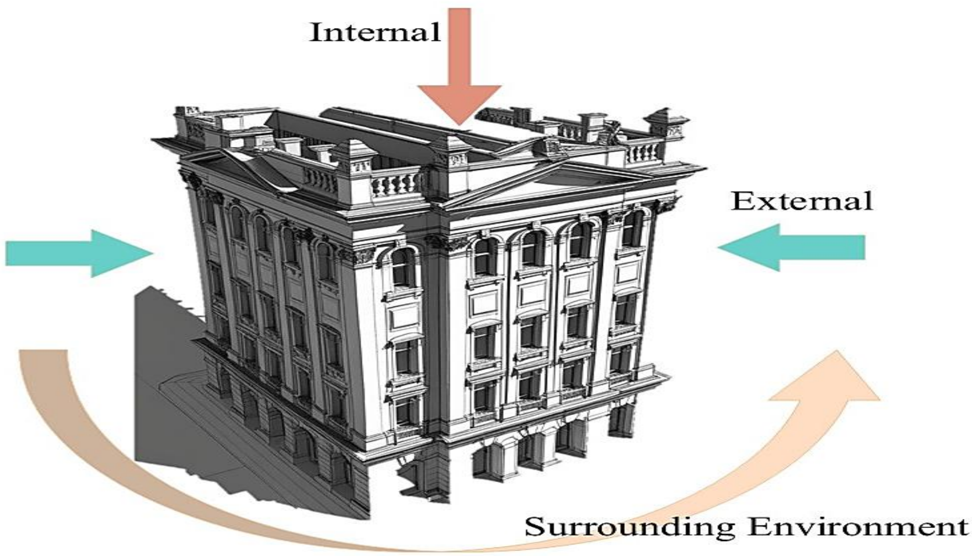

Fig. 4. The Three Impact Points of a Building

By focusing on these three impact point we can specify the knowledge needed into three domains of research, specific point of advancement integration and adaptation of the new generation of architect guiding into focusing on "what it is" and "what will be" with the basis of knowledge on "what was" already ingrained in them, it will open eyes to those who want to specify their profession or studies into a single angle without forgetting the impact of the two other on one common building, therefore knowing that the knowledge of each impactful technology on the building present to the use and understanding their use in a construction.

5.2. Result and response: A flexible coursework plan for emerging, re-emerging and futuristic concept technologies in architecture

As a result this research will aim to creat a new specialization in architecture focused on smart architecture advancements, their maniability and use for a smart life, for this a Flexible coursework on the subject will facilitate the learning process by cutting the program in different research module.

This course aims to prepare students to incorporate cutting-edge technologies into architectural design and practice. By combining theoretical lectures, practical exercises, and real-world examples, students will gain a deep understanding of the latest technological advancements and how to apply them to the built environment.

Specifically, the course will:

- Introduce students to a variety of emerging technologies relevant to architecture;
- Develop students' ability to assess the potential advantages and drawbacks of these technologies;
- Provide students with hands-on experience in utilizing emerging technologies for architectural design;
- Encourage innovation and creative thinking in architectural design.

