Building new competencies of architects and civil engineers through an educational offer in timber construction: a case study of Polish and Lithuanian students

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ABSTRACT: The article outlines an innovative approach by schools of architecture and civil engineering to educate professionals skilled in hybrid timber building construction and design, thereby filling the educational gap in the area of timber construction. To answer the question of what student competencies should be developed in the design and construction of sustainable, high-performance hybrid wood structures, a survey was conducted among several wood product design and manufacturing companies in Europe. Then, in an attempt to prepare an innovative educational course programme on sustainable design of hybrid timber buildings, the current educational offerings of selected architecture and civil engineering faculties of European universities were examined. The article presents the survey results from Poland and Lithuania. The results of the survey show a lack of comprehensive education subjects to shape the competencies of architecture and civil engineering students. The offered subjects need to be improved in relation to modern hybrid timber structures to provide the graduates with the required competencies. This research was carried out as part of the EU project *Sustainable, High-Performance Hybrid Timber Building (HiHTC)*

Keywords: Sustainable design, hybrid timber building, timber construction, education survey, project based learning

INTRODUCTION

Concerned about the environment and climate change, modern architecture seeks sustainable solutions. Architects strive to design buildings that meet the needs of current and future generations of users. In addition, these buildings must be safe and aesthetically pleasing. The basis of sustainable design is the use of environmentally friendly materials and respecting the tradition of building culture [1-3].

The modern timber industry is able to meet these requirements. Products used to make structures, such as beams, floor slabs and columns can be made from glued laminated timber (glulam) [4][5]. They are based on solid wood - a natural material. This is one of the nature friendly building materials [6]. Energy consumption during production of these materials is low [7]. There is no large amount of waste gas. The waste produced can be used to produce other wood-based materials. These include oriented strand board (OSB) and plywood, which are used for floors and roofs [8].

Designed buildings must be safe, and attention must be paid to the load-bearing capacity of the structure, as well as fire safety. Glulam is a relatively strong material [9]. It is possible to design roofs with spans of up to 200 metres. Roof trusses can have a curvilinear shape. In many cases this makes the building more attractive. The material also has a high fire rating [10].

Another important factor in sustainable design is the economic aspect. It is necessary to find solutions that are durable, functional and affordable for investors. Well-preserved wooden elements can last for centuries without deterioration [11]. Poland and Lithuania have large forest resources. Procuring raw materials and manufacturing wooden elements is not a problem. The proximity of forests reduces the amount of greenhouse gases produced by transporting wood over long distances and lowers production costs [12]. Glulam is a prefabricated material produced in an off-site factory. The advantage of glulam components is the high precision of the manufacturing quality. Assembly is quicker and the cost of constructing the building is lower.

The role of the architect is to create buildings that meet the canons of design quality, the aesthetic qualities of modern architecture. Some solutions require large spans, a curved shape of the building or the roof. Glulam can meet these requirements and, as a solid wood-based material, is very aesthetically pleasing. It is currently possible to design spans of up to 200 metres with a curved shape [13].

Unfortunately, it is not currently possible to design and construct buildings made entirely of timber. Parts of the building, such as the foundation or the garage, must be made of concrete or reinforced concrete materials. In addition, national building regulations in EU countries must be taken into account. In Poland and Lithuania, strict fire regulations are a limitation. It is also necessary to consider the elements responsible for the stability of the structure. It is then advantageous to use additional stiffening elements made of steel. These principles force architects and builders to combine timber with steel and concrete. The result is hybrid structures. The combination of materials commonly used in architecture with environmentally friendly materials is more environmentally friendly. This creates the need for new technical solutions.

In order to create a sustainable environment in the face of current climate change issues, architects and engineers are increasingly combining timber structures with reinforced concrete or metal structures and designing sustainable hybrid timber buildings. However, higher education in countries such as Poland and Lithuania gives more attention to steel and concrete structures than to the design of low-rise timber buildings. So, to meet market needs and respond to global challenges, it is necessary to prepare professionals with practical skills in the design and construction of hybrid timber buildings.

