The concept of an intelligent building in architectural education

Branislav Puškár, Edita Vráblová & Michal Czafík

Slovak University of Technology in Bratislava
Bratislava, Slovakia

ABSTRACT: The implementation of the latest technological innovations into the architectural concept of the building is an integral part of current architectural design. The technologies should be applied appropriately with regard to the future occupant. Therefore, it is important to pay attention to the understanding of specific technologies and their interrelationships already in the architectural concept phase during architectural education. In this article, the authors deal with the application of the intelligent building concept in the educational process in the Faculty of Architecture and Design at Slovak University of Technology in Bratislava, Slovakia. This learning supports students' ability to broadly consider and differentiate a myriad of technologies. The authors present the Hong Kong definition of intelligent building, which prioritises the needs of the user over smart technology itself, and subsequently describe its application within the pedagogical process at the Bachelor, engineering and doctoral studies. The aim of this article is to present the preferences of the intelligent building concept in students' tuition.

INTRODUCTION

Architectural engineering education in regard to intelligent buildings supports students' thinking in a broader context. An advanced intelligent building architectural concept is of considerable importance, especially in view of its future economic efficiency, functionality, comfort and value. The creative energy that has been spent on designing this high-quality architectural concept will save energy in the operation of the building in the future and ensure the comfort of its users.

> *This concept basically entails a continuous process of corresponding any environmental, social, and economic sustainability features to building designs. By depending on this design, building inhabitants and occupants will have more flexibility and comfort as well as maintaining the cost effectiveness of the building energy features* [1].

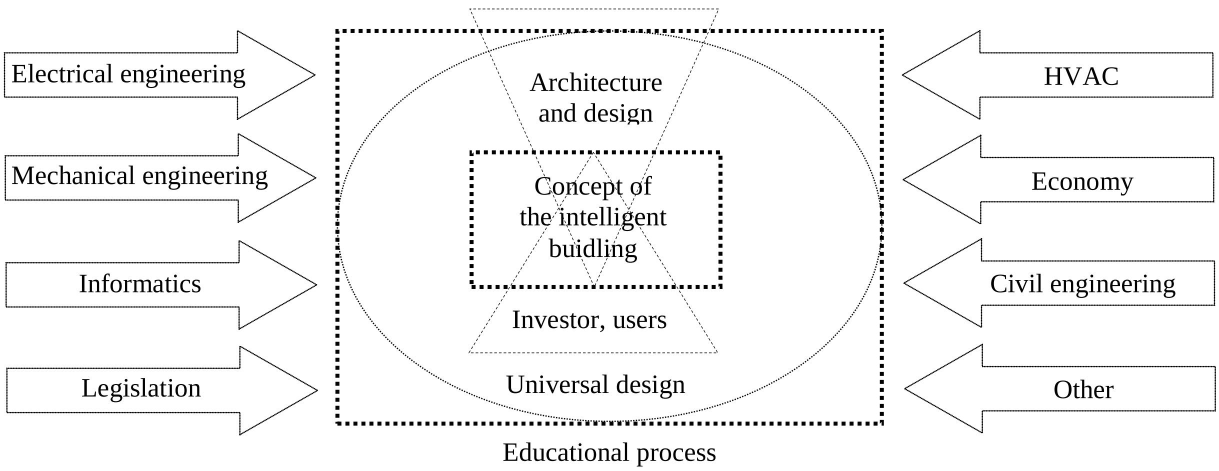

Figure 1: Determinants influencing the design of the intelligent building concept in the teaching process (HVAC - heating, ventilation and air conditioning).

The quality of the architectural concept is as important in the creation of an intelligent building as it is in a conventional building (see Figure 1). It is essential that this aspect is taken into account in the educational process and that universities produce graduates with advanced skills who are ready for professional practice [2] and able to meet the current requirements of the user, the investor, as well as society as a whole.

During the teaching process, it is necessary to pay attention to the gradual application of other scientific disciplines (mechanical engineering, electrical engineering, civil engineering, informatics, economics, legislation, and other), as well as to relevant technological equipment. The implementation of the determinants in an intelligent building without prior careful consideration cannot entirely fulfil the user's needs.

