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conversas entre arquitetos e engenheiros no ensino de projeto
conversation between architects and engineers in architectural design teaching

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Abstract

The structural education in architecture schools emphasize that the dialogue between professionals should be the connecting point between the conception of the structural morphology, to be carried out by the architect, and its validation and construction by the structural engineer. However, is this dialogue actually happening? The aim of this work is to study the conversational model proposed by Paul Pangaro (2009), based on Gordon Pask's Conversation Theory (1976a), and investigate if a dialogic process between architectural design and structural education in architectural schools in fact occurs, or if it is possible to propose a new conversational model, promoting transdisciplinary participation and collaboration practices.

Keywords: Architectural design teaching, Structural education, Conversation Theory, Cybernetics

1 Introduction

Structural education is a key element for stimulating architecture students to think about the relations between form, materiality and tectonics, since it assists in the reasoning of physical design processes, leading to a point of convergence between the disciplines of architectural design and structural engineering, whose lack of organicity only accentuates the fragmentation between design and construction. Structural education in architecture should not be an end in itself as in civil engineering courses that form professionals who develop structural calculations but a means for students to think about the tectonics[1] of the form. The fragmentation between the disciplines of architectural design and structural engineering corroborates to an atectonic[2] design thinking, favoring the simplistic application of technique and the generation of fashion images (Frampton, 1995). .

For decades, structural education in architecture schools has trained architects to the same routine of structural engineers, in which there is no critical, reflexive and dialogical knowledge (Santos and Kapp, 2014).

With disciplines focused mainly on quantitative aspects, they are too abstract and do not offer architectural students adequate tools to take ownership of the relationship between material behavior and structural systems design. Thus, they fail to develop a structural logic from an analytical understanding of the various possible solutions to a design problem.

However, the education plans of structural disciplines offered in the architectural schools emphasize that the dialogue between professionals should be the connecting point between the conception of the structural form (to be carried out by the architect) and its validation and construction by the structural engineer. But in teaching practice, is this desirable dialogue between architectural design disciplines and structural education effectively taking place?

To analyze this, we propose a methodology that employs the conversational model of Pangaro (2009) based on the concepts developed by Gordon Pask's Theory of Conversation (1976a). Thus, an adapted conversational model will be used to analyze the relationship between architectural design teaching and structural education in order to identify the existing problems in the current model. With this, it will be possible to propose a conversational model among these disciplines that allows an effective dialogic practice of design, enabling architecture students to elaborate new project systems that encourage the construction of a collective practice of knowledge through participatory[3] and collaborative[4] processes, in which architecture becomes an understanding, rather than an autonomous discipline (Montaner, 2017).

2 Conversation Theory

The Conversational Theory was developed by Gordon Pask (1976a) and originated from a cybernetic assembly[5], in which the fundamental idea is that learning occurs through conversations about the subject matter of the discipline, making knowledge explicit. Pask defines conversation as "an intersection between two second order systems in which humans, machines and environments may be engaged in a collaborative exchange of information". When applied to the design process, second-order[6], cybernetics redefines it as a conversation in which participants must learn together. According to Pask (1980), the Theory of Conversation is used to illustrate an argument in favor of reflexive and relativistic theories in cybernetics and systems studies. Language is fundamental, in which, through a means of processing, has as its property the ability to question, command, respond, obey and explain a certain goal.

Dubberly and Pangaro (2009) use Gordon Pask's cybernetic models of conversation theory because they are based on an in-depth study of the interactions between *human-human* and *human-machine*, believing that only through conversation it is only possible to learn new concepts, share and evolve knowledge, and confirm agreement. In conversation the output of one learning system becomes the input to another.

