The HDH Model for the Development of Creative Structural Thinking and Its Applications to Other Systems

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Abstract**—**Teaching structures and structural design in architectural studies is considered a difficult mission due to complex reasons and circumstances. This article proposes a new conceptual model (HDH) for teaching structures and structural design in architectural studies. Because of its systems-thinking orientation it is also relevant and applicable to other fields and systems. The HDH model was developed in order to encourage the integration of science and art, especially in relation to structures, in architectural studies.

Keywords**—**Structural Thinking, Conceptual Design, Teaching Structures, Systems Thinking.

I. Introduction

As architecture has many aspects, including structural aspects, it is one of the most interdisciplinary professions. The structural aspects, which relate mainly to the physical loads affecting buildings and their architectural implications, are considered as part of the scientific, engineering and technological aspects of architecture. The understanding and the integration of these aspects in the architectural design process has become more and more problematic in the information era. In many cases students in architecture tend to experience difficulties understanding and integrating the enormous amount of information they are exposed to in the design process. This crisis is particularly acute in science, engineering and technology courses, largely in relation to structures. In many cases, students struggle to cope with structural knowledge and often do not see it as an integral part of the design process. Much effort has been invested in creating new concepts for improving the teaching of construction, including structures by researchers, teachers universities, and others (for example: [1], [2]). There are many reasons why this situation has arisen and it seems that in order to integrate science and art in architectural studies, including structural aspects, the adoption of a multidimensional, holistic approach is necessary. One such interdisciplinary approach has already been introduced by the author [3]. In this approach various elements of the problem were addressed, such as teaching methods; teaching staff in different courses, including the design studio; visualization in scientific teaching, etc.

One element of this approach is the need for a conceptual model to organize the structural knowledge during the architectural studies. This article focuses on the development of an initial model, which is seen as one of the most important strategic elements in tackling the problem, namely, how to teach structures during the architectural studies. It is important to note that the model relates mostly to one facet of the problem. Thus, it is only one initial step of a series that can be taken to achieve the integration of structural aspects in architectural studies as part of an overall integration of science and art in these studies.

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II. Structural Aspects

A. Structural Aspects in Architecture throughout History

All through human civilization, structural aspects have been just as important as historical, cultural, sociological and environmental aspects in architecture. Structural aspects were part of the scientific, engineering and technological aspects and, in general, it is possible to identify a high level of integration between them and architecture as a whole. Indeed, in the past, the distinction between architecture and engineering was blurred and generally the “architect” and “engineer” did not exist as separate entities. Accordingly, there was a very strong connection between science and art and as a result, architectural language was profoundly influenced by structural considerations. Examples of this harmony between structures and architecture can be identified throughout the ages: Egyptian and Greek temples, Roman architecture, Gothic cathedrals, Renaissance architecture and other examples.

The Industrial Revolution and its effects accelerated a large-scale specialization all over the world and a gap widened between architecture and engineering. The next revolution – the information revolution – accelerated and heightened these mega-trends and more and more cognitive difficulties were encountered when trying to bridge the gap between architecture and engineering.

In this new situation, the structural aspects were in many cases pushed aside during the architectural design process. In many cases, unlike in the past, architects were not obliged to consider structural aspects from the early stages of a design process. Engineers were not always involved in the early stages of the conceptual design and architects in many cases tended to think that “the structural consultant will solve the problems later”. Consequently, the architectural language was not as enriched from the structural aspects as it could have been.

B. Teaching Structures in Architectural Studies

Courses dealing with structures are considered an integral part of any architectural studies programs. Usually, they include issues like statics, strength of materials, conceptual understanding of structures and there are even computational methods and other means [4], [5]. Their importance in architectural education, and later in the practical world, is not in doubt. In spite of this, in many schools of architecture worldwide the "art" of teaching structures is facing difficulties. Although there are numerous reasons for this situation, it is often an outcome of cognitive difficulties due to the complexity involved in the integration of a relatively large quantity of fundamental scientific knowledge with other aspects of architecture. As a result, in many cases, many students experience difficulties connecting physics with architecture. In many cases these courses are perceived as mathematical, possessing relatively little relevance to architectural design processes. They are mainly considered to be largely related to structural-functional aspects, rather than design and visual language. The approach of including structural aspects as part of the form generators is rarely seen in the design process. Calculations, in many cases, are not connected to design and they are in many cases in a contradiction with qualitative-conceptual structural thinking.