> *The integration of computer and information technology into the BEMS (Building Energy Management Systems) has been very popular recently. Such central co-ordination systems are able to monitor and control many of the activities and services associated with buildings. In this effort, significant is the role of the decision support systems, which can contribute to the continuous energy management of the daily operations of a typical building, aiming to preserve the comfort conditions of buildings' occupants and minimize the energy consumption and cost* [3].

Creating the architecture of intelligent buildings is also an aesthetic process. According to architect Adolf Loos, everyone must be pleased with the house, not only the architect. Unlike the work of art that may, but does not have to please everyone as it is a private creation of the artist [4]. If the architecture reflects the needs of its users, residents or operators, and meets the required functional and aesthetic qualities, the concept of an intelligent building can be effectively implemented at the optimal economic cost.

The architectural concept of an intelligent building forms an integral part of the definition of an intelligent building across different countries. It appears in various forms, focusing on different criteria depending on local needs and characteristics. The European definition of an intelligent building reveals the features of the architectural concept referred to as *quality design*. A good intelligent building design incorporates a number of procedures and methods that pave the way to a functional intelligent building.

> *Living in an era of smart technologies and innovations means there are now many more concepts and projects around the world by which to reverse the negative impact that humans have had on the environment* [5].

In the USA, the features of the intelligent building architectural concept appear in the form of adaptability contained in a building structure capable of meeting the changing demands of the changing users. Asian institutes have introduced an architectural concept in the form of specific requirements for an intelligent building solution. In Japan, the concept responds to the population density and is manifested by atria and vegetation roofs [6]. In Singapore, the architectural concept of intelligent buildings is linked to a wider urban framework with the support of intelligent communication technologies creating a smart city [7].

In the educational process, it is necessary to explain the complex image of intelligent buildings, which differs depending on location and time. It responds to the regional specifics and appears in various forms. The initial architectural concept is an important part of the intelligent building design. It creates aesthetic qualities, influences psychological effects on users and provides for long-term and timeless value. These criteria should be part of the pedagogical process at universities teaching architectural design of intelligent buildings [8].

The tuition dedicated to intelligent buildings is a complex and gradual process that cannot be taught by conventional methods. The complexity is hereby represented mainly by students' sound familiarity with individual software programs, the typology, building structures and building technologies (integrated professions).

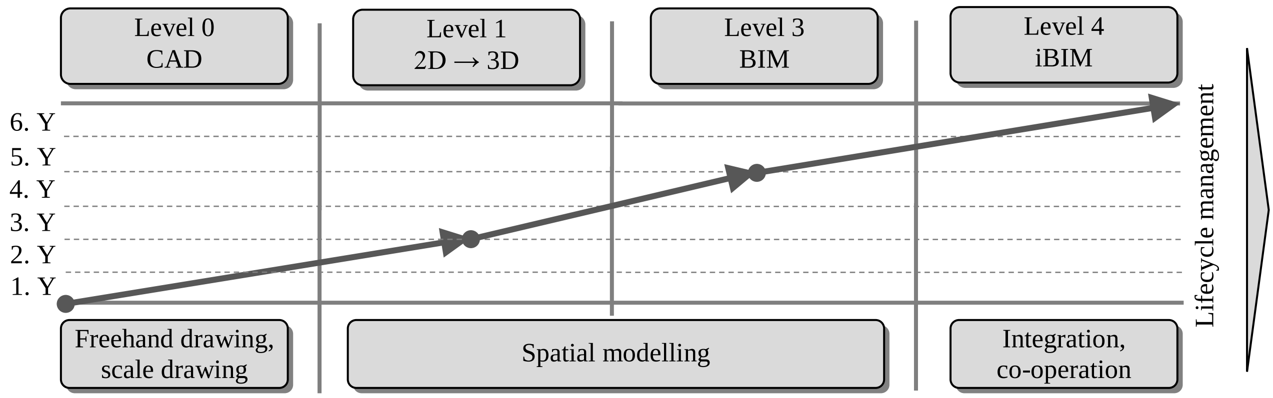

Figure 2: Educational process of the intelligent buildings architectural design (Y-year).

