Teaching progressive technologies in architectural design

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ABSTRACT: The focus of this article is on the new forms of interaction between progressive technologies and the teaching of architectural design. The goal of the study described in this article is to introduce the new forms of interaction applied, the analysis of the methodology used, and to verify through students' results the success of applying the modes of interaction. Included are descriptions of the use of progressive technologies in teaching architectural design. Students' skills were evaluated on the use of progressive technologies in the creation of architectural concepts. Inspired inventiveness and research were demonstrated by the students, binding technology to architectural design. The results of this study have shown that the success of innovation in the teaching has been demonstrated.

INTRODUCTION

The trend in construction is towards the usage of progressive building technologies. Leveraging the progressive technologies is necessary to achieve almost zero energy consumption [1]. Hence, creating zero energy buildings [2] requires progressive technologies, i.e. the active use of solar energy, a new generation of heat pumps, the improvement of heat recovery systems, the creation of new efficient ventilation [3], refrigeration, air conditioning and hot air heating systems, as well as improved use of biomass and wind energy [4].

The development of building technologies includes the areas of renewable energy sources, heating and air conditioning, but in Slovakia, these are rare. On the other hand, these are the elements of progressive technologies, which provide new options for architectural design. One of the causes of the insufficient application of these progressive technologies is the lack of architects' knowledge of the use of these technologies in building design. The interaction between progressive technologies and architectural design is one of the fundamental requirements for architectural development in Slovakia.

There is a significant move towards the usage of progressive technologies for buildings in developed countries [5]. Progressive technologies in developed countries are incorporated into architectural solutions on a larger scale than in Slovakia [6]. Progressive technologies are very important for investors, because of the significantly lower operating costs. Slovakia is currently missing out on the application of progressive technologies of buildings, and new architectural works in Slovakia rarely use these. The causes of the low usage of progressive technologies in Slovakia are various, among them the lack of architects' knowledge of the use of progressive technologies in architectural design.

New principles are required to incorporate progressive technologies into architectural design, which is important in the development of architecture in Slovakia. These new principles of building design will become the theoretical basis for the further development of architecture. As progressive technologies develop, it is necessary to prepare architecture students for this development. They must be trained as part of the education of young architects to use the progressive technologies in architectural design.

RESEARCH ON PROGRESSIVE TECHNOLOGIES AND ARCHITECTURAL DESIGN

The research of the use of progressive technologies in architectural design was carried out during the lectures and tutorials covering progressive technologies for architects. Progressive technologies are taught on the courses, Technical Equipment of Buildings I and Technical Equipment of Buildings II. Assignment 5 was chosen from Technical Equipment of Buildings II, which is focused on the application of progressive technologies to the student's own architectural design. Students' architectural designs from the past two years were researched in detail with 110 students' works from 2017 studied. This was deemed sufficient for statistical evaluation [7].

RESEARCH METHODOLOGY

The goal of the research was to introduce new progressive technologies into the architectural design education of young architects and to scientifically analyse student results to demonstrate the success of this approach. The following topics were studied concerning progressive technologies and architectural design:

- new technologies in architecture - innovations and applications;
- leverage of progressive technologies in the creation of architectural concepts;
- leveraging of significant results in inventive concepts;
- assign and also link the logic of the architectural concept;
- inspiration in technologies as a spur to inventiveness - quality of energy;
- level of knowledge - understanding of energy and technology;
- exceptionality of a concept, technological maturity of a design, new architecture;
- inventive architecture.

The 110 students' works were subjected to scientific analysis and evaluated according to:

- skills in using progressive technologies for the creation of architectural concepts;
- inventiveness induced by inspiration from the technologies;
- exceptionality of the technology and architectural concepts;
- the binding of technology to architectural design;
- inventive architectural designs;
- research approaches to technologies in architectural design.

In the evaluation, the scientific methods of comparison, synthesis and deduction were used.

The use of progressive technologies in students' architectural designs was documented, viz.:

- the active use of solar energy;
- use of a new generation of heat pumps;
- improved heat recovery systems;
- new efficient ventilation;
- refrigeration;
- air conditioning;
- hot air heating systems;
- improved use of biomass and wind energy.

Detailed graphs with the results of the statistical evaluation are shown further in the article.

