Sustainability, Environmental Performance and Energy Efficiency in Higher Education: Faculty of Architecture, University of Zagreb

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Abstract. Sustainability, environmental performance and energy efficiency have become main subjects not only for the profession of architecture, but for every profession, as well. Within the scope of this conference, and more specifically the overall energy performance of buildings, the section dealing with the higher technical education has special relevance. The need for incorporating sustainability and energy parameters in higher education has been recognised for some considerable time now. As academic staff members teaching in technical courses at the Faculty of Architecture, University of Zagreb, we are always under time pressure in keeping up with the newest performances in structure and technology facing the question: How to realise and improve the graduate framework and the learning and teaching plan of environmental issues in the courses that we teach?

The paper examines available study programme ‘Architecture and Urban Studies’ within the master degree programme at the Department of Architectural Technology and Building Science. The new compulsory course Architecture and Technology 1 (AT1_2018/2019) addresses the topics of building energy consumption and emissions, rational use of energy, environmental impact, high performance efficiency and sustainable building. By comparing a selection of students’ works in different groups conducted experimentally for the first time, the paper will discuss the project approach, give a critical evaluation of the selected case studies and some lessons learned from attempts to incorporate environmental issues into the unit syllabus. Through this paper we attempt to share information and deepen the discussion within the academic community. Finally, as a contribution, it is expected to increase the ways by which parameters of energy and environmental sustainability can become an integral guiding principle in the design and delivery of all academic courses offered at the Faculty.

1. Croatian higher education: The Bologna Process

The higher education system in Croatia has undergone a comprehensive reform within the framework of the Bologna Process. The European Union adopted a united educational framework generally referred to as the Bologna Process. The Bologna Declaration was a declaration of the European education ministers signed in 1999 in Bologna, which marked the process of higher education reform. The Republic of Croatia signed the Bologna Declaration in 2001. Croatia has been a member country of the EU since 2013 but already in 2005 the reform of Croatian higher education was in line with the Bologna cycles. These activities contributed to alignment of the Croatian higher education with the European systems and its integration in the European Higher Education Area, improve the quality of
the study programmes and increase mobility. The implementation of the Bologna process had a crucial influence on teaching process in higher education system in Croatia. It is now structured according to three cycles (undergraduate, graduate and postgraduate). Higher education institutions in Croatia are universities (faculties and academies of arts), polytechnics and colleges. Currently there are 119 higher education institutions in Croatia, namely: 8 public universities, 2 private universities, 68 faculties and art academies and 1 university centre at public universities, 4 private polytechnics, 11 public polytechnics, 22 private colleges, and 3 public colleges. [1]

1.1. Faculty of Architecture, University of Zagreb: a 100-years long tradition
Architectural education, as one of the distinctive branches of education, has always been a special field of human creativity where engineering expertise meets artistic imagination. The Faculty of Architecture, University of Zagreb has the 100-year long tradition of architect education. The Faculty of Architecture is based on the academic formation of architects that has followed the tradition of engineering education. When founded in 1919, the Zagreb Faculty of Architecture was originally named the Royal Technical High School. In architecture department four generations of architects were educated until 1926. The name of the school itself meant that the educational context of construction courses was a distinct feature of the school. Since then, the teaching of technical disciplines to architecture students has long been recognized as important and challenging. In 1926 the school became part of the University of Zagreb, as a Faculty of Technical Studies. The Faculty of Architecture, Civil Engineering and Geodesy was formed in 1956. The independent unit as the Faculty of Architecture was formed in 1962. The present Faculty of Architecture comprises four departments – Department of Architectural Design, Department of Urban and Physical Planning and Landscape Architecture, Department of Architectural Technology and Building Science and Department of History and Theory of Architecture. Available study programme Architecture and Urban Studies is a five-year-long programme in accordance with the Bologna process divided into two cycles: as the first cycle Bachelor degree 180 ECTS (three years) and the second cycle Masters at 90-120 ECTS (two years). [2]