> *Regarding the connection of architecture and structure (in an absolute meaning), it is not a problem to define the content of teaching as a whole, but there is a difficulty in individual steps and their intersection, so that one does not absorb the other. Architecture cannot possess structure in a false form and building structure cannot absorb architecture in a spiritless concept* [9].

The students of architecture should learn integrated design during a six-year course, which provides for a comprehensive understanding of the design process (see Figure 2).

Level 1 - is the teaching of basic manual and computer-aided drafting techniques, primarily computer-aided design (CAD) programs.

Level 2 - represents the teaching of techniques presenting two- and three-dimensional design.

Level 3 - teaching focuses on building information modelling (BIM) - it is a highly collaborative process that allows architects, engineers, contractors, manufacturers, and others to design and construct a structure or building within one 3D model.

Level 4 - pedagogy is devoted to the integration of intelligent systems and technologies into BIM and peer collaboration.

> *The changes brought on by education in the design methodology based on building information modelling (BIM) are much more profound. They require a different manner of thinking about a building and about the design process itself. A design revolution has started. Instead of producing flat drawings, the designer constructs a virtual 3D model, as well as an entire database of information about a building, the structure of its lifecycle and the manner of its use. With the aid of structures, surfaces and objects - the attributes, layouts and mutual interrelations, which are established by the designer - they can generate intelligent buildings* [10].

The entire life cycle of a building shall be considered in the comprehensive architectural design process. Integrated design requires not only close collaboration between the architects and the engineers from the very beginning of the design process, but it also the use of advanced design methods and tools. Advanced digital documentation and a digital model of the intelligent building are critical in the decisive stage of outstanding intelligent building design. According to Ehrlich *...advanced smart building design methods enable rigorous verification of smart buildings before their implementation* [11].

APPLIED DEFINITION OF AN INTELLIGENT BUILDING IN THE PEDAGOGICAL PROCESS

The Asian Institute of Intelligent Buildings (AIIB) in Hong Kong is an independent certification authority for intelligent buildings that has developed the Intelligent Buildings Index (IBI). The IBI is composed of 378 assessment modules. The basic modules include: environmentally friendly preservation of health and energy (M1); space use and flexibility (M2); operation and maintenance costs (M3); comfort (M4); work performance (M5); fire resistance (M6); culture (M7); image of high technology (M8). The main environmental quality modules form the first definition level of an intelligent building. At the second level, the modules are associated with facilities that can be modified and extended. According to the AIIB, these innovative two levels allow a new definition of an intelligent building to be formulated:

> *An intelligent building is designed and implemented on the basis of an appropriate selection of environmental quality modules to meet the requirements of the occupants, while appropriate building amenities are being chosen so to achieve the long-term value of the building* [12].

The AIIB's definition of an intelligent building, as stated above, includes two basic levels. The first one represents the needs of contractors, owners and users, and the second includes supporting technologies. Proper alignment of the two levels according to the needs of contractors, owners and users ensures that the productivity and market value of intelligent buildings are achieved.

The AIIB's definition prioritises the user, their needs and requirements, while the actual setting of the supporting technologies and devices only come from the specific needs. This is in reverse to some other countries, where the aggregate number of facilities and services directly shapes the concept of an intelligent building.

According to Wong and Wang:

> *...this new definition gives designers clear direction and sufficient detail to enable high-quality intelligent building design in accordance with the intelligent building definition and to provide users and the general public with a fair platform for evaluating intelligent building performance* [13].

Architecture students need to be made aware of the discrepancy that often arises with single-level definitions, between users' expectations of an intelligent building and the actual experience of that building. The contradiction arises by defining an intelligent building according to the required equipment and technologies. The development of a two-level definition was driven by several research studies that pointed out the disadvantages of a single-level definition. If the user of an intelligent building is subservient to the technology, this usually leads to a situation where the technology does not meet the user's needs, which can unacceptably reduce productivity and increase operating costs.

The modules of the first level of the AIIB's definition can be sorted according to the requirements of a specific user. The ordering of the modules also allows the modification of the definition to reflect different typologies of buildings.