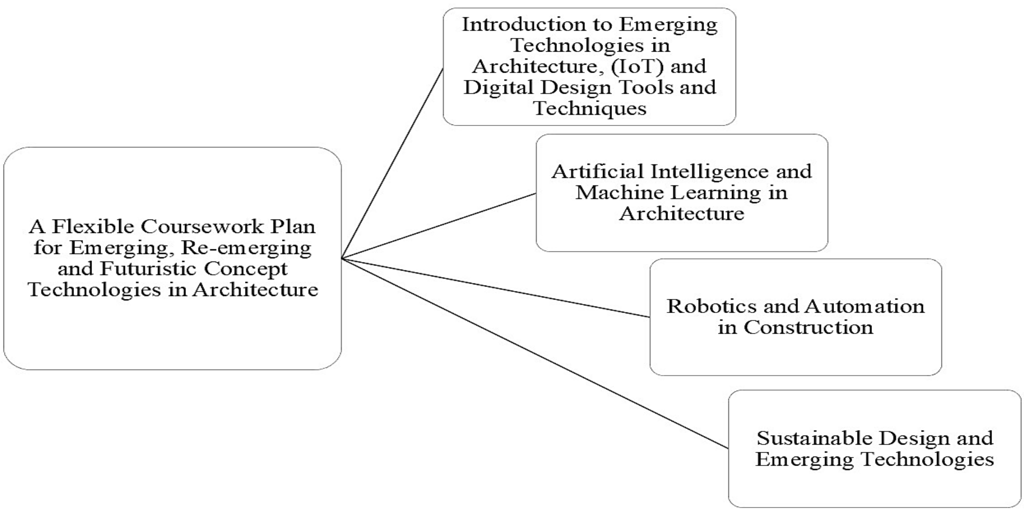

Fig. 5. The First Four Modules

This coursework plan is designed to be adaptable to different emerging technologies. By focusing on core principles and methodologies, students can apply their knowledge to a wide range of technologies as they evolve. The specific content of each module can be tailored to the latest advancements and industry trends following the four typologies of smart architecture as a basis for the modules (2.2. Construction of references), as technology advances modules can be added or changed depending on the discoveries uncovered, hence having the four categories as the basis of the Coursework and specialization.

5.3. Interdisciplinary collaboration

Interdisciplinary teams are fantastic because they bring together diverse perspectives and expertise to solve tricky problems. For example, when it comes to energy efficiency, engineers can work on optimizing building systems, while architects focus on designing spaces that make the most of natural light and airflow. In the realm of smart building technologies, computer scientists and software engineers can craft intelligent systems that gather and analyze data to boost overall building performance. Urban planners can also play a vital role by teaming up with architects to create sustainable, resilient urban environments tailored to the needs of communities.

On top of that, engaging in project-based learning gives students invaluable hands-on experience. As they dive into real-world projects, they sharpen their critical thinking, problem-solving, and teamwork skills—all of which are essential in smart architecture. This practical approach not only deepens their understanding of theoretical concepts but also equips them to contribute effectively to future collaborative efforts.

As an example: Designing a Net-Zero Energy Building [19, 20].

A net zero energy building is designed by the interdisciplinary team consisting of engineers, architects and sustainability consultants. Combined, the three of them set out to design a building that produced as much energy as they used — or a net-zero structure.

Achieving this goal requires addressing some key considerations. The envelope of an energy-efficient building, which is a key factor in reducing the consumption of energy, must be optimized first. Launching high-performance HVAC will also improve energy efficiency and comfort.

And the addition of renewable energy sources — solar, wind and geothermal top that list — helps reach net-zero status as well. In addition to these sources of energy, we also need good solutions to store energy so that energy that is generated can be used when needed. Finally, by integrating building automation and control systems, energy use can be monitored and managed, enhancing the sustainability goals of the building.

To better integrate architects into the industry, partnerships with technology companies can be game-changers. Collaborations can lead to the development of cutting-edge solutions for smart buildings. Additionally, continuous learning and professional development are vital for architects to stay up-to-date with the latest technological advancements and sustainable design trends. By working alongside engineers, computer scientists, and other professionals, and by engaging in real-world projects, students can gain practical experience and develop the skills necessary to tackle the challenges and seize the opportunities of smart architecture [3, 18].

6. Conclusion

The advancement of technology has greatly changed the architectural world and has led us into a new phase of smart architecture. Older traditions assume a society that can afford to have its buildings under-utilized for a long period of time at an enormous expense, whilst keeping them conserved until the next reallocation.

A specialized coursework in smart architecture gives students a strong background in the traditional principles of architecture with preparation for what the future holds for the built environment.A multidisciplinary, project-oriented, and real-world approach cultivates the methods and opportunities for the next generation of students to create and execute smart building systems [3].

With technology constantly evolving, architects must keep abreast of new directions, trends, and innovations. The architects who create young and old areas with the help of industry experts and lifelong learning will stay at the forefront of the field. With an eye toward new technologies and sustainable design, we can create functional, beautiful buildings that are environmentally responsible and socially equitable.