RESULTS AND ANALYSIS OF THE RESEARCH

For presentational purposes, the following progressive technologies were chosen:

- energy usage with the help of photovoltaic modules and solar collectors;
- new heating, ventilating, air conditioning (HVAC) systems - heat pumps, heating systems, air conditioning systems;
- application of new ecological systems - collection and use of rainwater, wind generators, green roofs and façades;
- research approach to innovative technologies.

Of course, the students also used other progressive technologies and modern construction materials for windows, floors, walls, and so on.

In the analysis of active solar elements, creative incorporation was differentiated from the usual application. Creative application of solar elements means unusual shape, its own unique design, inventive placement or exceptional detail. An interesting example is the creative photovoltaic elements in Figure 1, by student Monika Brijová for an apartment building (the initial design was mentored by Assoc. Prof. Ing. arch. Ľubica Selcová, PhD). There are unique photovoltaic elements on part of the roof and on the corrugated protruding façade. Apart from utilising the solar energy, there is an intelligent shading element rotating in the direction of sunlight. This flexible photovoltaic design with a low carbon footprint decreases carbon emissions by 40 percent compared to glass photovoltaic modules.

The following were considered for the incorporation of solar elements into students' architectural designs:

a) creative incorporation of solar collectors;
b) standard incorporation of solar collectors;
c) no application of solar collectors;

d) creative incorporation of photovoltaic modules;
e) standard incorporation of photovoltaic modules on roof;
f) standard incorporation of photovoltaic modules on façade;
g) no application of photovoltaic modules.

The results of the statistical evaluation of solar elements into students' architectural designs are shown in Figure 2 (letters correspond to the letters in the list immediately above).

Solar collectors were usually incorporated into roof levels, but there were also atypical applications. Photovoltaic modules were usually applied into roof levels. There were significantly fewer photovoltaic façades since students were designing low-rise buildings with three or four floors. Creative incorporation of photovoltaic façades was inspirational, but there were few of them. Solar collectors were incorporated in some form by 34 percent of students and photovoltaic modules were incorporated by 24 percent of students. The goal is to significantly increase these percentages. This evaluation pointed out areas needing more work with students. New approaches and forms of communication are needed with students, to encourage them to be more creative.

Figure 1: Example of creative photovoltaic element in architectural design of student Monika Brijová.

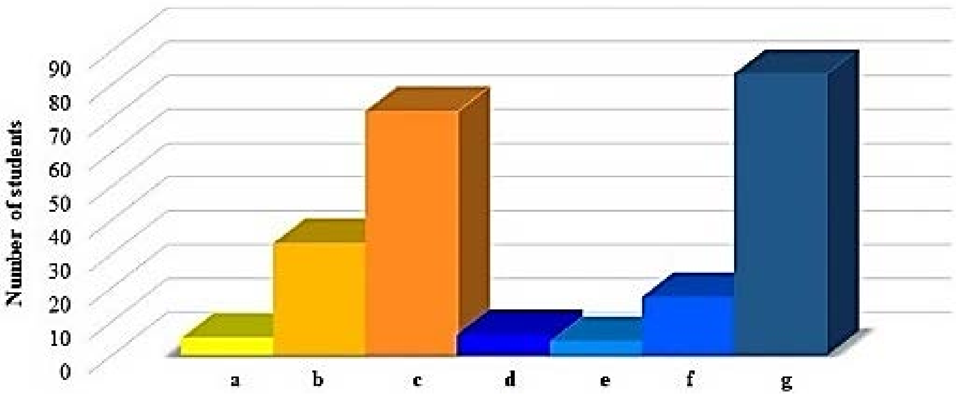

Figure 2: Evaluation of the incorporation of solar elements.

Another evaluation focused on new HVAC systems. The application of a modern heat source such as heat pumps was included. Creative solutions for HVAC systems were individually researched. These were mainly air conditioning systems, more specifically air distribution systems, creative placement of vents for air supply and vents to extract air. Next, were heating systems; namely, new designs of panel radiators and applications of radiant heatings.

The following were considered for the incorporation of HVAC systems into students' architectural designs:

a) application of heat pumps;
b) no application of heat pumps;
c) creative application of new heating systems;
d) creative application of new air conditioning systems;
e) standard application of new heating systems;
f) standard application of new air conditioning systems;
g) standard application of new heating systems and air conditioning systems.