The first generation to begin the studies of Architecture and Urban Planning at the Faculty of Architecture, University of Zagreb under the new curriculum was the generation of students in the academic year 2005/2006. The curriculum of architecture education programme has undergone a comprehensive reform. The creation of modules within the studies, the integration of related courses into a single module, the reduction of the number of exams, the introduction of colloquy and the implementation of practical work after third year of studies were fundamental changes. Ensuring educational quality is one of the key responsibilities of higher educational institutions and of those who work in them. The study programme is accredited by the Ministry of Science, Education and Sport confirming that graduates from a degree programme meet the defined output standards. The programme has for many years been influenced by the requirements of accreditation by the professional institutions and external agencies. The Agency for Science and Higher Education conducted the process for re-accreditation of higher education institutions in accordance with the 2011 and 2018 Re-accreditation Plan. [1]

1.2. Curriculum revision for a Master’s degree programme
Architecture and engineering curricula are continually being refreshed to keep up with developments within architecture and building engineering. This is to include recent advances in engineering knowledge and also to incorporate new and developing areas such as sustainable development and energy efficiency. The need for incorporating sustainability and energy parameters in higher education has been recognized for some considerable time now. Construction courses have always had a great importance in the architecture curriculum. A lot of technical knowledge is given to the students in their bachelor's degree education. In building construction courses’ syllabus students gain elementary technical knowledge in technical drawing, building construction systems, building materials, building physics, structures, elements and detailing of construction systems. Design courses of curriculum are
the combination of technical, theoretical and expression based courses. The construction is a necessary and inseparable part of the design process. As academic staff members teaching in technical courses, we are always under time pressure in keeping up with the newest performances in structure and technology and facing the question: How to realize and improve the graduate framework and the learning and teaching plan of environmental issues in the courses that we teach? So, the paper examines available study programme Architecture and Urban Studies within the Master's degree programme at the Department of Architectural Technology and Building Science. Overview of the curriculum outline of graduate study programme shows obvious lack of technical courses (figure 1). Only three courses were scheduled and taught: the mandatory courses Sustainable Building 1 and 2, two 1-hour lecture series (for all students) and only one practical course Architectural Technology and Sustainable Design Studio 3, determined only for a small group of students (6-10).

Figure 1. Curriculum outline 2017/18, Graduate study programme, Faculty of Architecture, Zagreb [3]

The Faculty Board agreed with the fact of the technical courses deficit but insisted on keeping the outlined guidelines in creating the independent students research work concept. An edited curriculum
for the academic year 2018/2019 was schemed with an additional module named ‘Research, seminars, projects’.

2. New course Architecture and Technology 1 2018/2019
Architectural technology is a discipline that spans architecture, building science and engineering. The new compulsory course Architecture and Technology 1 (AT1_2018/2019) addresses the topics of building energy consumption and emissions, rational use of energy, environmental impact, high performance efficiency, high tech technology and sustainable building. New materials and technologies generated new design challenges and construction methods. Architectural technology is related to the different elements of a building and their interactions, and is closely aligned with advances in building science. The course is designed in the form of a seminar. In Croatia the word seminar is used to refer to a university class that includes a term paper or project, as opposed to a lecture class. It is a new form of teaching the environmental and energy efficient topics at the Faculty. Weekly schedule for teaching the course units was 3 lesson hours a week (for 15 week period) and 1 ECTS credit. Seminars are for smaller groups of students led by a tutor/mentor. Seminars are designed for students to talk about topics in the course reading or lectures in detail, so students have to take an active part in the class and make a presentation.

At the start of the winter semester, the module coordinator and the Head of the Department decided that freedom and flexibility should be given to the teachers to choose the subjects of their interest and expertise and have a complete autonomy over how they work and what they experiment with. Selected mentors and co-mentors formed groups/units and provided a list of possible topics to study. Six general topics were set and it was left up to 121 students to choose a topic and a mentor depending on the skills and interests. In the diverse nature of the projects being undertaken, ranging from ‘CO₂ footprint of nearly zero energy buildings’, ‘Interactions’, ‘Modular structures’, ‘Contemporary architectural detail’ to ‘Modern technologies in architectural design’ and ‘Alternative building strategies’, for the purpose of this paper, two groups were inspected in detail and presented as case studies.