In conversation systems, based on cybernetic theory, humans, machines and environments can be engaged in collaborative information exchange. For Dubberly and Pangaro (2009), the conversation process occurs when its participants perform the following tasks:

1. Open a channel by sending an initial message of common interest;

2. Commit to engage with a symmetrical relationship between participants;

3. Construct meaning, in which the basis of the conversation must be the sharing of contexts, with common language and same social norms;

4. Evolve, since the conversation affects both participants, in which changes brought about by the conversations have lasting value;

5. Converge on agreement through common goals;

6. Act or transact, developing cooperative relationships;

The Conversion Theory applied to teaching practices requires the developed methodology to have a cyclicality that allows the student to reconstruct a concept and a consistency, allowing all the approached topics to be identified separately (Pask, 1976b), creating new conversation processes. In the autonomous conversation model by Pangaro (2009), as shown in Figure 1, the *Participant A* is the one who initiates the process of collaboration through conversation, defining the initial goals according to their point of view, articulating the logic of conducting the conversation considering that new goals or new opportunities can emerge during the process. *Participant A* has access to a learning structure but is unaware of some topics. *Participant B* should

have the answers to the questions of Participant A providing appropriated demonstrations (Pask, 1976b). The conversation begins only if one of the participants have a goal, specific or general, articulated or without form.

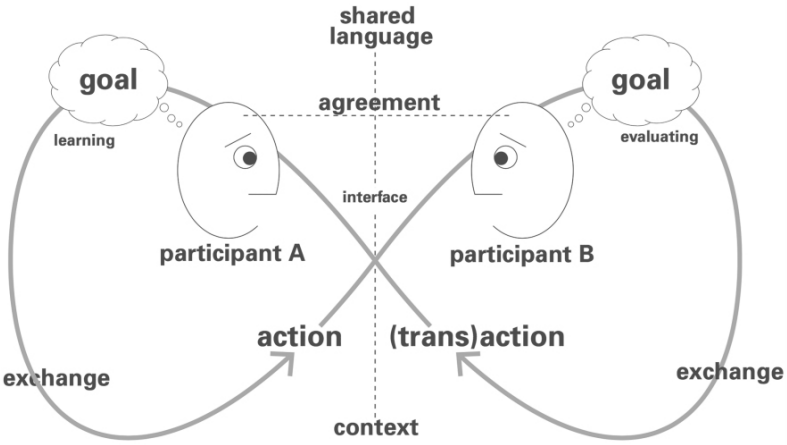

Fig. 1: Simplified view of Pask's view of conversation. Source: Pangaro, 2017. Available at:http://www.pangaro.com/published/Pangaro%E2%80%93Questions-for-Conversation_Theory_In_One_Hour-Kybernetes_2017.pdf>. [Accessed 30 June 2018].

Thus, Pangaro (2009) systematizes what would be a conversational model and establishes some requirements for its organization:

Context: moment, situation, place and/or shared history;

Language: initial shared means for conveying meaning;

Agreement: shared understanding of concepts, intent, values that may lead to an action;

Exchange: availability for interaction, result of a shared language and a context conducive to interaction that can build an agreement;

Action and (Trans) action: cooperative conversation, circular and recursive.

3 Analysis of current teaching practice

In structure disciplines currently offered in architectural courses[7], what exists is a technical communication. For Pask (apud Pangaro, 2017), the difference between communication and conversation is that for the dialogue to occur something must be transformed for one or more participants, be it the understanding of the subject, concepts, intentions or values. If this transformation does not occur, what happened was a mere exchange of messages.

The current model of structural education is fragmented into disciplines that follow a similar civil engineering education, having disciplines of theoretical foundation (introduction to structural systems), intermediate knowledge (structural analysis and materials' resistance) and specific advanced knowledge (concrete, steel and wood). All disciplines have as bias the structural analysis by the analytical method that is using mathematical equations. Experimental methods, focused on the development of physical models, and computational methods that allow a better visualization of the physical behavior of the models are not used. In this way, students are only instrumented with an abstract mathematical language that is difficult to apply to architectural design. In this way, is the mathematical and abstract language used for teaching structures in architectural schools enough for the establishment of a conversational practice?

In architectural teaching, design disciplines wish to learn about structures for definitions of spatiality, morphology, and construction materiality. The role of teaching structures is a cooperative action with the dialogue to be established. Thus, in this dialogue, architectural design teaching is *Participant A* (which initiates the conversation with an action) and structural education is *Participant B* (which reacts to this action with a transaction).

The objective of this dialogue should be to provide the architect with structural knowledge that allows flexibility in structural parameters in harmony with spatial articulation. The structure in a tectonic design

conception is not an autonomous object that must suit the space or vice versa. The architectural design teaching is (or should be) the driver of the conversation between agents, promoting the opening of common channels of conversation. In the current teaching model there is no formalized environment for the conversation with teaching of structures to take place.