The results of the statistical evaluation of HVAC systems in students' architectural designs are shown in Figure 3 (letters correspond to the letters in the list immediately above).

Heat pumps were incorporated by 41 percent of students, which is satisfactory. However, more attention should be paid to the possibility of leveraging heat pumps in architectural designs. Creative solutions for heating and air conditioning systems were fewer and so more work needs to be done with students in this field. The most frequent incorporation into architectural designs was the use of new heating systems ('e' in Figure 3). The most dominant buildings were low-rise residential and a gymnasium. Air conditioning systems are not yet used in these types of buildings in Slovakia, with a few exceptions.

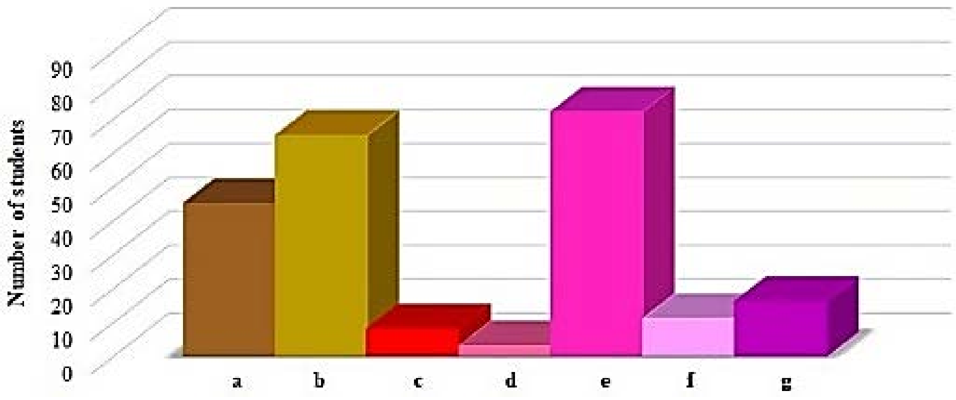

Figure 3: Evaluation of the incorporation of HVAC systems.

Next, new ecological systems were analysed: collection and use of rainwater, wind generators, green roofs and green façades. Application of wind generators, green roofs and green façades requires creativity since they are rarely used; therefore, creativity and standard application were not differentiated in the analysis.

The following were considered for the incorporation of ecological systems into students' architectural designs:

a) collection and use of rainwater;
b) no collection and use of rainwater;
c) application of wind generators;
d) no application of wind generators;
e) green roof;
f) green façade;
g) no green roof or green façade.

The results of statistical evaluation of the use of ecological systems in students' architectural designs are shown in Figure 4 (letters correspond to the letters in the list immediately above).

The evaluation shows that the students were most impressed by the collection and use of rainwater. The number of applications of wind generators was satisfactory; dominated by applications in the surroundings of the buildings. In the future, it will be necessary to work on the placement of the building. Applications of green roofs and green façades were exceptionally interesting and inspirational. Work with students on these green technologies should be intensified.

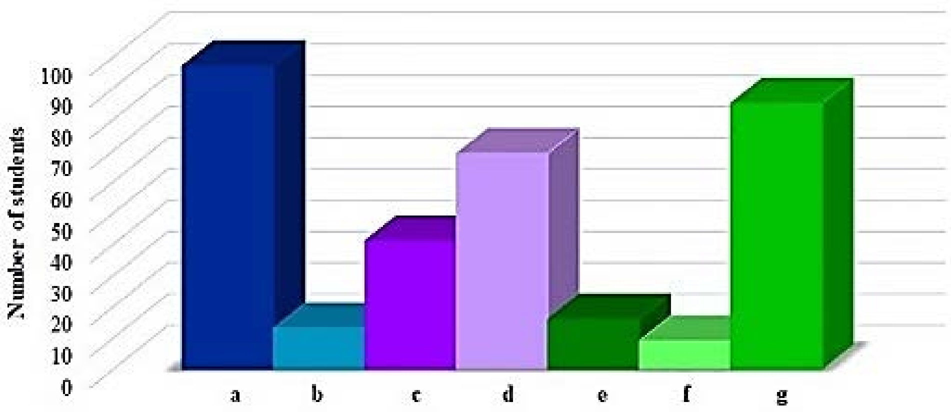

Figure 4: Evaluation of the incorporation of ecological systems.