2.1. AT1_Case studies 1 – 2
The paper discusses different course concepts of teacher autonomy. The basic methodological approach was used: quantitative and comparative. By comparing a selection of students' works from two different groups (mentor are the authors of this paper), an insight of the course will be given. The course was conducted for the first time, so the paper will discuss the project approach; give a critical evaluation of the selected case studies and some lessons learned from attempts to incorporate environmental issues into the unit syllabus.

2.2. Case study 1: ‘CO₂ footprint of nearly zero-energy buildings’
Sustainable design performance targets were defined in a wide range of areas: environmental impact of nearly zero-energy buildings (nZEBs), operational energy use reduction (with associated carbon emission reductions) and use of environmentally preferable materials. The main point of interest was put on nearly zero-energy buildings because the deadline for design of nearly zero-energy buildings is approaching. After 31 December 2020 all new buildings in the EU need to be nearly zero-energy. At the beginning of the semester students worked individually and researched general topics related to CO₂ emissions, nearly-zero energy buildings, production and carbon footprint of the most commonly used building materials. During the semester, students were divided into 7 equal groups and were encouraged and mentored to calculate the CO₂ emissions of their own undergraduate design projects: design of a family house, apartment buildings, commercial buildings (3 groups: 2 students x 2 projects) and one group analyzed an educational building. The operational energy projections for the buildings were performed using the computer software EnCert-HR v.2.42 to estimate the annual energy use of buildings for heating, cooling, preparation of domestic hot water, ventilation and lighting. Using the appropriate thermo-technical systems and photovoltaic panels buildings were
transformed to nZEB standard. The embodied energy and carbon emissions related to the building construction were evaluated using the data about CO₂ emissions for materials production and calculation for emissions for production of used materials. Finally, a subsequent step in the comparison process was to address equivalent carbon dioxide emissions as opposed to embodied energy. The results are summarized in Figure 2 below:

![Figure 2. CO₂ footprint of nearly zero-energy buildings, results of students' calculations, group ‘CO₂ footprint’, mentors: Z. Veršić, M. Binički, 21 students, average group grade: 4.48, January 2019, AT1_2018/2019, Faculty of Architecture, Zagreb](image)

The results from Figure 2 indicate that in case of nearly zero-energy buildings, the emission of the embodied energy are several times higher than the operational one. In the end, the concept of a nearly zero-energy building should have been designed with the aim of achieving as low CO₂ footprint. The emphasis was on selecting energy source and materials with lower carbon footprint, taking into account the requirements of load capacity and ‘fire safety.

2.3. Case study 2: ‘Interactions / the impact of buildings on people – the impact of people on buildings’

The impact of buildings on the health and well being of people who spend 90% of their time indoors is very strong. The buildings ‘shape’ their users in terms of health, physical well-being and emotions. The well-being and productivity of the users are thus major assets, which crucially depend on the quality of the spaces. Regarding the reverse process – the importance and impact of human behavior on the energy characteristics of the building can also be researched. The user's behavior can endanger thoughtful energy concept. Differences in user behavior (in the same physical conditions) can result in large differences in energy consumption. A variety of planning tools for healthy and sustainable buildings have been developed over the past 20 years. There are many evaluation methods that can be used to design and document building performance. The intention of this small research was the evaluation of the interaction of buildings and users. Students taking part in this class focused on the following research problems: Why is a building never equally comfortable for all people? Which measures can improve indoor quality? How do indoor spaces psychologically affect users?

The group was free to choose its own direction and sub-topics. We let the students choose whom they wish to work with. Students suggested their own interest such as ‘Light in Architecture’, ‘Kinetics in Architecture’, ‘Manipulation in Commercial Buildings’, ‘Physiology in Architecture’, ‘Sensory Architecture’, ‘Architecture out of Fear’ and ‘Temporary Architecture'. Within the framework of the course, it was possible for seminar paper to be entirely literature-based, so the focus
of attention was on existing knowledge presented in literature and its analysis with pro/con information. Global issue topics were researched in order to investigate the Croatian approach and suggest possible solutions. On a weekly basis, topics were described, presented and argued.