An advantage of the assessment of intelligent buildings by the AIIB is the possibility to define the needs, priorities and goals of the users. Setting a range of needs and expectations for an intelligent building will enable the creation of an effective form of intelligent building.

A drawback of the methodology is the poorly differentiated relationship to place, context and historical connections, abstracted in the eight modules. None of the modules defines the urban context. All modules define the intelligent building in isolation without the broader relationships and connections that are commonly considered in the architectural concept.

TEACHING THE CONCEPT OF AN INTELLIGENT BUILDING AT THE UNDERGRADUATE LEVEL

At the Bachelor's level in the Faculty of Architecture and Design at Slovak University of Technology in Bratislava, Slovakia (1st - 4th year), students work on simple designs of intelligent buildings. The topics of creative assignments are selected according to the year of study and have an escalating typological difficulty [14]. Students design a single-family house, followed by an apartment building and a civic building, concluding with a comprehensive Bachelor's thesis project. Design processing techniques play an important role in the pedagogical process in the development of the initial concept.

Several student approaches to the development of architectural concepts are known in the pedagogical practice at the undergraduate level. The most common way of displaying a student's idea is to create a simple volumetric solution, which is then functionally and typologically processed according to the assignment. The student creates throughout the semester the volume in the context of the surrounding buildings, and adjusts the layout and form during individual consultations. The student develops an architectural expression of an intelligent building by creating a three-dimensional virtual and physical model.

The characteristic elements of an intelligent building that the student can apply - the atrium and the penthouse - become apparent already in the elaboration of the model showing the architectural concept of an intelligent building. Students often complement the concept with biophilic elements - vegetation walls and roofs. Biophilic design is now often associated with intelligent buildings and sustainable architecture [15]. The students often apply an integrated control system as their preferred choice out of electronic intelligent control systems.

The preferred modules for the architectural concept at the Bachelor's degree level are module M1- environmentally friendly conservation of health and energy, module M3 - operation and maintenance costs and module M4 - comfort. The consequent integration of innovative technologies partly changes the perspective on the pedagogical process itself. The teacher no longer consults with the student only the architectural concept itself, but concurrently also the concept of an intelligent building.

TEACHING THE CONCEPT OF AN INTELLIGENT BUILDING AT THE ENGINEERING STAGE OF THE STUDY

At the engineering level, students work on more complex intelligent building designs. These are mainly multifunctional residential complexes, civic buildings, etc. Primarily verification design methods, i.e. working with software supporting building information modelling plays an important role in the pedagogical process. On the other hand, computer numerical control (CNC) machines and 3D printing technologies are used more often than manually generated physical models in the processing of the physical model of intelligent buildings. Multisensor design is applied in the intelligent building concept:

> *...by designing experiences that congruently engage more of the senses we may be better able to enhance the quality of life while at the same time also creating more immersive, engaging, and memorable multisensory experiences* [16].

Students often supplement the concept of an intelligent building with elements generated by 3D printing. They often apply intelligent assistant technologies when using the electronic intelligent control systems. The preferred modules for the architectural concept at the engineering degree level are module M2 - space use and flexibility, module M5 - work performance and module M6 - fire resistance.

The teacher not only introduces students to the concept of an intelligent building, but also assists them in laboratories with the use of progressive design methods, such as virtual reality and virtual environments. Similar to the Batchelor's level, several students' approaches to the development of architectural concepts are known at the engineering degree level. The most common way of modelling an intelligent building concept is using software supporting building information modelling and virtual reality in the concept creation. Simulated movement inside an intelligent building is feasible in a virtual reality laboratory (known as Oculus).

Students at the engineering level sometimes look too hard for an idea. Their ideas range across different areas that have been inspirational to them in real architectural projects. They most often draw ideas from the living and non-living systems - biophilic design - which is a common method of creating intelligent buildings.

The teacher at the engineering level of study motivates students to justify their idea. Interdisciplinary aspects often appear in the architectural design of intelligent buildings at this level. The overlaps with other disciplines allow architecture to address different aspects, e.g. social, economic or ecological. The presentation of an idea in students' studio work and in students' competitions is the most important stage of student skills and knowledge demonstration at the engineering degree level.

