IS A DIGITAL MODEL WORTH A THOUSAND PICTURES?

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Abstract. This communication addresses the use of a new type of referents database in the context of an architectural design studio. It discusses the results of design experiences held with the objective to study the cognitive effects of a teaching approach based on precedents and metaphors available as interactive and reusable digital models to students. The introduction of this referent-based approach is inspired by three major principles: the largely accepted fact that the creative work of architects is highly supported by referring to precedents and metaphors; the use of algorithmic digital methods to encapsulate architectural knowledge; and the constructivist approach to architectural design education. The study finds that the role of the modeled referents is helpful for the design studio learning, and that they are most creatively used when internalized by the student.

1. Introduction

This communication addresses the use of a new type of referents database in the context of an architectural design studio. It discusses design experiences held with the objective to study the cognitive effects of a teaching approach based on referents available as interactive and reusable digital models to students. In other words, if a picture is worth a thousand words, is a digital model worth a thousand pictures in the context of architectural design education?

Based on previous work, this article reports a qualitative study performed with students in architecture given the possibility to use a library of referents during their work on a design task. Together with visual material, the library included algorithmic and parametric models of architectural know-how. The communication consists of five main parts: a first one giving the background for the study; a second one, discussing the methodology used; a third one presenting the observations held; a fourth one showing some results, and finally a discussion together with the future avenues of this research.

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2. Background

The introduction of this referent-based approach is inspired by three major principles: the largely accepted fact that the creative work of architects is highly supported by referring to precedents and metaphors; the use of algorithmic digital methods to encapsulate architectural knowledge; and the constructionist approach to architectural design education.

2.1. ON THE ROLE OF ARCHITECTURAL REFERENTS

We use the term referent to indicate all kinds of objects or phenomena to which an architect would eventually refer, either for inspiration (in metaphors) or for finding 'how-to' information (in precedents) during a design process. The distinction between metaphors and precedents is important but we will not specifically discuss it in this paper. We prefer the term 'referent' to 'reference' because of its more specific meaning in design.

The role of referents in architectural design and in design learning is largely described in the literature. Without going into any details, we will mention some main aspects revealed in the numerous studies on the theme. The role of analogical transfer (which is the cognitive mechanism of metaphors and precedents) is crucial for the processes of recognition, classification and naming (Minski 1985). In an architectural context, Léglise (2000) states that a person best perceives and understands new things based on analogies with past experiences. With the words of Schön (1988), the 'Design World' of architects consists of referents and "things to think with", that embody implicitly architectural know-how. Oxman (1994) speaks of knowledge chunks, indicating by this term the design knowledge on precedents. According to Kalay (2004) referents and cases offer holistic knowledge and provide a shortcut to a solution of a complex problem. These last three examples are particularly important in the context of our study because they provide a direct link between a referent and architectural know-how.

Reconsidering referents form a digital point of view, brought up the idea of augmenting their cognitive role by providing digital models rather than only text and pictures.

2.2. ON ALGORITHMS, OR THE NEED FOR ARCHITECTURAL KNOW-HOW

Whilst in the time of Vitruvius or during the Middle Ages architectural and building knowledge was directly transferred from master to apprentice architect, with the separation of architects as a profession, and with their alienation from the construction site, visual referents began playing a much more important role. This trend was enormously boosted in recent years by the Internet. Nowadays architectural culture is extremely visual, this way

taking advantage of the powers of a 'visual thinking' and, in the same time, often suffering from lack of information on the 'why' and 'how' of a drawing or picture. At the same time some authors find an increased insufficiency of architectural knowledge in young architects, blaming partially the computer for this (Akin 2002, Fernandez 2002).

