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To think in architecture, to feel in structure: *Teaching Structural Design* in the Faculty of Architecture

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ABSTRACT: The structure of education within the Faculty of Architecture, Slovak University of Technology, Bratislava, Slovakia, is a standing topic of discussion. The authors have tried to perfect a model, which could join knowledge of architecture, civil engineering, statics and material in a natural way. The structure is an element, which has the power to connect them. It connects the thought with matter in education and in real architecture. Integration of the knowledge of structures and civil engineering is a part of the study programmes in subjects from the studio creation group. The first part is a theoretical preparation in individual blocks of compulsory subjects with a focus on structure, which confirms the need to direct the education by encouraging analytical thinking, understanding of structural principles and, finally, attempting to try something new and unconventional (an experiment) in the studio. This system is being tested, but it follows the line from mechanical absorption and gathering the knowledge to constructional creativity. This is the only way to confirm the motto *To think in architecture, to feel in structure.* The motto is broad and offers freedom of creativity, and encourages exploration, cooperation and discussion in the multi-genre science in which architecture is located.

Keywords: Thinking of architecture, structure, teaching, design, creativity

INTRODUCTION

The task of civil engineering is to teach students the ways to materialise an architectural idea. In the vitruvian triad, it is a part called *firmitas.* Architecture is a continuous fight in its materialisation - competition with gravity. Gravity as a basic natural law tries to draw together everything tangible to the Earth's surface. Material is exploited from the soil, and it is processed and formed to answer the thoughts of an architect about the environment creation for a human life. The fight with gravity is solved by nature in the most elegant way - the growth of most organisms takes place in a line directed to the centre of the Earth. Building, in fact, copies this process. Structuring should offer the student of architecture information about the beauty of construction, how the construction lives and how it resists the pressure of gravity. In the end, a student must have a rational answer to all the *why?* questions.

An architect should feel what is going on in a structure without needing to count it exactly. Naturally, an important part for the future materialisation of an architect's creative thought is an information chain, which finishes at the building site by the realisation of the building. Author expression (in case of students it is maturing) is a language of expression, which can be used to form a creative purpose. Maturing thought crystallisation is evident also in the educational process and this is determined by the level (intellect) of students, as well as teachers [1].

PERCEPTION OF STRUCTURE

Structures of many famous architectural masterpieces are inspiring. They are inspiring if the architecture and structure create a homogeneous unit, if the structure is not an obstacle to perceive the work and the architectonic shape creates a logical structural solution. Perception of structure is connected with a typological kind of a building, its size and function [2]. Perception in this respect can be characterised by one of the feelings, which excite the imagination by their size, dimensions, where the range and height are surprising as are the difficulty of shapes.

In reviewing the story of twentieth and twenty-first century engineering, it is interesting to speculate to what advances in computing have shaped what is possible to build [3]. The ones who experience difficult *prose* over the board with a drawing pen, and used to overcome resistance to communication with a screen instead of a personal contact of their own hand and drawing paper, they surely appreciate the shift to more challenging shapes of buildings. Possibilities of more

demonstrative display through computer technology allow moving borders of respect higher. On the other hand, they cannot substitute the sense for construction. They can define, help to draw, modify and model, they support creativity.

DISCUSSION: HOW TO (TEACH TO) UNDERSTAND CONSTRUCTION

The basic question is: how to teach a student to understand construction, how to perceive construction, how to solve construction problems in architectonic pieces? As Sir Ove Arup stated: *Engineering is a creative activity involving imagination, intuition and deliberate choice,* it is exactly what should a student-architect understand [4].

It is important to follow the modern exciting serial of the relationship between architecture and construction. Its stories take place from the 19th Century. As an example, the construction of London Paddington's railway station by Isambard Kingdom Brunel (1854) in London provided a distinctive inspiration for cooperation between an architect (Nicholas Grimshaw) and a structural designer (Tony Hunt). A connection to iconic steel lace can also be felt with architect Gerkan and his Berlin station Lehrter (2006, Von Gerkan, Marg & Partner, statics Jorg Schlaich, Bergermann & Partner) [5]. All of these are examples of logical internal and external balance - constructional and aesthetic. Construction in architecture requires a technical understanding, a tool for materialising thought and function but mostly as modelling the integral parts of an architectonic piece.