In this way, we will first analyze the current teaching practice through the bias of the conversational model, verifying if there is a conversation between architectural design teaching and structural education within the context of each discipline:

***Participant A*: Architectural Design Teaching**

Context: architectural design disciplines;

Language: manual or digital representation methods of architectural design;

Agreement: launch of the structure according to pre-dimensioning criteria;

Exchange: when it occurs, it happens through the analysis of examples and counter-examples of structural solutions of analogous works. It may also occur consulting the specific bibliography of structural knowledge directed to the learning of architects;

Action and (Trans) action: practically does not occur. It depends on the individual willingness of design teachers and students to seek some contact with the teachers of structures disciplines.

***Participant B*: Structural Education**

Context: disciplines of structures;

Language: mathematics through analytical method;

Agreement: according to the subjects of the disciplines, only the basic concepts of the contents are offered in such a way that the architects can carry out a structural pre-dimensioning and dialogue with structural engineers in professional practice;

Exchange: the inadequacy of the application of language to design development does not allow the exchange;

Action and (Trans) action: practically nonexistent since the exchanges are made difficult by the language used;

In the current model, there is no possibility of feedback, and a process of linear causality is created. According to Dubberly and Pangaro (2015a), this linear process does not allow the iteration, which would be the correction of the error, and the convergence of objectives among the participating agents, limiting design to simplified feedbacks. In this way, for the proposition of a conversational model between the architectural design teaching and structural education, it is important that there is a context that allows the possibility of multiple feedbacks, promoting circularity and recursion. For this, it is fundamental that *Participant B* interacts in the context of *Participant A*, developing a common language, with explicit goals, in a context that facilitates the exchanges, in which these will serve as the basis for a joint action and for the creation of new values.

4 Proposal of a Conversational Model

Cybernetics studies how systems organize themselves, dealing with how they communicate internally and with other systems, which stimulates collaborative transdisciplinary thinking. For Von Foerster (apud Dubberly and Pangaro, 2015b, p.5, our translation), "one can and should try to communicate beyond the boundaries, and often the abysses, that separate the various sciences".

Some attempts to promote this integration have been developed to improve the dialogue between architectural design teaching and structural education. As can be seen in III Eneeea[8], some Brazilian universities focus on a language modification (experimental methods with the use of physical models or investigations in experimental building sites), others involve new participants (engineering professors present in the design disciplines) and some even propose a new conversational model.

However, these propositions are focused on technical communication and do not present meaningful reflections regarding changes in architecture itself and its contemporary condition. For Montaner (2016), contemporary architecture has a contextualist and complex synthesis character, in which a new pragmatism is reformulated through practical tools of knowledge, analysis and design. According to him, the diagrammatic practices and the digital tools facilitate the development of an architectural theory related to an interactive pragmatism. Pangaro (2011) believes that design development should be more concerned with the design process than with the shape of objects, and that without the creation of a new language, innovation is limited to improvements in existing processes. But how do we develop a new language?

The proposal of a new conversational model between the architectural design teaching and structural education seeks to promote a common language among the participants, so that it is possible for the exchanges to be effectively carried out. For this, it is fundamental that *Participant B* promotes its (trans) action within the same environment of design teaching (*Participant A*). *Participant B* can be a machine (use of structural analysis software) or a human (teacher of structures disciplines). In this way, the proposed conversations are about promoting human-machine interaction or human-machine-human interaction.

5 *Human-machine* conversation

In the first hypothesis, which we will call the *Conversational Model Type 1* (focusing on *human-machine* conversation), the proposal is to develop a teaching model in which students use structural analysis software to develop performance-based design methodologies (with focus on optimization, generation or computational form-finding) in the existing design disciplines. This model, as elucidated in Table 1, consists of involving *Participant B* in the conversation (structural analysis software) through *human-machine* interaction. This conversational model produces the following interactions:

	***Participant A** - action*		***Participant B** – (trans)action*
Conversation	**Human** (*A.1*)	**Human** (*A.2*)	**Machine** *(B.1)*
Human (*A.1*)	between architectural design teacher`s	students – architectural design teacher	structural analysis software – architectural design teacher
Human (*A.2*)	architectural design teacher - students	Between students	structural analysis software – students
Machine (*B.1*)	architectural design teacher - structural analysis software	students - structural analysis software	computacional iteraction

Table 1: Conversacional Model Type 1. Source: Prepared by the author.