METHODS

New developments require specialists who can design, construct and modify hybrid structures. With a view to defining a competency framework for future engineers in this field, a detailed study of labour market needs and an analysis of available education were carried out.

As a first step, companies from Poland and Lithuania involved in the timber construction sector were surveyed to draw on the knowledge and experience in the sector to determine the competencies they expect from their future employees. This market needs survey formed the basis for identifying the qualities that university graduates should possess, thus providing a framework for further research.

The survey in the form of a questionnaire was sent out to targeted companies supplying timber to the construction industry, construction companies, timber associations, design companies, wood processing companies, manufacturers and constructors of timber and wood-based buildings, architects, engineers, technologists and suppliers of timber components and others. The questionnaire was widely distributed to companies via e-mail distribution lists, a web-based (on-line) surveys and in written form. The aim of the survey was to identify the skills required of graduates in the field of timber construction. This was followed by an examination of the educational offer in this field.

The next step involved investigating the educational offerings of architecture and civil engineering faculties in European universities, but specifically, the education survey was based on the study programmes of technical universities in Poland and Lithuania. The analysis covered education in the faculties of architecture and civil engineering. The number of subjects in the study programme dedicated to timber construction was checked. It was also examined how many subjects contain elements that focus on timber construction or how many are entirely devoted to timber construction. The purpose of the analysis was to answer the question of whether the study programmes of universities meet the skills requirements of the companies involved in hybrid timber construction.

RESULTS AND DISCUSSION

In regard to the market needs survey, a total of 57 responses were received - 33 from Lithuanian and 24 from Polish companies. Based on the survey, the most needed skills in the timber construction market are: understanding the moisture properties of wooden buildings and ability to calculate, read and use drawings. There are also several skills and competencies in wood construction required by the labour market. Table 1 shows the detailed results of the survey.

Table 1: The results of the market needs survey for timber structures.

No	Skills and competencies in timber construction required by the labour market	Very much required	Required	Not required	Not applicable
1	Understanding of wood species	14	27	15	1
2	Knowledge of modern engineered timber products	26	28	3	0
3	Understanding of hybrid timber construction (using different materials)	21	23	10	1
4	Structural design skills	25	17	14	1
5	BIM application skills	13	14	28	2
6	Understanding of the fire safety requirements	19	28	10	0
7	Understanding of the acoustic performance of timber buildings	23	27	7	0
8	Understanding of the moisture performance of timber buildings	36	17	4	0
9	Organisational and planning skills of timber construction projects	13	35	8	1

10	Management skills in hybrid timber construction projects	13	28	13	3
11	Safety assurance in construction of timber buildings	13	30	11	3
12	Understanding of the environmental impacts	17	20	20	0
13	Maintenance of hybrid timber buildings	11	29	14	3
14	Understanding written documents and writing clearly	8	38	8	3
15	Ability to calculate, read and use drawings	31	20	6	0
16	Ability to learn skills	19	35	3	0
17	Negotiation skills	3	29	23	2
18	Acquiring, interpreting and communicating information	9	38	9	1
19	Leadership skills	5	26	24	2
20	Team working	19	34	4	0
21	Information and communication technology skills	9	30	14	4
22	Decision-making skills	10	40	4	3
23	Problem-solving skills	23	34	0	0
24	Efficient use of materials, technology, equipment and tools	21	33	3	0
25	Ability to work accurately and in compliance with standards	23	31	3	0

The market analysis was followed by the education survey as indicated above. In order to prepare an innovative educational programme on the sustainable design of hybrid timber buildings, the educational offerings of architecture and civil engineering faculties in European universities were analysed. Detailed analyses were carried out for Gdańsk University of Technology (Gdańsk Tech) and Kaunas University of Applied Engineering Sciences (KTK), Lithuania.