The results of the statistical evaluation of a research approach to innovative technologies in students' architectural designs showed that 51 percent of students incorporated a new idea. The evaluation shows that some of the students had problems with the research approach and finding new inspirational thoughts.

Some students had an exceptionally positive research approach to innovative technologies. Their inspirations led to exceptionally creative incorporations into their architectural designs. The first such exceptional concept came from the student Máté Asbóth (see Figure 5). He focused on the developing technology of biological photovoltaics, which he incorporated into interestingly shaped roof levels of a new school site (entrance area, storage area, foyer, gymnasium, cafeteria). The initial design was mentored by Ing. arch. Štefan Polakovič.

Biological photovoltaics is an energy-generating technology, which uses oxygenic photoautotrophic organisms to harvest light and produce electrical power. Biological photovoltaic devices are a type of biological electrochemical system or microbial fuel cell, and are sometimes also called photo-microbial fuel cells or *living solar cells* [8]. In a biological photovoltaic system, electrons generated by photolysis of water are transferred to an anode [9]. A relatively high-potential reaction takes place at the cathode, and the resulting potential difference drives current through an external circuit to do useful work. As with other fuel cells biological photovoltaic systems are divided into anodic and cathodic half-cells.

Oxygenic photosynthetic biological material, such as purified photosystems or whole algal or cyanobacterial cells, are employed in the anodic half-cell. These organisms are able to use light energy to drive the oxidation of water, and a fraction of the electrons produced by this reaction are transferred to the extracellular environment, where they can be used to reduce the anode. No heterotrophic organisms are included in the anodic chamber - electrode reduction is performed directly by the photosynthetic material. The higher electrode potential of the cathodic reaction relative to the reduction of the anode, drives current through an external circuit. For example, oxygen may be reduced to water at the cathode, although other electron acceptors can be used. If water is regenerated, there is a closed loop in terms of electron flow (similar to a conventional photovoltaic system), i.e. light energy is the only net input required for production of electrical power.

In one case, a student focused on the application of moss, which uses energy from sunlight to convert carbon dioxide from the atmosphere into organic matter. Some of these organic compounds are released into the soil, where bacteria break down the organic compounds, releasing electrons. Electrons are captured by the conductive materials, creating an anode. Moss grew on the anode. Moss is usually found in cities, in the holes of floor tiling, on the roofs, on the walls and on the trees; therefore, this system is easily adapted to an urban environment.

In comparison to bigger plants, moss has other advantages, such as small weight, higher absorption level of water no healing requirements, high tolerance to dryness and low maintenance requirements. The student mentioned above created forms - hollow bricks for the placement of moss, which can create special microclimatic conditions helping to keep the moss alive. The lower part of the brick was glazed. To make the brick waterproof, the rest of the brick was porous clay without coating. This clay absorbs passively the water, so the system can passively intake the water from the rain and at the same time hydrogel maintains the humidity. These hollow bricks were creatively incorporated into the interestingly shaped roof levels of a new school site.