While teaching architectonic creativity, *the finished* architecture should be affected by emotions and intuitiveness of the perceiver. The technological part of education can also work with imagination. Mathematical expression of the sensed and seen can be followed. The language of mathematics will be more readily accepted ...as *each mathematical equation, although it is quantified correctly, it is not beautiful in mathematical sense as each architectonic item although perfect in a construction way, it is not good in architectonic sense* [6].

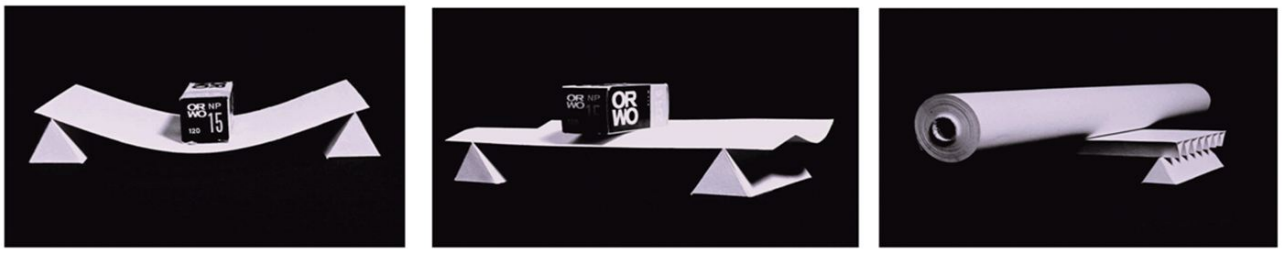

Figure:1-3: Approach of static principles in structures: simply but impressively (photo Špaček).

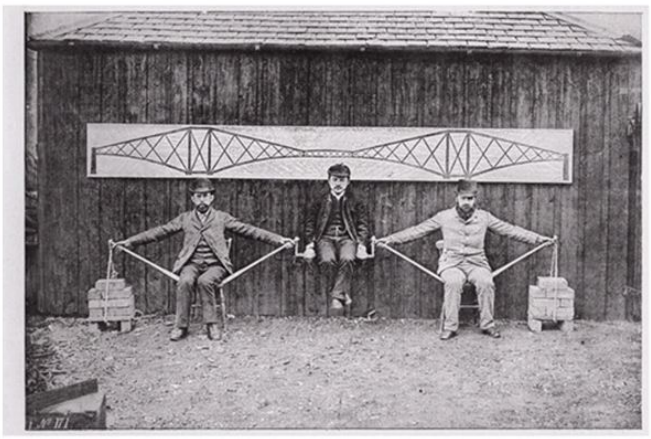

Figure 4: Forth Bridge - demonstration of action the force in structure [8].

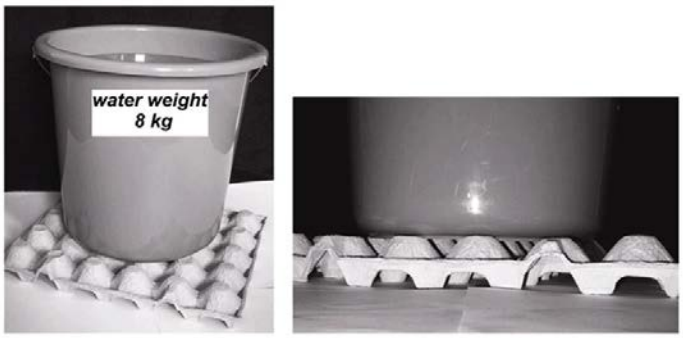

Figure5: Bearing capacity of spatial structure, object lesson of the carton (photo Ilkovič).

When teaching architecture, hard knowledge through soft methods should be facilitated. In fact, hard methods should be used only marginally, to show that product performance calculations are also necessary. In this connection, P.M. Hildreth and C. Kimble can be mentioned. They characterise knowledge in their publication while hard knowledge is codified and soft knowledge is less quantified and seizable [7]. From an architect's perspective, soft knowledge is oriented to architectonic sense.

A famous picture of Scotland's Forth Bridge shows a direct physical experience with a static principle of construction (Figure 4) [8]. Visualising is easily acceptable and transformed through visual suggestion and students can receive a physical advance in their concepts of construction (Figure 1 to 3, and Figure 5).

