Sustainable architecture in education

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ABSTRACT: The notion of *sustainable architecture* relating to human- and environment-friendly investments in view of economic and social aspects, is differently implemented in various countries. Thus, this article is focused on a five-month study on differences and similarities in architectural education in Turkey and Poland - two European countries with different climate and irradiation conditions. A joint curriculum was launched for one semester at both universities, and then evaluated through interview-surveys, peer-to-peer feedback, critical analysis and synthesis. The study's findings reveal the differences and similarities in both teaching, and creating sustainable, climate-related architectural ideas and concepts. They highlight the most important aspects of sustainable environment education, and enable further development of a more international approach towards architects and urban planners' education. Also, they show the effectiveness of certain teaching methods and tools giving a set of guidelines aimed at potential activities, improvements and the future growth of sustainable teaching.

INTRODUCTION

Education on sustainability for engineers, especially in the field of architecture, is a highly complex process, including theory and practice based on interdisciplinary knowledge and experience. Nowadays, due to climate changes, natural environment, economic and political issues, it has become particularly crucial and more demanding for the current and future global civilisation [1]. Attempts to integrate sustainability and energy efficiency into architectural education curricula through various theory and practice-based courses are common approaches at most universities and technical schools, implementing new themes into old courses and introducing new proposals. However, the most effective way to instil sustainability principles is the architectural design studio, where all theoretical and practical knowledge gained by students during their studies becomes useful in the scope of a design problem. Celadyn [1] and Schön [2] see this teaching form as a virtual world, where skills are learned with low risk and under proper supervision.

In this article, the authors present a comparative case study aiming at evaluation and forming sound guidelines for sustainability education for engineers and Bachelors of architecture. Students from the Faculty of Architecture at Wrocław University of Science and Technology (FA-WUST), Poland, and the Faculty of Architecture and Design at Bahçeşehir University (FAD-BAU), Turkey, were involved in this study. The study was guided by a pre-prepared common curriculum, research projects and involved supervisors. The authors also intended to examine common points and differences in the teaching approach to students from both countries, and to make a comparison based on climatic, geographic and cultural facts that would lead to conclusions useful for teachers and researchers.

RESEARCH OUTLINE

The construction industry has a significant obligation towards sustainable development as it is accountable for 35% of global energy use and 38% of CO_2 emissions, followed by factories, ineffective artificial heating and cooling systems, and harmful commercial practices [3]. In view of this situation, varied organisations and researchers try to introduce global changes to hold and possibly reverse the negative effects of development, usage and production. Firstly, the International Union of Architects (UIA) has defined principles for the ecologically-balanced and sustainable built- and natural environment, including the rational utilisation of available resources, which guided the vision of architectural schools, where education should be focused on a proper understanding of the life cycle of materials, issues of ecological sustainability, environmental impact, design for reduced use of energy, as well as passive systems and their management [4]. The National Architectural Accrediting Board (NAAB) mentions ecological knowledge and responsibility among its programme criteria stating that architectural education should enable future architects to mitigate climate change responsibly by leveraging ecological sustainability, advanced building performance, adaptation and resilience principles in their work [5]. The importance of sustainable education of engineers, especially in architecture has been previously stressed in numerous publications, and through various activates and enterprises.

In the article, *The outcomes and achievements of the Urban Design end Education Programme,* Olszewski and Pudlowski focused on educational issues and the showcasing of good-practice projects, which are crucial in training and broad dissemination, not only in the professional and educational environment, but also for general public [6]. This programme had a wide range and covered many other key education issues, forming a new approach towards the overall training of engineers. Attention must be also brought to a vast number of later articles in this respect, i.e. Haupt's discussion on the role of nature in teaching architects [7], Anastasiadis and Metaxas' outline of education for spatial and urban planners [8] or Trocka-Leszczyńska stressing the role of passive energy gains [9]. A great example are climate change organisations (CCOs) created by scientists and environmental activists, who unite over social media and others to raise public awareness on climate threats and its prevention solutions [10]. The need for sustainable architectural developments and education in this area has not weakened throughout time, as these ideas are a basis for a sustainable built environment, as pollution and degradation of natural resources is still frightfully rising [8].