A detailed look at the engineering curricula of the architecture programme at Gdańsk Tech shows a total of 85 subjects. These include 12 construction subjects, of which only six include elements of timber construction. An analysis of the engineering curriculum at Gdańsk Tech shows a total of 63 subjects. Of these, 28 are construction subjects, of which only six include elements of timber construction. Only one subject is entirely dedicated to timber construction. Table 2 and Figure 1 show the results of the analysis of subjects at the both Gdańsk Tech faculties.

Table 2: Overview of the study programmes at Gdańsk Tech in the field of timber structures (number of subjects).

Gdańsk University of Technology	Faculty of Architecture	Faculty of Civil and Environmental Engineering
Total number of subjects in the programme of study	85	63
Construction subjects without timber component	6	21
Subjects in part containing topics of timber construction	6	6
Subjects entirely devoted to timber structures	0	1

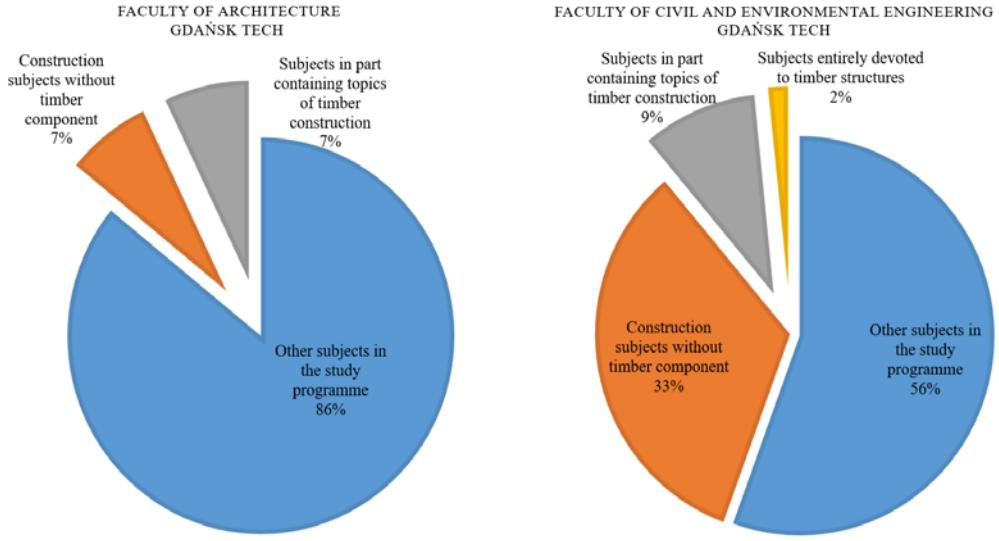

Figure 1: Overview of the study programmes at Gdańsk Tech in the field of timber structures (in percentages).

At Kaunas University of Applied Engineering Sciences, future engineers study surveying, structures and their design, engineering systems for buildings, construction technologies, repair technologies, building maintenance, learn to prepare cost calculations and organise construction works, etc. Theoretical knowledge is consolidated and developed during the practical training, which is divided into five phases and lasts up to 20 weeks in total: initial training and surveying

fieldwork take place at KTK; construction technologies, industry and final internships take place at partner companies. Table 3 and Figure 2 show the results of the analysis of subjects in relation to timber structures.

Table 3: Overview of the study programmes at KTK in the field of timber structures (number of subjects).