Besides architectural and energy-efficient topics, some groups decided to explore interdisciplinary research practices. Environmental problems and contemporary social issues such as current political migrations, immigration, climate change and consequently disasters, greatly influence the existing architecture. Fast building of modular, provisional and sustainable buildings, were also examined. Figure 3 is presenting cover pages of seven final research paper topics.

Figure 3. Cover pages of seminar papers, final presentations, group ‘Interactions’, mentors: I. Muraj, D. Mandić, 21 students, average group grade: 3.76, January 2019, AT1_2018/2019, Faculty of Architecture, Zagreb

3. Course evaluation / Lessons learnt
Evaluation is a way of understanding the effects of our teaching on students’ learning. It is an integral part of good professional practice and the systematic development of teaching expertise. Quality in teaching and learning is not simply the product of experience, it also depends on the regular monitoring of teaching performance. There are many motives for evaluating the impact and effectiveness of courses and teaching. New courses are usually keen to find out what their strengths and weaknesses are and how their teaching compares with that of other colleagues. In contemporary practice in higher education, there are three main sources of feedback (from students, from teaching colleagues and self-generated feedback). [5]

3.1. Feedback from students
By far the commonest source of feedback is feedback from students who are qualified to comment on matters such as clarity of presentation, pacing of material, assignment deadlines and helpfulness of tutors on written work. In January 2019 a final survey was conducted on a sample of 79 students (out of 120). An important issue of this assessment was the willingness of students to participate in the process of evaluation at the end of winter semester. A rather large percent (41 student = 34.16%) didn't give any answer, presumably because they had not a defined opinion. The course evaluation was a digital questionnaire, which required a selected response answer to a series of questions in order to evaluate the instruction for a given course. The survey was made out of two parts: the first part
examined the students opinion about three new courses and the second part dealt with semester in general. The survey was organised and conducted by students. [4]

When asked to assess the functioning of the course Architecture and Technology 1, the surveyed stated, that it was neither good nor bad. Among the surveyed students, 7.7% of them didn't know what was expected from them. On the other hand, 16.7% of them were definitely satisfied with the course. The surveyed scored the organization of the course with an average of 5.8 points, out of 10 (figure 4).

![Figure 4. Clear learning expectations, post-processing student survey for the course AT1_2018/2019, Faculty of Architecture, Zagreb](image)

When asked about additional burden that was put on them in comparison with other courses, the surveyed scored the course with an average of 4.8 points (out of 10). Only 1.3% of the surveyed see the whole course as a considerable additional burden. The majority of the surveyed students, almost one half or 39.8% were satisfied with their working conditions (figure 5). We can assume that the course AT1 was well balanced.

![Figure 5. The burden of the learning, post-processing student survey for the course AT1_2018/2019, Faculty of Architecture, Zagreb](image)

Through feedback, teachers assess whether their students are really learning. Among the surveyed students, 59% of them think that they acquired new knowledge, and 41% of them think that new knowledge is lacking (figure 6).
Students rated the course AT1 with an average of 3.2 points (out of 5); while 15.4% of them rated the course very badly, and 20.5% of them stated that the course was functioning perfectly and rated the course with excellent (figure 7). However, we can conclude that there is a difference in opinions and ranking of priorities, which mainly depends on the fact that the survey was made for the course in general, and not specifically for 6 separate sample groups.

Based on the findings of the conducted survey among 79 interviewed students, who were asked to give their suggestions and complaints for the master’s degree programme, we can draw two main conclusions. The former cover their particular interests for master degree study to be more targeted. Students should be able to choose their own classes. They have proposed elective instead of mandatory courses. The latter are of general importance, such as proposal for reducing the burden of student’s learning in general by reducing the great number of courses. A general students’ impression on the semester is not satisfactory. The data extracted from the survey will be used as a data source for presenting students’ views in front of faculty bodies in order to improve the study. In these circumstances it may reasonably be expected that the next review of the curriculum is expected.