AIM AND METHOD

Based on the described state-of-the-art knowledge, it was crucial to place this study in line with previous research and gains, and on such basis formulate the following aims of this article:

- Aim 1: to compare two teaching approaches in Poland and Turkey on education in sustainable architectural design.
- Aim 2: to evaluate the used teaching methods and identify good and effective practice that could be applied in European countries and be useful in a world-wide perspective.
- Aim 3: final - to introduce new teaching and research approaches and assess them to form guidelines and directions for academic teachers in architecture and architectural engineering field.

Between August and September 2020, a curriculum scope was prepared for common classes in a design studio format, based on previous data and within both universities' framework. This was done through comparative analyses and synthesis that selected important and common elements. The authors prepared a list of sustainable architecture design studio elements, included as Table 1 in this article. It was done for the comparison of students' projects and surveys. From October 2020, the common curriculum has been implemented for students of level studies 1 in both Poland (7th semester) and Turkey (6th semester). The literature recommended to students was based on common and publicly accessible books and articles [1][8][11-16].

All classes were proceeded by a theoretical introduction by lecturers. On that basis, students were developing concepts and ideas, then progressed to design in the following workflow: study (site, sustainability, climate, traffic, greenery, etc), defining a function (research hub or training facilities in Turkey and public community buildings in Poland), concept for urban and architectural solutions (1:500 scale), workshops, plans and sections (1:200/1:100 scale), elevations, perspectives. But most importantly, schemes and graphs were developed with descriptions showing sustainable assumptions and proposed solutions, sustainability strategy studies, diagrams, schemes, etc. That was followed by sustainable design details, scale 1:50, 1:20, if needed. The final proposals were assessed including technical drawings, physical models, digital visualisation, sustainability strategies and graphic project presentation. Due to the Covid-19 pandemic, classes in Poland were carried out on-line and in Turkey students had a hybrid system that also included face-to-face sessions. However, after the 6th week of the semester, the Turkish university had to switch back to on-line education.

In each group, five students were asked to complete a course assessment survey and pass on their overall perceptions about the course, which was conducted in late January 2021. The questionnaire survey was formulated by teachers with the use of available literature [11-16] and previous procedures from the WUST [17]. Based on the projects' in-class reviews, final grading, and the survey's findings on the teaching methods and the overall process, new teaching guidelines have been formulated for future educators.

EDUCATION SYSTEMS

The Faculty of Architecture at Wrocław University of Science and Technology (FA-WUST) and the Faculty of Architecture and Design at Bahçeşehir University (FAD-BAU) deliver education according to the Bologna system. In Poland, however, there are two level studies - the 1st level with a Bachelor degree in engineering/architecture upon completion, and the 2nd level studies with a Master degree. In Turkey, there is a single level curriculum and the graduates of faculties of architecture are awarded the Bachelor of Architecture degree after four years (eight semesters) of studies. In the FA-WUST, several teaching methods are used: design by research - at all stages of study, flipped classroom - especially at the literature and data review stages, learning by project - which is especially important in later student activities, such as analysis, elaboration of building working schemes or sustainable architectural and building detail elaboration. Tutors are using e-learning platforms and tools to structure the classes and students' self-work [17].

At the FAD-BAU, along with theoretical curricula, the design studios are the core of architectural education, where students can practically experiment using their design skills and knowledge gained from other courses delivered in both the digital and physical form. In the design studio, instructors use various teaching strategies and approaches, such as learning by doing, collaborative design, research-based learning, etc. Communication between the instructors

and students, as well as access to the course documentation is facilitated by an e-learning platform used by various schools.

CLIMATE COMPARISON

According to the Polish Institute of Meteorology and Water Management the climate and weather conditions in Poland are changeable, unstable, as observed throughout the years [18]. The air circulation is rather random and caused by oceanic and continental air masses, with characteristic local abnormalities. The certified climate data for the years 1981-2010 are as follows: average yearly temperatures for a substantial area of the country ranges between: 7-9 °C, in minor parts dropping to 3 °C or raising up to 9 °C, with rain from 450-650 mm for a substantial area of the country and 700-1,600 mm in minor parts. The average yearly sunshine duration in the aforementioned time period ranged from 1,500-1,800 hours in major parts of the land [17]. This data has to be supplemented with information from the Photovoltaic Geographical Information System in Europe, where monthly solar irradiation estimates are as follows: for Warszawa (Polish capital; location, lat/lon: 52.234, 21.010) - global horizontal irradiation for 2005: January 16.56 (kWh/m2), July (peak) 181.78 (kWh/m2), December (bottom) 12.05 (kWh/m2); direct normal irradiation for January: 26.04 (kWh/m2), July (peak) 156.23 (kWh/m2), December (bottom) 14.12 (kWh/m2) [19].