References

[1] E. van Hinte, M. Neelen, J. Vink and P. Vollaard, Smart Architecture, Rotterdam: 010 Publishers, 2003.

[2] F. M. Abo-Elazm, Ali and S. M. Ali, "The concept of " Local Smart Architecture " : An Approach to Appropriate Local Sustainable Buildings," ResearchGate, 2017.

[3] I. A. Drobot, "Smart Aspects of Academic Life: Research and Education," in *Smart Cities International Conference (SCIC) Proceedings*, 2023.

[4] L. Catarinucci, D. de Donna, L. Mainetti, L. Palano, L. Patrono and M. L. Stefanizzi, "An IoT-Aware Architecture for Smart Healthcare Systems," *IEEE Internet of Things Journal,* vol. 2, no. 6, pp. 515-526, December 2015.

[5] M. Senegala, "Rethinking Smart Architecture: Some Strategic Design Frameworks," *International Journal of Architectural Computing,* vol. 4, no. 3, 2006.

[6] A. Chigwenya and T. I. Zhakata, "Adopting Green Building Technologies for Sustainable Development: Insights from Harare, Zimbabwe," *International Journal of Real Estate Studies,* vol. 14, no. 2, pp. 8-17, 2020.

[7] D. M. Addington and L. D. Schodek, Smart Materials and New Technologies For the architecture and design professions, Elsevier, 2005.

[8] C. G. Lally, "Emerging Technologies, Re-Emerging Techniques," *The French Review,* vol. 74, no. 1, pp. 72-80, 2000.

[9] G. Marchis, "Employing AI in Regional Development: The Need for a Strategic Approach," *Smart Cities International Conference (SCIC) Proceedings,* vol. 11, p. 539–548, 2024.

[10] S. V. S. Sreeramagiri, "Biomimetics: Applications in Structural Design," *International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET),* vol. 10, no. 7, 2021.

[11] S. Mahmudova, "BIOMIMETICS NOTIONS PROBLEMS AND TECHNOLOGIES," *Bionics of Intelligence,* vol. 1, no. 92, pp. 31-35, 2019.

[12] N. Blessing, "CONSTRUCTION IN THE REPUBLIC OF ZIMBABWE:RURAL AND URBAN BUILDINGS," *V Международный студенческий строительный форум-2020,* 2020.

[13] V. I. Tanyanyiwa and O. S. Juba, "Green buildings and water management in Harare, Zimbabwe," *UPLanD - Journal of Urban Planning, Landscape & Environmental Design,* vol. 3, no. 2, pp. 83-92, 2018.

[14] G. M. Akash, "Application of biomimetics in design of vehicles–A review," *International Research Journal of Engineering and Technology (IRJET),* vol. 7, no. 3, 2020.

[15] S. Tatam, Evolutionary Ideas: Unlocking ancient innovation to solve tomorrow’s challenges, Harriman House, 2022.

[16] J. Mullan , "Re-Emerging Technologies: What's Hot and What's Not!," *Legal Information Management,* vol. 14, no. 3, pp. 168-173, 2014.

[17] S. Linić, V. Lučanin, S. Živković, M. Raković, S. Ristić, B. Radojković and S. Polić, "Multidisciplinary research method for designing and selection of bio-inspired," *Journal of the Brazilian Society of Mechanical Sciences and Engineering,* vol. 43, no. 57, 2021.

[18] A. B. Camară, "Knowledge dynamicsfor smart leaders and smart cities," *Smart Cities International Conference (SCIC) Peoceedings,* vol. 10, 2022.

[19] M. Kapsalaki, V. Leal and M. Santamouris, "A methodology for economic efficient design of Net Zero Energy Buildings," *Energy and Buildings,* vol. 55, pp. 765-778, 2012.

[20] L. Aelenei, D. Aelenei, H. Gonçalves and R. Lollini, "Design Issues for Net Zero-Energy Buildings," *Open House International,* vol. 38, no. 3, 2012.