> *The design of VR-based educational methods should be expected to shift learning styles from teacher-centred to student-centred learning in a virtual or virtual-reality blended environment* [17].

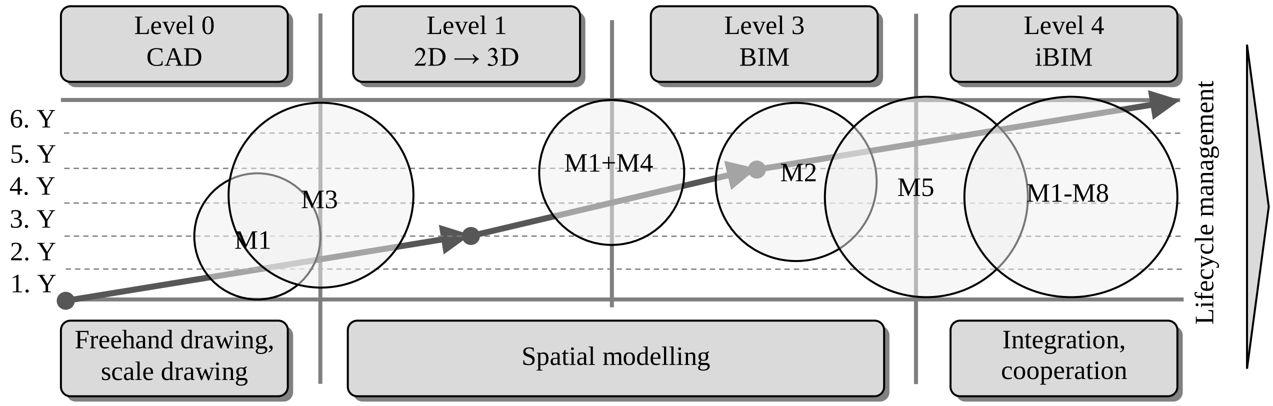

Figure 3: Application of the eight modules in the educational process of architectural design of intelligent buildings (Y-year) (M - module).

APPLICATION OF THE INTELLIGENT BUILDING CONCEPT AT THE POSTGRADUATE LEVEL

At the PhD level, students work with the concept of an intelligent building at a scientific level, therefore an individual approach is required when applying modules M1 through to M8. The students elaborate their research into a written scientific thesis.

The approach to the intelligent building concept is based on the exploration of complex interdisciplinary aspects. The students explore in great detail the sub-issues of intelligent buildings - discomforts, user preferences, economic and social aspects within the broad issue of intelligent buildings. The dissertation must include their own authentic research, based on theoretical and experimental scientific methods.

Research may consist of experiments in physical or virtual environments. At the PhD level, research on intelligent buildings often involves medical measurements of physiological functions, which are important to studies on stress factors affecting users of smart environments. This type of research enables the elimination of undesirable phenomena in intelligent buildings, such as discomforts occurring in the environment with inappropriately designed smart devices.

Currently, several students in the Faculty of Architecture and Design are involved in the Promoting Universal Design (PUD) project. The PhD students involved in the PUD project are analysing and comparing conventional and intelligent buildings, where the principle of universal design has been applied to their design. Universal design in the intelligent building concept represents a challenging adaptation of building operation to users with specific needs, significant limitations, physical, mental and cognitive functions.

> *An inclusive society accepts the diversity of people with different mobility and perception abilities/limitations and offers opportunities for participation in social life for everyone. Architects and designers play a very important role in creation of inclusive society, because they have strong impact on how people will feel themselves in the environment - included or excluded ones* [18].

Module M7 - culture and M8 - image of high technology, which reflect the social and cultural aspects of the environment are featured in the experimental designs of intelligent buildings at the PhD level.

CONCLUSIONS

In this article, the authors analyse the teaching and research of the concept of intelligent buildings at three degree levels of higher education. In this context, they reveal the frequency of the indoor environment quality modules occurrences described in the Hong Kong definition of an intelligent building in the undergraduate, engineering and postgraduate level of study. Although teaching of architecture is individual and inclusive (each student and each teacher practice different principles and modes of communication), certain preferences and practices appropriate for each level of education may be formulated. An important point in intelligent building education is the preference of advanced architectural concepts over technology and the preference of user expectations over economic benefits.