Kaunas University of Applied Engineering Sciences	Faculty of Construction Engineering
Total number of subjects in the programme of study	58
Construction subjects without timber component	13
Subjects in part containing topics of timber construction	2
Subjects entirely devoted to timber structures	0

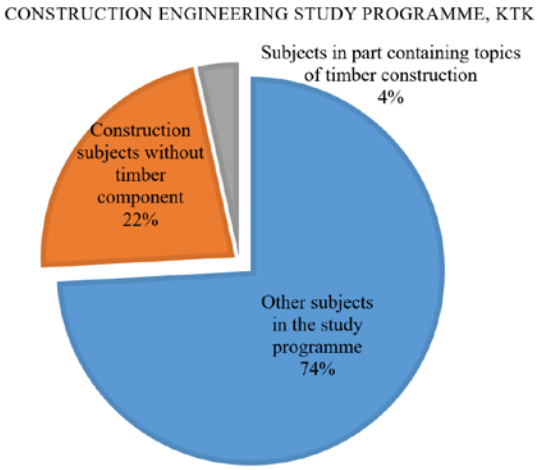

Figure 2: Overview of the study programmes at KTK in the field of timber structures (in percentages).

A review of engineering programmes at the national level in Poland and Lithuania in relation to the content of timber construction subjects shows the similar results.

In Poland, there are 17 faculties of architecture at state universities (including Gdańsk Tech). Education in the field of design and construction of wooden structures is provided by 16 universities at the faculties of architecture. These universities provide education in the field of timber-related issues (design and construction), mainly during Bachelor's studies. Most of the timber-related issues are included at the beginning of the studies as part of the building materials and general building technology subjects, which cover the topic in a general way.

Students can deepen their knowledge of timber construction through subjects in the Master's programme, as well as through specialised subjects and additional programmes. Additional design advice on timber aspects can be provided during architectural design subjects as part of the project. In addition to technological and engineering fields, most faculties of architecture in Poland also teach the history of wooden architecture and the design of wooden architecture.

In some universities, architecture is represented in the faculties of architecture and civil engineering as a combined programme. In these faculties, wood issues are combined and closely integrated for both fields of study.

Education in the field of design and construction of wooden structures is provided by the faculties of civil engineering at 16 universities. Subjects at the Bachelor level are usually held during one semester at universities in Warsaw, Łódź, Częstochowa, Białystok, Kielce, Lublin, Opole, Koszalin and Szczecin. These subjects consist of a lecture (usually two hours per week) and one hour of practice. Students from Warsaw, Wrocław and Poznań can deepen their knowledge of timber construction during their Master's studies. As part of the Master's programme, the Wooden Structures subject consists of two hours of lectures and two hours of design work.

In Lithuania there are five universities with the study field engineering sciences and study programmes civil engineering (including KTK). Timber design and construction is taught at four universities as part of their Bachelor level programmes in subjects, such as Metal and Timber Structures, Timber Construction, Engineering Structures, Building Construction Fundamentals. The aim of all the subjects is to provide students with knowledge of the materials of metal and timber structures, joints, their behaviour and the principles of structural design, and the design and analysis of engineering structures. In addition, the Bachelor's degree programme in building materials and engineering structures at Kaunas Forestry and Environmental Engineering College (KMAIK) provides knowledge of materials used in the production of ferroconcrete, metal, wooden and composite structures, as well as the basics of calculating and designing these structures and their application in water engineering.

The Master's degree programmes, available at Vilnius Gediminas Technical University (VGTU) and Kaunas Technical University (KUT), enable students to deepen their knowledge of modern wooden structures and innovations in building

products technology, with the aim of exploring the prospects and challenges associated with the development and application of modern production technologies. Technology development and application enables students to get acquainted with the basics of calculation, construction and evaluation of their behaviour of modern complex wooden structures.

The above-mentioned timber-related subjects in Poland and Lithuania are only a small part of the overall educational programme for future engineers and architects in these countries. Among these subjects in the curricula of the faculties of architecture and civil engineering, only some are dedicated exclusively to timber. In Poland, only 23% of these subjects are exclusively dedicated to timber issues, while in Lithuania it is almost 40% (Table 4 and Figure 3). Table 4 below shows the distribution of subjects between those with a wood-related component and those devoted exclusively to timber issues.

Table 4: Overview of timber related subjects in study programmes for architects and engineers in Poland and Lithuania.