Turkey is a country with different weather conditions in its regions. Between the coast in the southwest and the inlands in the east, there is a substantial difference in average temperatures, as well as the precipitation amount and type. The climate of Istanbul, the area of interest for the project, is generally characterised as a transition between the Mediterranean and Black Sea climates [20]. It is mostly rainy and cold in winter; humid and hot in summer. According to the Turkish State Meteorological Service, the yearly average temperature in Istanbul between 1929 and 2019 was 14.5 °C, varying between 10.7 °C and 18.7 °C [21]; the total hours of sunlight were 2,370 hours per year; and the average amount of rain received in a year was between 310-360 mm. [22]. Additionally, information from the Photovoltaic Geographical Information System in Europe, points to monthly solar irradiation estimates for Istanbul: (location; lat/lon: 41.050, 29.077) - global horizontal irradiation for 2005: January 41.25 (kWh/m2), July (peak) 228.82 (kWh/m2), December (bottom) 40.24 (kWh/m2); direct normal irradiation for January: 50.06 (kWh/m2), July (peak) 234.02 (kWh/m2), December (bottom) 48.63 (kWh/m2) [19].

CASE STUDY

Third-year design studios at the FAD-BAU have the general topic *Multifunctional building design in an urban and historical context*. Accordingly, each semester, students are challenged with multi-aspect design problems in various locations of the city. During the semester when the project was undertaken, students were asked to design a research and technology hub in a central part of Istanbul, the hometown of the University. Although the general topic and a rough architectural programme with an approximate size of 3,000 sqm were given, each student was expected to create their own thematic approach and architectural programme based on the analysis conducted in the first phase of the design process. Thus, each student was encouraged to have a unique proposal derived from the emerging needs and requirements of the area of interest.

The following five areas are examples for this article: (1B) sustainable development research and application hub in the Anadoluhisarı district in Istanbul; (2B) robotics in agriculture research hub in Anadoluhisarı; (3B) science and history research centre in Anadoluhisarı; (4B) nature awareness centre in Anadoluhisarı; and (5B) research hub for pharmaceutical technologies in Anadoluhisarı. At the same time, in the FA-WUST, students focused on various public buildings with community and cultural functions. There were few approaches: (1W) creation of a pavilion designated to yoga training in mountains in Spain; (2W) open cultural hub erected as an infill building in Wrocław city centre, Poland; (3W) centre and residential units for homeless in Wrocław; (4W) local centre for single-family houses in Rzeszów, Poland; and (5W) tourist shelter in Dzikowiec in the mountains in the southern part of Poland. The sustainable elements of the project are marked in the table below, where + and - represent the presence or lack of an element in the project (Table 1).

Table 1: The sustainable elements of the students' project, the Polish and Turkish indicators.

No.	Sustainable design element	1B	2B	3B	4B	5B	1W	2W	3W	4W	5W
1	Natural materials	+	-	+	+	-	+	+	+	+	+
2	Local transport	+	-	-	-	+	+	+	+	+	+
3	Economy in investment planning	+	+	-	-	+	+	-	+	-	+
4	Natural elements in the open space	+	+	+	+	+	+	+	+	+	+
5	Green roof	+	-	+	+	+	-	-	-	-	-
6	Natural elements in the interior space	+	-	-	+	-	+	+	+	+	+
7	Natural ventilation/cross ventilation	+	+	+	+	+	+	+	+	+	+
8	Natural lighting	+	+	+	+	+	+	+	+	+	+
9	Passive energy gain	+	+	+	+	+	-	-	-	+	+
10	Solar orientation	+	+	+	+	+	-	+	-	+	+

11	Compact building form	-	-	-	-	-	+	-	+	+	+
12	Low-tech solutions	+	+	+	+	+	+	+	+	+	+
13	High-tech solutions	+	+	+	+	+	-	+	+	+	+
14	Building management system (BMS)	+	-	-	-	-	-	-	-	-	-
15	Weather stations	-	-	-	-	-	-	-	-	-	-
16	Recycling/recycled materials	+	-	-	+	+	-	-	+	+	-
17	Renewable energy sources	+	+	-	+	+	+	+	+	+	+
18	CO_2 production limitation in a building	+	-	+	+	-	+	+	+	+	+
19	Cradle-to-cradle design	-	-	-	-	-	-	-	-	-	-
20	Life cycle building programming	+	-	-	-	-	-	-	-	-	-
21	Shading elements	+	+	+	+	+	+	+	+	+	+
22	Water harvesting	+	-	-	+	+	+	+	-	+	-
23	Others (not pointed by tutors)	-	+	-	+	+	+	-	+	-	-