3.2. Feedback from teaching colleagues
There was a regular end-of-the-semester employee staff meeting in order to assess achievements of the new course Architecture and Technology 1 and to discuss the course strategy review, the result of students’ work and the students’ survey results. In general, all mentors were satisfied with the work done. At the beginning of the semester, while starting a brand new course for the semester, all mentors were very optimistic and active, with positive attitude, but there were some circumstances, which may had contributed to the results achieved. Mentors reported that students prioritized the other tasks during the semester and complained not to have time to prepare all the assignments. At some other points, there was a lot of students’ criticism expressed concerning the disorganization, impreciseness and at some point repetition of the curriculum. Based on the findings of the conducted survey, we can draw two main conclusions: to be more organized and better defined. Anyone teaching in higher education knows that it is not so easy to decide what matters and what does not, when teaching their discipline. So, for revising the coursework assessment the next year, a new question paper – more formative assessment has to occur throughout every class (group), not as a course in general. This will give us more accurate data.

An important issue of this students’ assessment was the comparison of all three new courses. The results have shown that other two new courses ‘Town planning’ and ‘Architecture’ were rated 2.4 and 2.6 points (out of 5). The course AT1 was rated the highest - 3.2. It can be, therefore, assumed that the course Architecture and Technology 1 has proved likeable and has demonstrated how effectively students can utilize new technology to gather, analyze and interpret information.
3.3. Self-generated feedback

As the course deals with contemporary issues in architectural technology, it is expected that students learn about the processes and knowledge related to the latest technology in the design of buildings. Preparing to teach a new course is not easy. No university teacher can realistically subject every aspect of his or her day-to-day practice to constant review. University teaching staff are often left to develop their own understanding of teaching and learning. The paper discusses different concepts of teacher autonomy. Case studies are used to give examples of practice in classes and references are provided to give the reader an inside information about the course. The focus was on the students' experiences of group work. Environmental issues like energy and environmental sustainability were explored in different ways. Students of the first group were calculating the carbon footprint of their own undergraduate project designs, and trying to transform them into nearly zero-energy buildings, with accent on materials used and thinking about the life cycle of materials and the buildings. The second group of seven papers had a more flexible project plan. Literature based research methodology was used to explore the possibilities for new challenges in the field of energy-efficient, healthy and sustainable buildings made of natural and local materials.

Conclusion

This paper provides a current view of the context for learning and teaching in architecture and outlines some approaches for curriculum design. The aim of this paper is to create a reading of how, in the form of a seminar, the new technical course could be integrated into the architectural curriculum. The basic elements of the discussed educational model are presented in this paper, as well as its potential and limitation. The long-term benefits of the new course in edited curriculum of the master’s degree are:
- Every mentor has the possibility to affirm his independent work. This gives the mentor more freedom to explore issues in the scope of architectural technology.
- Using curriculum differentiation to respond to students' diversity.
- Every group has different concepts of teacher autonomy. For students it is very comfortable - the choice of a technical topic / the choice of mentor to work with.
- Updating of course curriculum, change of main topics and subtopics on a yearly basis.
- Making it possible that the new and contemporary relevant technical topics are defining the training of future architects.

The paper also presents and analyses data of survey carried out among first-generation students based on their attitudes and opinions about the edited master’s degree curriculum. A compromise between the two sides would most likely result in the new curriculum. Through this paper we attempt to share information and deepen the discussion within the academic community. Finally, as a contribution, it is expected to increase the ways by which parameters of energy and environmental sustainability can become an integral guiding principle of all academic courses offered at the Faculty.

References

[1] The Croatian Agency for Science and Higher Education (ASHE) https://www.azvo.hr/en/
[2] University of Zagreb, Faculty of Architecture, Undergraduate and Graduate Studies in Architecture and Urbanism, Curricula 2008 (Zagreb: Arhitektonski fakultet Sveučilišta u Zagrebu) http://www.arhitekt.hr/
[3] Faculty of Architecture, Zagreb, Yearbook 2014/15, 2015 (Zagreb: Arhitektonska fakultet Sveučilišta u Zagrebu)
[4] Final Student Survey Report, winter semester 2018/19, February 2019 (Zagreb: Arhitektonska fakultet Sveučilišta u Zagrebu)
[5] Fry H Ketteridge S and Marshall S A Handbook for Teaching and Learning in Higher Education, Enhancing Academic and Practice - 3rd ed. 2009 (New York: Routledge)