No	Country (number of faculties/ A - architecture; CEE - civil and environmental engineering; CE - construction engineering)	Subjects related to timber structures		Subjects devoted to timber structures	
1	Poland (16 A and 19 CEE)	46	77%	14	23%
2	Lithuania (2 A and 3 CE)	6	60%	4	40%

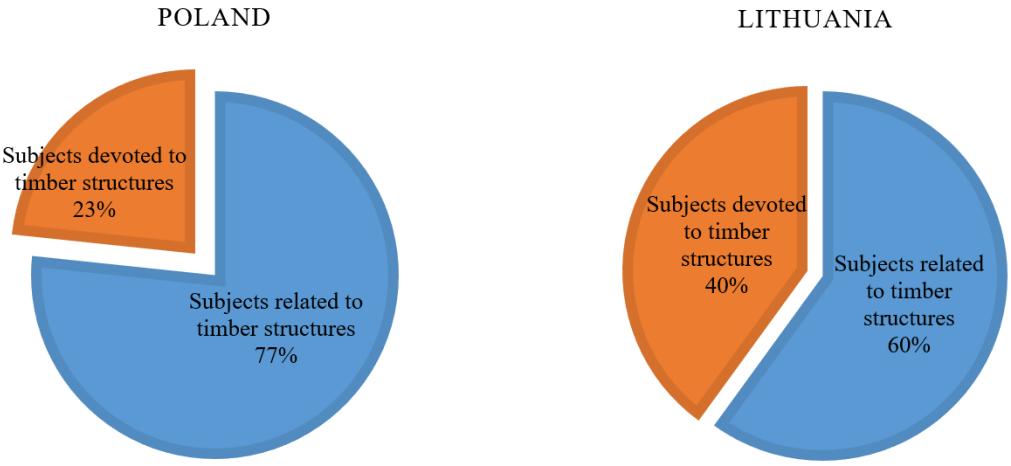

Figure 3: Distribution of purely timber-related subjects and subjects with a timber component present in study programmes for architects and engineers in Poland and Lithuania (in percentages).

The aim of the education survey was to analyse the current educational offer and how it could be improved in the light of understanding the needs of timber construction companies. The survey demonstrates that there is a lack of comprehensive educational subjects that shape students' competencies. The subjects need to be improved in relation to modern hybrid timber construction. It is necessary to introduce new subjects, expand and improve timber education at technical universities in order to meet the needs of the modern age.

To develop hybrid timber construction, it is important to create appropriate subjects at universities. Graduates must be well-educated to design and construct modern hybrid timber buildings. For this purpose, the educational offer of the faculties of architecture and civil engineering in Poland and Lithuania was checked. The results shows that higher education in Poland and Lithuania focuses on reinforced concrete, steel and masonry structures. Therefore, there is an impetus for change in the education of construction engineers and architects.

CONCLUSIONS

Based on the survey conducted, it is clear that the main problem regarding the implementation of sustainable timber construction in Lithuania and Poland is the low level of available education in this sector. The subject of sustainable timber construction is one of the most overlooked subjects offered at higher education institutions, as it is not offered or is offered in a very limited form. Professionals, entrepreneurs, employers have difficulties in finding appropriate qualified staff.

The surveyed companies suggest implementing a greater number of practical lessons and additional visits to relevant companies and practices in order to improve competencies and skills in the training of students in the field of timber building and construction. Furthermore, they also point out the necessity of creating an entirely new teaching subjects that focuses on sustainable timber building design and construction.

There is a clear lack of hybrid timber design and construction topics in the existing building and structures subjects. The programme related to the design of steel or concrete structures does not allow students to learn how to use wood as an additional structural material (construction of a roof or wall panel) or it is done in a very general way. In fact, there are no typical hybrid construction subjects in the field of wood and wood-based materials at the examined faculties. Thus, new subjects should be introduced to meet the needs of companies involved in modern hybrid timber construction.