Some other elements from students' self-research were: water clinging plants and clams, regeneration of destroyed natural landscape surrounding the building, promoting sustainability to others through the project, trees as shading instead of typical architectural blinds, roofing material that reflects the sunlight (the building does contribute to reduce the heat island effect in the area) and vertical gardens. It was encouraging that students were willing to propose their own original ideas and solutions.

At the end of the semester, an interview-survey was conducted among a selected group of students to gauge their opinions about sustainability in general and the sustainability strategies they followed in their design proposals. There were two multiple-choice questions that elicited significant replies from the students.

The first question was about rating strategies utilised in sustainable architecture, where students were expected to indicate the most important ones. Both student groups agreed that renewable energy sources were the most important sustainability feature. In addition, the Polish students highlighted passive energy gain and natural ventilation as important strategies, while the Turkish students mostly focused on natural and recycled materials. This question provided some clues about the students' understanding of sustainability in general.

The second question was about the strategies applied in students' own design proposals. Regarding this question, both student groups shared a common point: the importance of the use of natural lighting. It was the only sustainability strategy highlighted by all the students. Besides that, the Turkish group mentioned three additional strategies they used in their design proposals; namely, solar orientation, natural ventilation and natural elements in the open space. On the other hand, the Polish students highlighted natural materials and natural elements in the interior space as the strategies used in their designs. The different reactions to this question emphasise the climatic differences between the locations. This question also helped to understand the students' awareness of sustainability issues in relation to their own design proposals. Some students demonstrated such awareness in their project proposals, but not in their survey responses. For instance, all five Turkish students used façade elements as shade generators and passive energy gain strategies in their design proposals, but they did not mention that in the survey. Likewise, some Polish students apparently used renewable energy sources in their design proposals and they also utilised natural ventilation in the building; however, they mostly did not mention those in their survey answers (Table 1).

CONCLUSIONS

In relation to the study aims, the following conclusions have been reached:

Aim 1 - Weather and climate data shows that Istanbul is a suitable city for solar studies and alternative energy production. Additionally, in the last years, the weather conditions and precipitation amount have changed drastically, so that water management has become an important topic for energy efficiency strategies in design. While in Poland, there are two main trends, visible in sustainable design and connected with the aforementioned conditions. The first one originates from regional solutions, i.e. roof forms, local and natural building materials, passive heat gains if possible. The second is based on technological developments in the field of energy optimisation and renewable resources use with reinforcement from appliances, such as solar or photovoltaic panels, heat pumps, weather stations, etc. Summing up the observations of the student work conducted in both faculties of architecture it can be stated that they generally reflected the aforementioned conditions required for sustainable design. So, the applied teaching approach can be viewed as effective, can continue and be developed further - the diversification for each specific climate is necessary and must be outlined by tutors for each locality, before classes.

Based on Table 1, it can be stated that at both universities, students were aware and willing to use natural and recycled materials, renewable energy in passive or high-tech manner, as well as were aware of the sunlight's importance and its relation towards the building. What is now lacking in Poland is green roof popularity; and due to a certain building tradition, most of the roofs designed during this study, were gable ones. Hence, it seems that students could learn more on vertical gardens and interior greenery systems. In both groups, students were not willing to use selected high-tech

solutions, which as established, is connected with their insufficient knowledge about such solutions and their comprehensives. The use of high-tech systems may be discouraging due to the need for specific additional installations and electric energy. In Poland, due to insufficient irradiation in some places energy gains are not possible, therefore not considered. However, this issue needs further research and should definitely be more emphasised in the current and future education of architects.

Aim 2 - Although a common framework for both design studios was prepared before the semester, there were differences in the workflow because of the unique characteristics of the faculties, locations and students. The first difference was about the selection of location for the project. The FA-WUST students were totally free to choose their own site, while the FDA-BAU students were given two options in the same neighbourhood. This different approach to the site selection impacted on the result: the site analysis phase of the project was quite productive at the FDA-BAU, as the students could collaborate and learn about the site's features directly from each other; on the other hand, the FA-WUST students had to do all analytical work individually, which helped them to get familiar with the location much more effectively. Accordingly, the FA-WUST students demonstrated more diversity in the choice of sustainability strategies, because they were dealing with different site conditions, while the FDA-BAU students shared more common strategies, which appeared precise and correct for the characteristics of the work area. The authors' recommendation is to incorporate diverse strategies in different design studios, so that trainees could benefit from both methods.