METHODOLOGY OF TEACHING

Generally and more or less intentionally, methods like PBL - problem based learning are used, eventually, in a more developed form: PPBL - problem and project based learning. A teacher sets a problem in an assignment, which is solved then, in a project development way. In teaching studio creation, methods based on problem or project teaching should always be applied and, eventually, in a combination of problem and project teaching. It is definitely valid in a matter because working to produce an artistic creation from the start, leads to the use of more developed methods and approaches. [9].

If rules and borders are known, it is possible to work with creative tools in a qualified way. Knowing the possibilities, technical and technological qualities, principles and rules of creation are connected vessels with the logic of interpretation in an architectonic work (Figure 6).

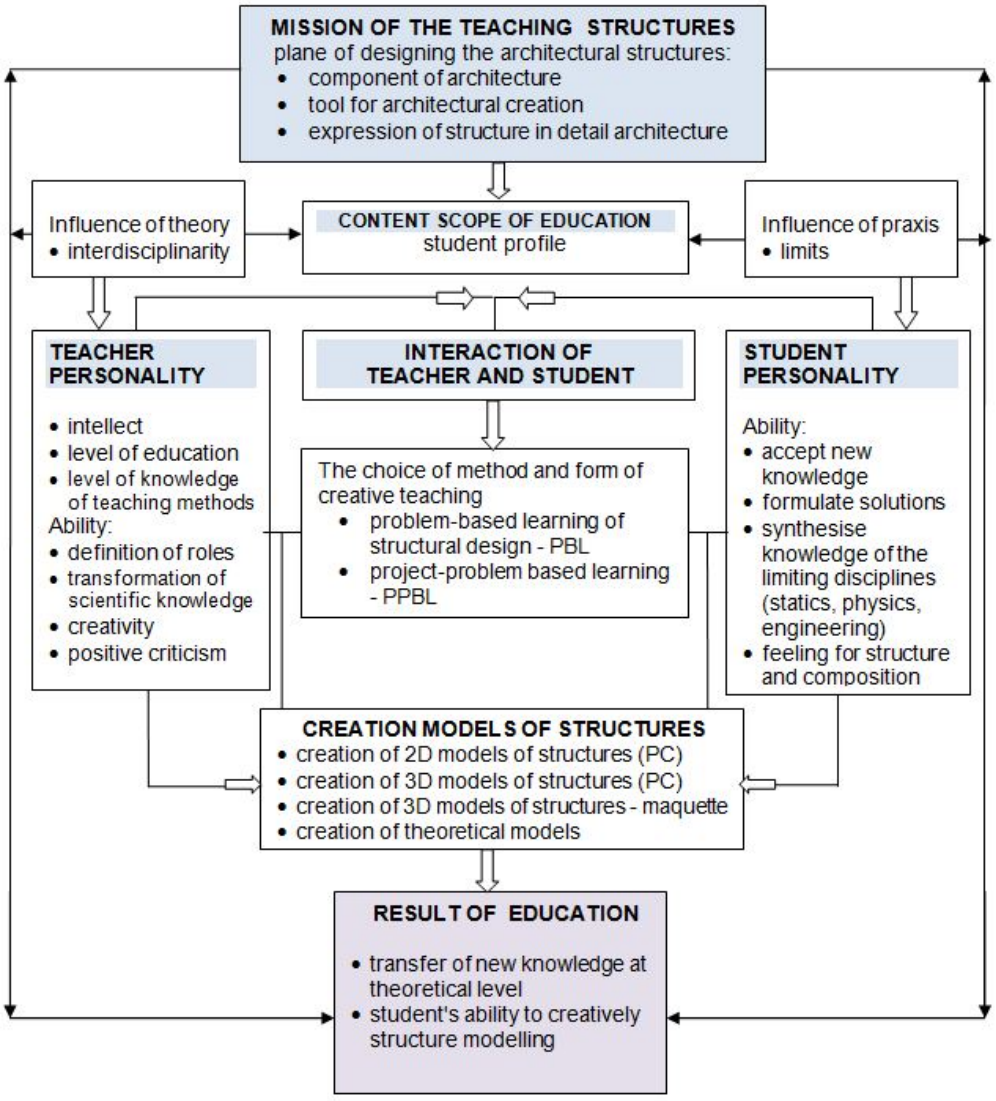

Figure 6: Didactic model of education in architectural structures (Ilkovič, 2014).