In order to fill the gap in the educational offer of the faculties of architecture and civil engineering, an e-learning subject has been proposed as part of the EU project - Sustainable, High-Performance Hybrid Timber Construction (HiHTC) [14]. In line with the objectives of the above-mentioned project, a new international transdisciplinary module on sustainable, high-performance hybrid timber construction has been delivered to meet the needs of universities and labour market representatives. The HiHTC was designed to meet the future needs of higher education in sustainable, high-performance hybrid timber building construction through innovative, student-centred learning methods that transcend borders and disciplines. By addressing evolving challenges and tackling complex problems, it aims to enhance and foster global learning [15].

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BIOGRAPHIES

Justyna Borucka is an assistant professor in the Faculty of Architecture at Gdańsk University of Technology (FA-Gdańsk Tech), Poland, and the Vice-Dean for Development and Internationalsiation of the FA-Gdańsk Tech. Since 2015, she has served as a board member and Vice President of the Polish Architects Association (SARP Wybrzeże). She was a DAAD Scholar of International Women's University Kassel, Germany (2000) and a DAAD postgraduate scholar at HAWK, Hildeshiem, Germany (1999-2000). She has been a visiting researcher at many European universities among others: HafenCity University, Germany; L'Aquila University, Italy; Royal Academy Copenhagen and Technical University of Denmark, Denmark; Aalto University, Finland; Gazi University, Turkey; TU/e Eindhoven University of Technology, Nederlands; Pavia University and Florence University, Italy; and a visiting professor at Sapienza University of Rome, Italy (2016); Royal Danish Academy, Denmark (2018); and most recently at Luzofona University, Lisbon, Portugal (2023). At Gdańsk Tech she is the coordinator and member of the team in the international educational programme *HiHTC*. She has been conducting research and actions promoting various forms of participation and urban regeneration interventions into the public spaces and preservation of cultural heritage.

Tomasz Zybała is an assistant and a doctoral student in the Faculty of Architecture at Gdańsk University of Technology (FA-Gdańsk Tech), Poland. He is a civil engineer by education and profession. In his research, he focuses on the historic timber architecture of the Vistula Delta and the building structures conservation. Other scientific areas of research are: building structures and structural mechanics. He has conducted research within national and international projects, for instance, *Geometric and strength analysis of historic carpentry joints* under the National Science Centre grant. He is also a member of the team in the international educational programme: *HiHTC - Sustainable, High-Performance Hybrid Timber Building Construction*. He is the author and co-author of publications in Polish and foreign scientific journals. In his teaching work, he focuses on explaining the technical part of architecture. He provides classes in building structures and structural mechanics.

Rosita Norvaišienė, PhD, is an associate professor at the University of Applied Engineering Sciences, Vilnius, Lithuania and a scientific researcher at the Building Physics Laboratory of the Institute of Architecture and Construction of Kaunas University of Technology (KUT), Lithuania. She conducts research in civil engineering and materials engineering, currently within the project: *Energy Performance of Buildings*. Her main scientific area of research are: sustainable construction, calculation of energy efficiency of buildings, research on local materials, manufactured with low energy consumption, performance evaluation of thermal-insulation materials and systems. Other scientific areas of research are: building physics and construction technology; building energy efficiency and management; environment and sustainable development. She is a qualified expert for energy performance certification of buildings, a member of the Editorial Committee of the journal *Engineering and Educational Technology*. He international co-operation involved such engagements as the national representative on the COST Management Committee C 25 *Sustainability of Constructions - Integrated Approach to Life-time Structural Engineering* (2006-2010); TU1205 *Building Integration of Solar Thermal Systems (BISTS)* (2013-2017); and CA16232 *European Energy Poverty: Agenda Co-Creation and Knowledge Innovation* (2017-2021). She is the KUT coordinator and member of the team in the international educational programme *HiHTC*. She is the author of 32 publications, including ten journal articles and 16 conference proceedings papers.