The second important difference between the two student groups was the level of detail they used for explaining the sustainability strategies. It largely depended on the size and scale of the total designed area, which differed between the two groups. The FDA-BAU group had to deal with a 3,000 sqm construction area, while it was around 1,000 sqm for the FA-WUST students. Therefore, the details gathered by the FDA-BAU students were rather conceptual than technical, while the FA-WUST students utilised almost all the technical details about the systems. This difference is consistent with the architectural education systems, as BAU graduates become architects upon completion, while WUST graduates become engineers-architects.

Another remarkable point is the inclusion of economic and social perspectives. This aspect was not as visible as it did not occur in most of the proposals. The lectures about sustainability given at the FDA-BAU and FA-WUST not only touched on the environmental aspect of projects, but they also included the economic and social perspectives. Accordingly, some student work reflected that approach, highlighting the social and economic aspects of sustainability through certain strategies, such as reviving the old community routines (1B), building local community (2B, 4W), creating added value for the society from operations conducted in research facilities (2B, 3W) or conceptually focusing on the emerging problems of the global society and proposing solutions about operational issues for public health (5B).

Aim 3 - The study presented here is an example of experimental research seeking to determine if specific treatments influence certain outcomes [23]. Despite its limited sample size and specific local and climate conditions, the study has been adequately comprehensive for creating a general framework for teaching sustainability in architectural, and architectural engineering schools. It provides a template syllabus for the execution of theoretical and practical steps that educators can follow when attempting to implement sustainability strategies into the design process. Recommended, tested and proved by the authors is the following scheme: study (site, sustainability, climate, traffic, greenery, etc), defining a function (here a large scale public/health/research unit to be given), concept for urban and architectural solutions (1:500 scale), workshops, plans and sections (1:200/1:100 scale), façades, perspectives, schemes and graphs with descriptions showing sustainable assumptions and proposed solutions, sustainability strategy studies, diagrams, (for all stages), etc; followed by sustainable design detail, scale 1:50, 1:20 (if needed). The final proposals should contain: technical drawings, physical models, digital visualisation, sustainability strategies and graphic project presentation. Educators must be aware of the students' knowledge level before designing the syllabus and deciding on the requirements of the design studio. The experimental nature of the design studio needs to be supported through lectures including theoretical facts. The lectures and presentations must not be too complicated for students to understand; for example, high-tech solutions, but also not too superficial, so that students can benefit from them.

A critical aspect is the required detail level of sustainability strategies. Students tend to apply everything they learn into their designs, often without self-awareness as indicated earlier in this article. However, the true gain of the design studio occurs at the moment, when the educator finds out how the proposed sustainability systems can be technically implemented into the buildings, as it is a complicated and multifaceted process. Without ignoring the creative quality requirements of student proposals, the educator needs to introduce the technical details of the systems, so that students become aware about the potential real-life energy efficiency issues that they may face in the future.

Another important point is about the understanding of sustainability concepts - on which the students were extremely focused. The general impression is that sustainability is about environmental issues that affect the energy efficiency of buildings. However, the social and economic aspects of sustainability are as important as the environmental aspects. Those aspects need to be exposed in the design studio as well, so that students have a more holistic understanding about sustainability.

Hence, it is crucial to stress that the implementation of sustainability issues into architectural education is not the concern of the design studio alone, but also of the curriculum as a whole. The design studio is in the core of

architectural education, but it needs to be combined with other theoretical and technical courses to train better equipped graduates. Sustainability is a multifaceted concept that needs to be approached from various perspectives. Extracurricular activities, in addition to compulsory or elective courses, would have a positive impact on the incorporation of sustainability issues into architectural education. In regard to sustainability, the design studio will be more successful, if students are given enough information on this topic through other courses or extracurricular activities.

In the authors' opinion, the presented study confirms that inter-university experiments are beneficial to the overall teaching process as they reveal the strong and weaker points of each university's educational approach, and thus can be recommend as a sound method of quality improvement in engineering education.

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