III. The HDH Model

A. The General Concept

The HDH model – Holistic, Detailed, Holistic model – is based on the assumption that the cognitive process of learning and the perception of complex phenomena can be made more efficient if the learning-perception process consists of three principal stages: 1) holistic and initial overall-perception of the "whole picture", even if during the first stage the perception is more general and the understanding is relatively blurred; 2) detailed and more focused perception and learning of each part of the phenomena 3) holistic, but more rich learning of the "whole picture" at the end, from a comprehensive perspective.

Based on these three stages, a distinction is made in the HDH model between two kinds of courses in relation to structures: holistic courses (H) and detailed courses (D). The specific order of these courses can produce didactical benefits. The H courses have an integrative and holistic character and naturally they should be located at the edges - one at the beginning and the second at the end of the structural studies. The D courses should be located in the middle between the two H courses.

The first H course should provide an initial, overall view together with a basic knowledge. It can serve as a general introduction to the whole chain of structural courses. The D courses should provide more specific, deep, detailed knowledge of different elements of structures. Finally, the last H course, a summary of what has been learned, provides the total integration of all the structural studies.

A distinction in the proposed model may be made where the first holistic course is H_1 and the last is H_2. The detailed courses between the two holistic courses can also be distinguished where the first detailed course is D_1 and the last is $D_{n.}$ Depending on the circumstances, there may be several detailed courses when the whole expression for the model is H_1, D_{1-n}, $H_{2.}$ It can also be written as: H_1, nD, H_2, where "n" is the number of the detailed courses.

This basic model may have other versions in architectural study programs. For example, the first holistic course can act as an introduction, not only to the structural courses, but also to all the science, engineering and technology courses (including structures). In this version, the first holistic course can include two principal parts: a) general introduction, dealing with science, engineering and technology in architecture with a historic perspective b) introduction to structures with a focus on a wide scope of structural aspects. These aspects would be introduced therefore as a part of a much larger philosophical background of science, engineering and technology in architecture.

In general, teachers of both H and D courses should be able to integrate between science and art, and engineering and architecture. It is especially crucial when dealing with the H courses that have a more lateral character and more interdisciplinary features.

B. The First H Stage

The first H stage includes a course with a broad view. Its purpose is to provide an initial exposure to the main body of knowledge in structures as part of science, engineering and technology. It is therefore apparent that this has to be studied at early stages of the architectural studies (during the first year - preferably at the second part of the year as an initial background acquired in the first part of the year can help students to cope much better with the relative complexity of this course). The first stage of the H course can include a historical perspective of the development of science, engineering and technology in architecture. Specific examples illustrating the richness of the integration of science and art in relation to structures in different historical periods can be given. These can include, for example, the masterpieces of architecture since prehistoric era, ancient architecture and other creations later until our era. The main purpose at this stage is to expose the students to the fact that science (including structures) is not alien to architecture and art. Furthermore, science and art can often lead to holistic, rare and unique results that cannot be achieved without the ability to integrate them. Examples of architecture integrating not only structural considerations, but also geometry, climatic design, acoustics and other scientific aspects, can be vital in the first phase of knowledge acquisition. In addition, students can have also benefits if they are exposed to the integration of science in nature, for example in anatomy of the human body, plants and animals. Nature can stimulate curiosity and interest in relation to integrative-scientific thinking, especially during the early stages of the studies (first H course), but also in the later courses. Another topic that may also increase the level of integrative understanding of the scientific aspects is systems theories where the integrative and interdisciplinary approach is significant. It is possible to stress the principles of systems theory based on the heritage of Ludwig von Bertalanfy [6] and other researchers. This general background can provide a basic understanding about systems, types of systems, and improve the comprehension of scientific, engineering, and technological aspects, and their emergence in nature, architecture and other systems, including the structural system.