Message (mission) of constructions in architecture can be defined as:

- *Construction - a part of architecture* - knowing the patterns and technical principles of construction creation, expression of aesthetic value, creation of construction concepts;

- *Construction - a tool of interpretation of architecture* - knowing the function of space, tectonics, material and technology, methodology of scheme creation;
- *Construction - semantic and semiotic meaning in architecture* - expression of tools and details of construction, symbolism of construction, theory and methodology of detail creation [10].

Knowledge is presented in a logical sequence according to the level of difficulty in the teaching of construction. Understanding construction as a part of building means creating the sequence of steps, which are arranged in a way that a student will understand. These are the reasons why different forms of teaching (exercises - seminars, studio creation) are introduced gradually. The system of algorithms was useful for individual specific forms of teaching as a result of looking for an effective way to teach architecture students. The aim of applying the methodology of PBL is not only obligatory if the process of teaching is to be improved, but mainly, it is an appropriate way to motivate and challenge the students and *teach them how to learn* and also to think [11], something which seems unpopular these days. Because of this, the methods - algorithms which are used and modified by a student to get a desired result, were created. An algorithm is a proof of the creation of an individual solution, although it is not always the correct one. Encouragement of a cooperative teacher providing conceptual thinking and a team spirit of cooperation cannot be substituted in the process. At each problematic scenario something is assigned - a building - load bearing construction. Something must be searched for: what it that must be solved - work out the load bearing construction. The essence of good results is to proceed systematically, step-by-step. Education based on a practical problem on chosen examples of buildings is visual and offers the possibility of establishing an imaginary dialogue between the author of the object and a searching student. Methodology is expressed by the algorithms presented. The student is actively educated; knowledge from the studied subjects is enriched in the context of teacher, and this approach builds synthesised knowledge and extends cognition.

RESULTS: ALGORITHM OF TEACHING

Algorithm 1: Exercises, Structure-theoretical Subjects

Theoretical subjects in the higher grades of civil engineering, which are also creatively aimed in their content, inevitably follow the knowledge of typological character and empirical relationships that has been gained. These are used by students in the analysis of existing objects - architectonic works, which provide them a real view for different (typical and atypical) static - construction solutions.