These considerations lead us to the second principle applied to the referents: the introduction of algorithms in the digital architectural models. Made accessible by the introduction of computer technology into architectural practice, algorithms now have their place in the avant-garde of the profession (Abel 2004, Terzidis 2006). Some promising introduction of algorithmic generation of forms is made in architectural studios as well (Yakeley 2001, Weinand 2004, Tidafi and Iordanova 2006). The differences between algorithmic approaches and methods accommodating the 'paper-and-pen' way of thinking in architecture are underlined by Oxman (2006). Giving clear preference to 'digital thinking' when designing on a computer, the author enumerates three paradigmatic classes of digital models that could enrich the design methods of an architect with methods made possible by computers: formation, generation, and performance. All these have parametric modeling and algorithms as a creation base.

Using algorithms when designing brings at least two advantages: being able to define a generating rule or a process instead of representing one of its final instances; and having the possibility to produce multiple instances by intervening in the process description, this way stimulating a process of creative exploration of the design proposition. From an educational point of view, algorithms give the possibility to encode architectural knowledge linked to rules and laws (structural, climatic, compositional, etc.). It makes possible as well to encapsulate processes and to be able to visualize and test them as simulations in the time (energy optimization, manner of production, etc.).

In order to be able to explore different solutions based on variations of generating algorithms, students should be able first to encode them. According to some authors (Yakeley 2000), programming has a stimulating impact on design thinking. From our experience though, it is difficult, to introduce it directly in a digital studio, and not less unattainable to convince students used to visual and tactile manipulations when designing, of the interest of some programming. So, a more accommodating solution, having as well its own advantages, was working with pre-modeled examples. This way, students can see some visual aspects of the algorithmic model, together with its description. Often, the model would be linked to a real architectural precedent or a metaphor, thus providing a rather complete referencing basis: textual description of the 'what and why', model of the 'how', and visual representations. The fact that the 'how' is presented by an algorithmic digital

model gives the possibility for its reuse by students in a new design situations. The validation of this approach is one of the objectives of this study.

The introduction of referents modeled in an algorithmic way to the digital studio pursues a double objective: educating students in a new way of design thinking (based on process rather than on result) that could be complementary to traditional methods of design; as well as providing architectural know-how linked to design process and 'performative' architecture.

2.3. ON THE CONSTRUCTIONIST APPROACH TO EDUCATION

A third main inspiration for this research was the constructivist methodology giving the grounds for the constructionist educational approach, as well as for the digital modeling techniques taught to students. According to Piaget (1970) and Schön (1988), learning is especially effective when using know-how in a constructionist way (to create something new with it). With the words of Schön, architectural design is a process of 'reflective conversation with the materials of the situation' that uses different types of referents, including the past experience of the creator. These two studies lead us to the idea that it could be advantageous for the students to be given the possibility to design using referents containing architectural know-how, and being able to immediately reuse this know-how in their educational design projects. Based on previous work, the modeled referents encapsulate only 'chunks' of knowledge, in order to permit greater flexibility and to comply with constructivist memory structure theories (Minski 1985). This way, interactive "chunks of knowledge" serve as referents during the process of design. The constructivist approach is omnipresent in the methodology chosen for this research.

3. Methodology

The methodology identified for this study is purely qualitative and participative. This is motivated by the complexity of the research domain (design and education), as well as by the will to be able to study in depth a small number of participants (10 students) (Creswell 1998). The methodology part of the study will discuss three aspects: the methodology used for the creation of the referents library, the pedagogical approach introducing it into the digital studio, as well as the validation methodology.

3.1. THE REFERENTS LIBRARY

In the development of the proposed library, we have taken into account some recent studies on new computer methods for architectural education that look

for a way to integrate precedents into the architectural studio in an intelligent and intuitive way. But rather than proposing computer assistance based mainly on visual information on precedents, combined with keywords and "concepts" manipulation and association (Oxman 2004; Kocaturk and Veltkamp 2005), the digital-models referents library offered in our approach is directly linked to a modeling program and allows for knowledge transfer from a precedent to the new design.

3.1.1. The models

What is, in our comprehension, architectural know-how? It is the knowledge and the methods of work of an architect, that are perceivable in the actions posed during the design process (Tidafi 1996). It includes the following dimensions: (1) scientific knowledge: building rules (structural, climatic, physic), urban regulations, functional organization, etc.; (2) artistic knowledge: styles, formal composition, etc.; and (3) methods-of-design knowledge. Examples of all these dimensions can be found as encoded knowledge in the modeled referents.