In this model, *Participant A* are the architectural design teacher (*A.1*) and students (*A.2*), and *Participant B* is the structural analysis software (*B.1*). The design teacher establishes the dialogue with the software in two moments: first, in the selection and verification of the possibility of feedbacks according to the objective; and second, directing the students to interact with the software in the developed process. The conversation takes place between design teachers, students, and structural analysis software. The purpose of the *human-machine* dialogue is to broaden the possibilities for conversation.

Interacting with computers serves to assist in making decisions in complex situations. In advanced design environments, which for Oxman (2008) is considered to be performance-based design, through the use of interaction and iteration between *human-machine* and multiple agents it is possible to create a conversation process with multiple feedbacks and recursion. This process could have the potential to transform the relationships between architects and engineers through a common language provided by the digital medium in which values would be explicit and both would share the same goal.

Oxman (2012) defines performance as the ability to act directly on the physical properties of design and it can be extended to include qualitative aspects such as spatial factors in technical simulations. For Kolarevic (2005), the concept of performance goes far beyond aesthetic, functional and technical aspects, and can be extended to a financial, cultural, spatial and social dimension. The understanding of *performance*[9] as a process demands a revision of the understanding of the "built body" as a "static body", suggesting the etymological idea of the formation of the architectural object through movement.

In addition to the dialogue between architectural design and structures, the performance-based digital design includes the computer as part of the process, a third participant involved in the conversation. Incorporating technology as a conversation interface tool provides participants with a shared language for a cooperative dialogic process, facilitating the development of an interactive, iterative, circular, and recursive process. For Oxman and Oxman (2010), the digital cooperative process dilutes the matter of authorship of form, through investigative and experimental processes, reversing the way of thinking form, force and structure.

In this way, based on the *human-machine* conversation applied to teaching, the use of structural analysis software was proposed in design disciplines. Thus, we have the following structure for the development of the *Conversational Model Type1*:

Context: architectural design disciplines;

Language: use of simplified structural analysis software for structural form-finding integrated to theoretical classes of material properties;

Agreement: learning of structural analysis software to aid in the preliminary structural sizing of the proposed structural typology;

*Exchange:*the software provides the preliminary structural sizing through the amount of material required;

Action and (Trans) action: recursion in the preliminary sizing and in the choice of materials during the development of the architectural design;

In this model, what is observed is that students who already have intermediate and advanced knowledge (of both design and structures) can engage in the conversation model. This is because they can understand the objectives, the proposed language and in this way use the software transaction for application in the design process. However, what is perceived in this model is that the simplification of the used language does not allow the engagement for recursion and the engagement with other conversations, being only an efficient tool for the students to explore the materiality of the object.

6 *Human-machine-human* conversation

In a second hypothesis for the construction of the model, due to its limitations identified in *Type 1*, the demands of knowledge go beyond the human-machine conversation and it is necessary to include a new *Participant B*, who would be a structural engineering teacher. This can be introduced as a new element, extending the *human-machine* conversation to a *human-machine-human* conversation, opening new channels of conversations that need to be worked on. In this model, which will be identified as *Conversational Model Type 2*, several conversations can occur simultaneously as shown in Table 2, which would require the design teacher to explain to all participants the goals and values involved, with an agreement and an engagement of all in order to avoid disturbance, and consequently, conflicts of interest between the participants.