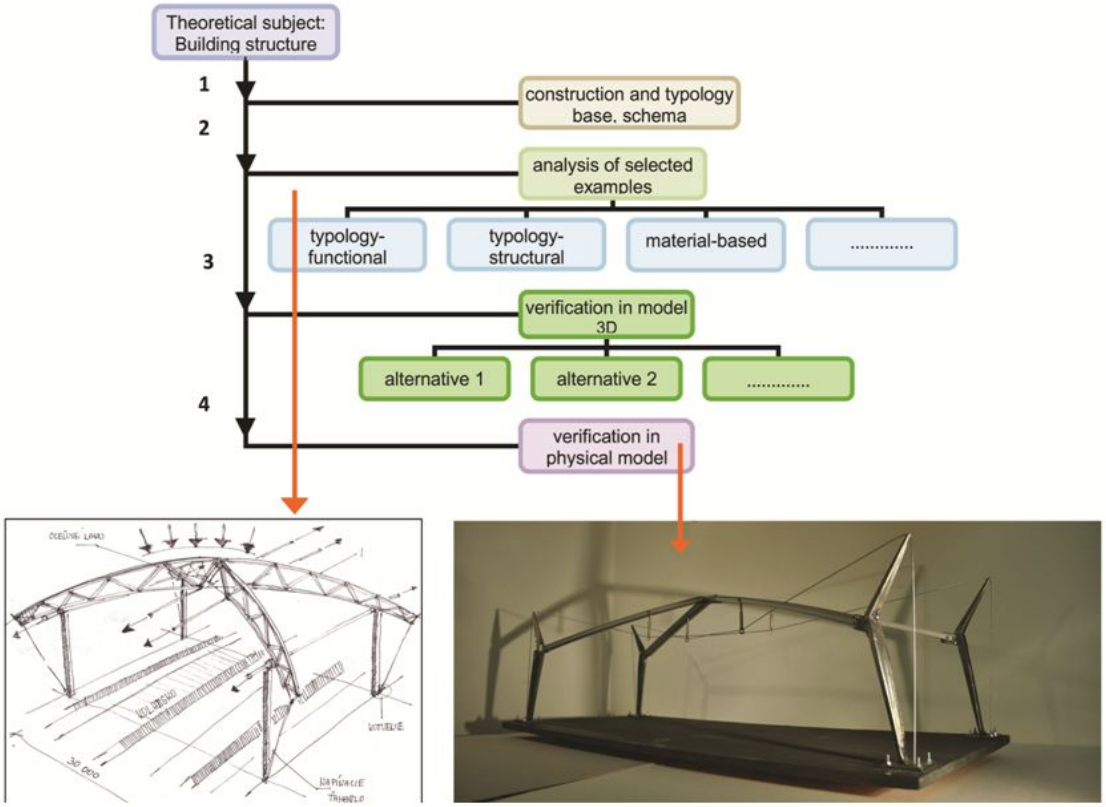

Figure 7: Application of Algorithm 1 in exercises - students' sketch and model of structures.

The aim is to identify a system - scheme and to understand a principle. It is up to the experience of a teacher to choose examples within the group of students, which will cover a certain typological scope of examples in a line from simple to a more difficult system. Analysis is not only at the level of the given solution, an asset in the following step is a proposal of an alternative structure also with using of a verification model (a physical model) (Figure 7). Understanding the essence of structure is reached by this method [12].

The interdisciplinary character of creation enables the above mentioned methods to be applied to problem-project education. The emotive and intuitive (artistic) side of a creative process in studios requires more intimate communication than education about facts. One has to be reminded that without an active approach and student creativity, satisfying results cannot be achieved. The best results are achieved only when there is a harmony between *arte* and *racio*. To motivate and encourage brainstorming methods is very important, as well as to assume responsibility, self-reflection, presentation and self-evaluation of a student [13].

The algorithm for design studio work (Figure 8) comes from looking for ideas and a concept when the indication of a structure solution can come only after the evaluation of many concepts. While being born as a compositional thought, architecture comes from the area of artistic feeling and fine art. Constructional thinking and structural design, are ways to materialise the first idea. An inspiration can come from famous architects who look for a border between a pure thought and its materialisation, between a work and a mass (e.g. neo-classicists C.N. Ledoux, E-L. Boulee, but also the modernism representative V. Obrtel). Rietveld's architectonic compositions are art compositions, which in case of Mrs Schröder´s house got into the state of material reality [14-16].

The proposal stage of an architectonic concept is the first objectification of images by an architect, and it depends on a certain case in what level is the own structural solution and in what level the structure will be transposed into an architectonic expression [17]. Then, verification follows: repetitive imaginary dialogue between individual parts of architecture, which can cause also a step back (it is in the name of purity or logicality of solution). This step is important for creative students (Figure 9).

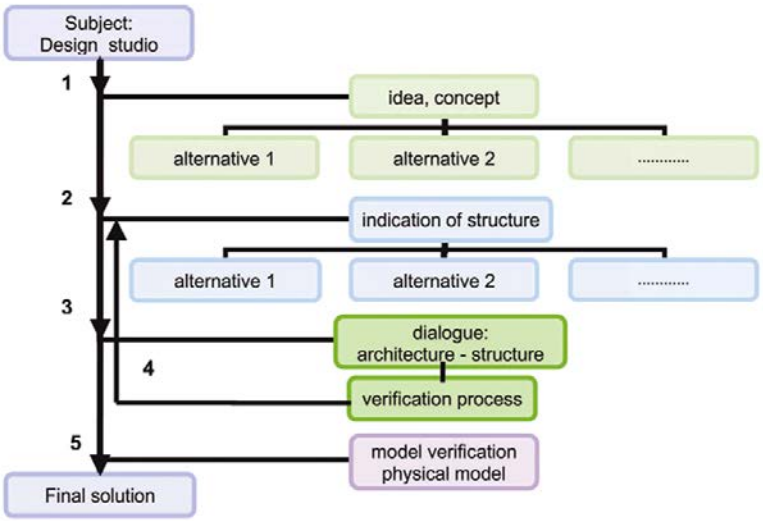

Figure 8: Algorithm 2.