The methodology for teaching the architectural concept of intelligent buildings in architectural design does not proffer one defined approach. The correct principle is to introduce and consider multidisciplinary perspectives of the problems of the intelligent building concept that the architect encounters in his/her practice. This is just a tool to develop individual thinking. Answering an infinite number of questions broadens the student's way of thinking and generates suggestions that he/she can learn or deny. As future architects working with the intelligent building concept, students should be pedagogically guided to adapt themselves to the requirements of the intelligent building user, the psychological aspects of architectural design, and a comfortable and healthy existence in an intelligent building.

ACKNOWLEDGEMENTS

This article is the result of the PUD project (ITMS2014+, No. 312041APA3), which is implemented thanks to the European Social Fund support.

REFERENCES

1. Omar, O., Intelligent building, definitions, factors and evaluation criteria of selection. *Alexandria Engng. J.*, 57, **4**, 2903-2910 (2018).
2. Husár, M., Varis, S.C. and Ondrejička, V., Analysis of the planning education in the light of the contemporary trends in planning. *Proc. IOP Conf. Ser.: Earth and Environ. Science,* Prague, CZ, 1-6 (2017).
3. Doukas, H., Patlitzianis, K.D., Iatropoulos, K. and Psarras, J., Intelligent building energy management system using rule sets. *Building and Environ.*, 42, **10**, 3562-3569(2007).
4. Loos, A. *Ornament is Crime*. London: Penguin Books Ltd. (1997).
5. Oberfrancová, L. and Špaček, R., Educating architects - an optimistic vision for building sustainability evaluation. *World Trans. on Engng. and Technol. Educ*., 18, **4**, 462-467 (2020).
6. Kim, J., Intelligent building technologies: a case of Japanese buildings. *J. of Architecture*, 1, **2**, 119-132 (1996).
7. Mahizhnan, A., Smart cities: the Singapore case. *Cities*, 16, **1**, 13-18 (1999).
8. Czafík, M., Puškár, B. and Vráblová, E., Conceptual - contextual thinking in architectural education. *Global J. of Engng. Educ.*, 23, **2**, 106-111 (2021).
9. Ilkovičová, Ľ. and Ilkovič, J., Basic of building structure in architectonic education. *Global J. of Engng Educ.*, 21, **2**, 150-156 (2019).
10. Jagiello-Kowalczyk, M. and Jamroży, M., Education of architects in the field of BIM technology. *Global J. of Engng. Educ.*, 18, **3**, 180-185 (2016).
11. Ehrlich, P., *What Is an Intelligent Building?* In: Barney, L. (Eds), Web Based Enterprise Energy and Building Automation Systems. New York: River Publishers, 17-22 (2007).
12. So, A.T.P., Wong, A.C.W. and Wong, K., A new definition of intelligent buildings for Asia. *Facilities*, 17, **12-13**, 485-491 (1999).
13. Wong, J.K.W., Hi, L. and Wang, S.W., Intelligent building research: a review. *Automation in Construction*, 14, **1**, 143-159 (2005).
14. Czafík, M., Puškár, B., Vráblová, E. and Bacová, A., Architectural education and residential buildings. *Global J. of Engng. Educ.*, 22, **3**, 222-227 (2020).
15. Zhong, W., Schröder, T. and Bekkering, J., Biophilic design in architecture and its contribution to health, well-being, and sustainability: a critical review. *Frontiers of Architectural Research*, 11, **1**, 114-141 (2022).
16. Spence, C., Senses of place: architectural design for the multisensory mind. *Cognitive Research: Principles and Implications*, 5, **46**, 1-26 (2020).
17. Wang, P., Wu, P., Wang, J., Chi, H. and Wang, X., A critical review of the use of virtual reality in construction engineering education and training. *Inter. J. of Environmental Research and Public Health*, 15, **6**, 1-18 (2018).
18. Ceresnova, Z. and Rollová, L., Implementation of inclusive strategies in education. *World Trans. on Engng. and Technol. Educ*., 13, **3**, 392-396 (2015).