According to Pask (1980), a person can have the perspective of more than one participant simultaneously, unifying the internal conversation. When adopting different roles, this participant should consider the merits of the various hypotheses that may arise from the other participants. In this model, the *Participant A* in the figure of the design teacher (*A.1*) would be the participant that performs this function. If there is no agreement and engagement with *Participant B* in the figure of the structural engineering teacher (*B.2*), the entire process may lead to a conflicting transaction, or even make it infeasible. In this proposition, several conversations may occur:

	***Participant A** - action*		***Participant B** – (trans)action*	
Conversation	**Human** (*A.1*)	**Human** (*A.2*)	**Machine** *(B.1)*	**Human** (*B.2*)
Human (*A.1*)	between architectural design teacher`s	students – architectural design teacher	structural analysis software – architectural design teacher	structural engineering teacher – architectural design teacher
Human (*A.2*)	architectural design teacher - students	between students	structural analysis software - students	structural engineering teacher – students
Machine (*B.1*)	architectural design teacher - structural analysis software	students - structural analysis software	computacional iteraction	prof.de estruturas - structural analysis software
Human (*B.2*)	architectural design teacher – structural engineering teacher	students – structural engineering teacher	validation of results	conversation between structural engineering teacher`s

Table 2: *Conversational Model Type 2*. Source: Prepared by the author.

The proposal to create the *Conversational Model Type 2*, considering all the complexity involved and the multiple interactions provided, is not to create a closed model but to create a system with explicit subjectivities, values and responsibilities allowing all participants to create. Conversation is necessary to converge on shared goals and therefore rearrange the situation in order to act together. In this way, the conversation between people is fundamental for understanding the principles of duality, complementarity and conservation. Like so, there can be no loss of concepts in the development of a unique environment for the two disciplines (design and structures). For Pask (1980), the principle of preserving the information to be transferred in the conversation through language and through other means is what maintains the coherence of the system. In this way, the proposition of a *Conversational Model Type 2* for the synthesis of all conversations that would occur internally, encompasses the following definitions:

Context: hybrid disciplines of architectural and structural design;

Language: learning of structural analysis software integrated to theoretical modules of structural design[10] in its quantitative and qualitative dimensions;

Agreement: learning of concepts and application in the software for iteration with the computational model;

*Exchange:*development of an iterative process in which the participants take the software evaluations as an interface for the dialogue;

Action and (Trans) action: recursion in the development of architectural design. The participation of the structural engineering teacher is required for the sophistication of the iteration. Architects and engineers develop a collaborative relationship;

In order to promote a circular and recursive process in a complex model like *Type 2*, the pedagogical structure of the proposed disciplines can be divided into four moments based on Pangaro (2011), being all iterative and recursive:

Conversation to Agree on Goals: moment that the objectives must be explained and agreed upon until they are brought to engagement;

Conversation to Design the Designing: moment of identification of irreplaceable knowledge for the design of a new space of possibilities;

Conversation to Create New Language: as a new space of possibilities evolves, a new language is shaped and defined;

Conversation to Agree on Means: agreement on the action plan for the development of products using the proposed conversational model.

Hybrid disciplines have the purpose to open dialogues without eliminating the possibility of maintaining the current disciplines of structures. On the contrary, to stimulate students to look for these theoretical tools to better understand how to use the resources of analysis and iteration provided by structural analysis software. The software's visual resources allow the visualization of the behavior of the structures, leading to recognition of the concepts learned through analytical mathematical models which, because they are too abstract, are generally not well understood.

What was noticed in the development of *Conversational Model Type 2* is that the difference between students with basic knowledge of structures and students with intermediate and advanced knowledge is not perceived, being that all of them engage in the development of the iterative process and require the participation of a structural engineering teacher in the process. This conversation can even extrapolate the edges of the discipline itself, enabling and encouraging students to seek new knowledge with other structural engineering teachers or even with other agents of construction industry (designers, industries and construction workers).

Students with advanced knowledge of both design and structures engage in a dialogue that overflows the discipline. These students seek the theoretical knowledge offered in the traditional disciplines of structures (some return to attend classes in disciplines such as materials' resistance and structural analysis), seek dialogue with other structural engineer teachers, seek other structural analysis softwares, other professionals in the field and even engage in a critical dialogue with the construction industry.

7 Conclusion

The modern division of labor has led architects and engineers to develop a collaborative relationship through help or support. That is, the architect develops a project and the engineer helps or assists them with their work, not acting jointly in its development. The change of relationship in the sense of developing a cooperative work redefines the positions of professionals and re-approximate the work of both, where the action takes place jointly for the same purpose.

The pedagogical proposal to develop conversational models for teaching design and structures goes through what Montaner (2017) proposes for a practice towards an architecture of action. For Dubberly and Pangaro (2015a), the conversation for action promotes an ethical (in agreement with goals), cooperative (in

agreement with means), innovative (creating a new language) and responsible (creating a new process) relation.