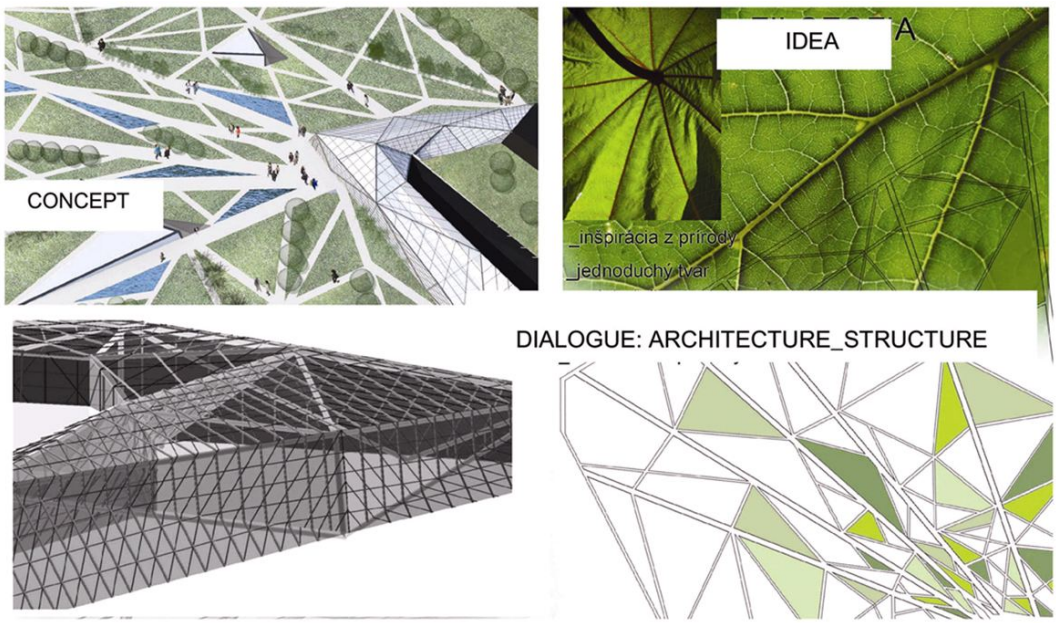

Figure 9: Idea-artistic feeling-concept-structural design (student's design studio - Greenery).

Only a dialogue moves the creation forward in the name of modification of ideas. *Architecture is not primarily a structure, but a space which should evoke an impact and wake moods in a person. That is why the mission of an architect is to elaborate this mood* [18]. The task of a teacher, a good teacher, is to present different moods. However, one has to realise that it is not possible for every student to master the given tasks at the same high level. It is the mastery of a good teacher, which will help find differences in a student's abilities.

CONCLUSIONS

In the system outlined in this article, there is the possibility to lean on levels of knowledge, using the cognition of what is important in teaching construction and creation gained in individual semesters. The depth of the motto presented in the introduction of this article can also be turned upside down: to think in structure, to feel in architecture. This little difference is important, inspiring students during the teaching of architecture. The most important thing is to teach students to think: to think in architecture. Generally, one can claim that a student should deserve a higher level of individual attitude. He/she should deserve it by climbing through the semesters and years, but also by his/her own initiative. To do architecture means to ask questions, it means to find own answers with a help of a teacher, *...we can immodestly say that thought of a praised, expressively strong architect* [19] are similar to the author's motto - *to provoke students to think about architecture, to create through experiences*.

An important part in the methodology is related to the way of finishing the subject. A fair evaluation system after individual steps of an algorithm combined with a final evaluation belongs to one of the motivational moments for student. A similar system of evaluation presents Herr, C.M. - criteria of evaluation are in four levels - quality of elaboration, suitability of solution, defence and explanation of the principle, ability to react to questions of a teacher [20]. Correctly *calibrated* evaluation pins down skills and knowledge of students and their ability to present this knowledge.

Education about structures in the Faculty of Architecture is the prevailing issue of concern, and it is approached based on the contemporary methodology of education. Its paramount aim is to encourage self-study and inspire creativity.

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