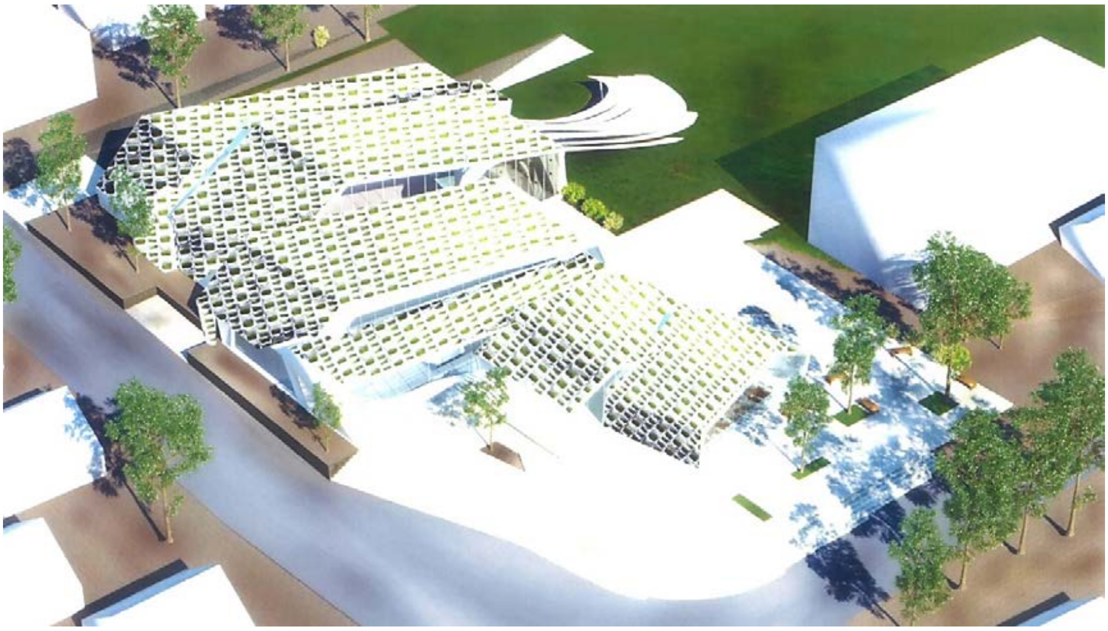

Figure 5: Architectural design of student Máté Asbóth, with biological photovoltaics.

Another example of the research approach to innovative technologies was the architectural design of student Jakub Hruška (see Figure 6), which was created to use progressive technologies. He designed a refugee camp, which represents a cheap and effective solution for the refugees of natural catastrophes and terrorism using progressive technologies - membrane and printable solar cells on thin-film.

The main constructional and expressional element is an ethylene-tetrafluoroethylene membrane over an aluminium frame on a steel construction. The membrane features are:

- transparency is 95 percent;
- economy - costs are lower by 70 percent compared to glass;
- resistance to high temperatures, chemicals and weather;
- security - elasticity during earthquakes and explosions;
- unique heat isolation properties.

Solar energy is used by new progressive technology - printable solar cells on thin-film, which will be placed inside since the membrane is UV permeable. It is an interesting example of interaction between progressive technologies and architectural design.

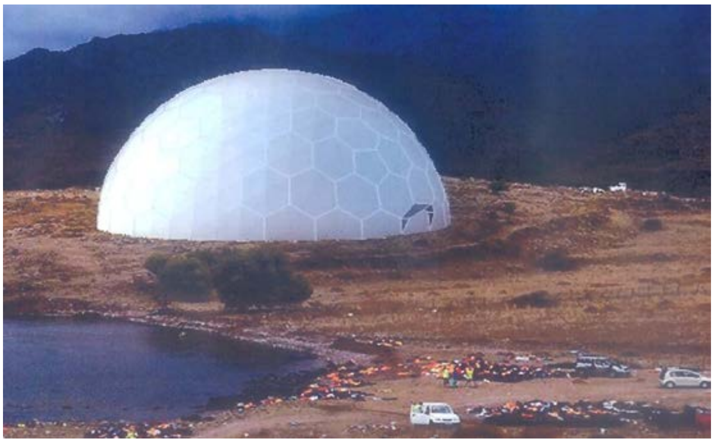

Figure 6: Architectural design of student Jakub Hruška.

CONCLUSIONS

The use of progressive technologies in architectural design was analysed and successful use was demonstrated by students' results. Statistical evaluation showed a positive bias of students in collecting and using rainwater, photovoltaic modules, solar collectors, new heating and air conditioning systems in their architectural designs. A good number was obtained of creative incorporations of solar elements, new HVAC and ecological systems in their architectural designs. The shortcomings were identified and future goals identified. These goals aim to achieve a higher number of incorporations of progressive technologies.

Some students sought for new inspirations for architectural design using progressive technology. Examples include biological photovoltaics and printable solar cells. Inspiration came from looking for new sources of energy and unconventional architectural design. This motivates students to acquire new knowledge of progressive technologies.

Progressive technologies can determine the quality of architectural designs and this was shown by the students' architectural designs. Students need to be motivated to increase their technical knowledge relevant to architectural design. Energy concepts of architectural design should be augmented by knowledge of new technologies. The students' work was influenced by *green architecture*. The application of progressive technologies in architecture was influenced by sustainability of the environment, which needs to be dealt with in the methodology of architectural design. Incorporating this into students' architectural design is highly important for their future.

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