According to Dubberly and Pangaro (2015a), knowledge of vocabulary and grammar is not a prerequisite but provides a more fertile ground for the emergence of poetry, and of delight. By designing interactive environments as computational extensions of human agency or new social discourses to govern social change, second-order design facilitates the emergence of conditions in which others can design, creating conditions in which conversations can emerge, thereby increasing the number of options open to all.

In order for structural education to be part of a conversation within the design disciplines it is necessary that the architectural design teaching be also open to the substitution of a typological model (with an adjustment of the linear form) for a topological performance model, in which the architect does not have control of the designed object but rather of the process, allowing architecture to emerge from participation and emergence between a variety of agents. The digital tools of structural analysis provide a set of iterativity between the parameters used to conceive the space and its possibilities of materialization through processes of optimization, generation or structural form-finding. In this case, the computer acts as a cybernetic instrument that responds to the parameters established by the students for the design of the structural system instructing and being instructed by it, in a recursive process that can add as many agents as necessary. In this process unexpected results can emerge, not foreseen initially, creating novelty for both participants.

The creation of collaborative design processes in which knowledge is built collectively through the participation of other agents leads to a paradigm shift. Established conversations can transform individuals and organizations by changing values and modes of arrangement, and conversation initiated in teaching can be replicated in professional practice. For Pangaro (2017), when a conversation begins, it never ends. In this way, we believe that the conversation initiated in the teaching environment has the capacity to transform professional practice, thus modifying the relationships between civil construction agents (architects, engineers, workers and users) and their forms of participation through the emergence of dialogical practices, in which the discussion is oriented by the object that connects or might connect them.

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1 To Framptom (1995) the meaning of tectonics varied greatly throughout the century. Due to cultural and ecological changes, and industrial and post-industrial development, as well as the emergence of a largely urban society, which has transformed the value of tectonics. In Greek etymology, the term tectonic derives from the word tekton meaning carpenter or builder. The term referred to a craftsman who worked with heavy materials, such as stone and wood, except metal. The term tekton also had a poetic connotation, in which the artisan explores the expression potential of the constructive technique. Thus, for Framptom (1995), tectonics refers to the poetics of construction, in which art and craft are intricately connected.

2 Seker used the concept of atectonic as "a manner in which the expressive interaction of load and support in architecture is visually neglected or obscured" (apud Frampton, 1995, p.19, our translation)

3 Participate: word composed by the notions of part, be part of, and grasp, take, indicating a voluntary and determined action.

4 Collaborate: the verb joins meaning in Latin (laborare) - work, feel pain, fatigue - to the collective condition given by the prefix co-set, with.

5 Cybernetics is a way to focus the design process and new design products, both being means and ends. The cybernetic structure involves objectives, recursivity and learning" (Dubberly and Pangaro, 2015a).

6 First-order cybernetics brings an understanding of circular causality to the understanding of interactive systems involving recursion, learning, and coevolution. Second-order cybernetics frames design as a conversation, and thus requires making values and viewpoints explicit, incorporating subjectivity and epistemology, creating conditions for participants to learn together (Dubberly, Pangaro, 2015a).

7 For the accomplishment of this analysis the teaching plans were used the disciplines of the Architecture and Urbanism Course of UFMG curriculum version 2014/1 and of the Civil Engineering Course of UFMG 1998/1 curricular version.

8 Third edition of a Brazilian national meeting of structural teaching in architecture schools, held in 2017, which sought to resume the discussion started in 1974 and 1985, respective dates of the first event and the second event. The proposal of the III ENEEEA was to update the discussion and expand it, discussing the possibilities of articulating the contents of structural teaching and architectural design teaching.

9 For the expansion of the concept of performance in the sense of developing a theory for digital architecture, this cannot be reduced to quantitative aspects. Some notes by Zumthor (2007) lead us to a reflection of the possibilities of appropriation of the term beyond a quantitative analysis of technical aspects, but for an assimilation that also encompasses the design process as a phenomenon.

10 Structural design involves designing the geometry, establishing the loadings and boundary conditions of the structure, knowing the properties of the materials and selecting the cross-sections of the elements of the

structure.