After this overall introduction of the first H course, structural systems are focused upon from a broad perspective. This can include basic exposure to different structural systems in different eras and places, structural requirements and their relation to other architectural aspects, including architectural language and other structural issues like: loads and forces, stresses, selected structural materials, different structural strategies etc. These issues are mainly studied qualitatively in conjunction with basic quantitative exercises. This stage can include the analysis of structural systems and possibly building models of existing structures. In addition, this stage should include creative and synthesis exercises to create conceptual structural solutions for basic structural problems, such as building small-scale models, working with free hand sketches and 3D physic models. In this case the students can load the structures with different loads to investigate the structural behavior of the structural system under the influence of these loads.

C. The D Stage

The D stage includes courses located between the two H courses. Unlike the H courses, which have a relatively broad view, the D courses have a deeper and detailed character and their role is to concentrate on specific elements and issues of the structural system introduced in general principles at the first stage.

The main purpose of the D courses is to enable students to analyze and understand the structural behavior and the performance of different structural elements, but also to be able to develop conceptual solutions for structural elements. The D courses are mostly concerned with statics and strength of materials. Naturally, this stage includes mathematical, quantitative and analytical exercises. For example: calculations of bending and shear diagrams, etc. of different structural elements like beams, frames and other elements. In spite of the detailed nature of the D courses it is possible to continue to engage in more advanced, overall structural design exercises, such as basically qualitative analysis and synthesis of integrative projects. The complexity of the projects can be constantly increased, which may help students maintain the holistic view acquired during the first H course. The aim of this approach is to enhance that calculations are not in conflict with design, but there can be harmony between them.

D. The Final H Stage

As in the first stage, this final H stage includes a course with a holistic and interdisciplinary view. Here, the main objective is to summarize all the structural knowledge acquired by thinking laterally when the students are familiar with most of the structural terminology and their understanding of structures is relatively deep. It is essential to create a clear distinction between this final course and the first H course because both have, in principle, the same character - they deal with system-thinking and an overall view. The course can include activities of analysis and synthesis. The analytical activity can include analysis of the structural performance of complex structures throughout history from the early days of human civilization. This analysis is comprehensive, holistic, multidimensional and it can include quantitative and qualitative exercises. The activity of synthesis can comprise a complex project (or projects), for which the students have to create conceptual solutions. This activity should have special characteristics that create a structural challenge: a wide span, exceptional structural loads and structural constrains. The process can be very creative including working with free hand sketches, 3D physic models and computers. In spite the computer abilities the importance of the 3D physic models in addition to the computerized models is great because it can help simulation to be more perceptible.

IV. The Relevancy of the Model to Other Fields and Systems

Despite the fact that the HDH model was developed in the field of structural studies in architecture, it is also relevant to other fields of study in both the academia and the outside world. In the academia it is relevant in many cases where there is a sequence of courses, generally in a linear chain, and where the whole picture is an outcome of a long “journey”. It is reasonable to assume that the longer and more complex the chain, the more the HDH model becomes relevant; in this scenario, understanding the “whole picture” is relatively complicated. Examples where the adoption of the HDH model would be beneficial include medicine, which comprises many detailed courses where the context of the whole understanding is especially important; the same can be said about history; regional studies; civil engineering etc. Outside the academy, this model could serve as a conceptual model for understanding any complex phenomena. First step H - a rapid and cursory scanning of the phenomenon to obtain as holistic a picture as possible in a very short time. In spite of the fact that this picture is not detailed, it facilitates strategic understanding. Following this stage, specific and profound knowledge is acquired, where every element of the picture is learned in detail. Finally, a general, overall scanning is made that serves as a summary and overview of the whole process.

V. Conclusions and Future Directions

The HDH model is a concept for teaching structures and it may have benefits especially in relation to the cognitive process of learning structures. There are thousands of schools of architecture throughout the world for which this model could be relevant. It may be possible to implement this model simultaneously in several universities to make a comparative test.

At this stage, it seems that apart from research on the whole concept of the HDH model, the great challenge is the first H course. Out of all the HDH courses, it seems that this is the most complicated to teach because at this stage the students have relatively little knowledge, but are nevertheless requested to develop an overall, conceptual understanding.

In parallel to research in architecture, it is vital to continue developing research on the application of the HDH model in other systems and fields of study.

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