3.1.2. The library integration

In previous work, we have already defined a modeling methodology for a similar kind of digital 'object types' (in the sense of Schön (1988)). But then, the proposed 'teaching assistant' was not integrated in free-modeling software. Now, the referents library is a free standing unit (a structure of folders), but can be accessed through a browsing interface of the main modeling software, Cinema4D in this case (Figure1).

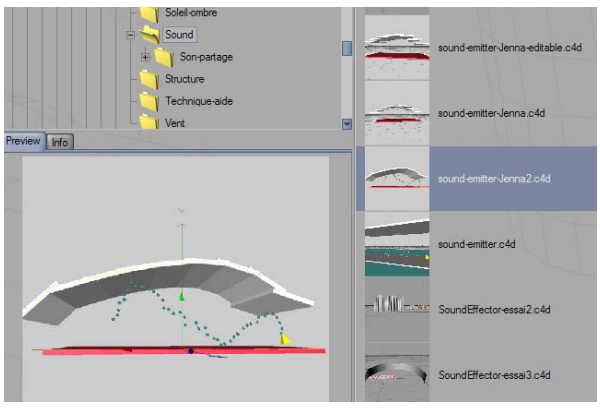

Figure 1. Integration of the referents library in a modeling software program

This gives the possibility to have visual representations (large thumbnails) of the models, as well as to be able to directly open or "merge" the referent model into the current scene. It also allows combining the use of

referent models and the know-how encoded in them, with other more traditional methods of design like free modeling and CAD.

One of the major concerns in researches on precedents databases is the possibility to personalize used referents and to keep track of visited items together with the connections (the analogies) that have lead to them in order to be able to create 'conceptual maps' for future use. This functionality is present in the proposed referents library through the creation of a named and dated entity keeping links to the concepts 'searched for' (fig. 2).

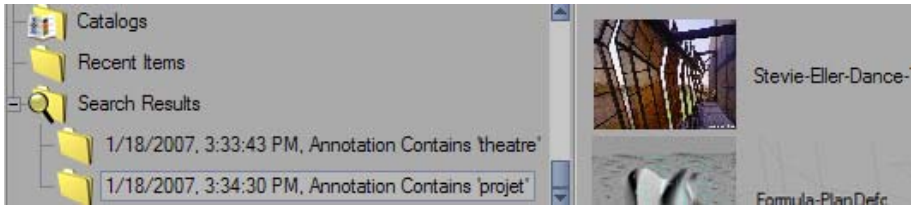

Figure 2. Personal annotation of referents and saving search results

Models, visual information (picture and drawings), textual descriptions, video recordings and sound files are organized in the same library structure provided by the tutor, but customizable by the student.

3.2. THE PEDAGOGICAL APPROACH

As we already mentioned, the pedagogical approach used in the studio is mainly based on the constructionist theory of education. Simultaneously, it integrates the opinion that even though architects are used to work with implicit knowledge (Lawson 1979), this is not as appropriate for design education (Akin 2002; Oxman 2004). Therefore, we provide the students with referent models whose design know-how can be made explicit. Two methods are used for this. One is including in the library a video and voice recording explaining the 'how' and the 'why' of a model together with its creation as an algorithmic model. Another method is the structure of the model itself. By creating algorithmic and parametric models with clear structure of relations, dependencies and/or objects, a student is able to understand the knowledge behind it. By changing a temporal component, processes can be 'explained' as well.

The students are initiated to the referents library progressively, starting at the beginning of the term. This process goes on together with the work on the studio project. Referent models aiming at specific aspects of the project development (form, semantics, site analysis, building structure, passive energy optimization, visibility, sound propagation) are introduced each week, thus bringing the students' attention to them (fig. 3: showing an example of a modeled 'chunk of knowledge' from a precedent interesting

from structural point of view). This way, both learning algorithmic design, and getting used to working with model-precedents is simultaneously achieved.

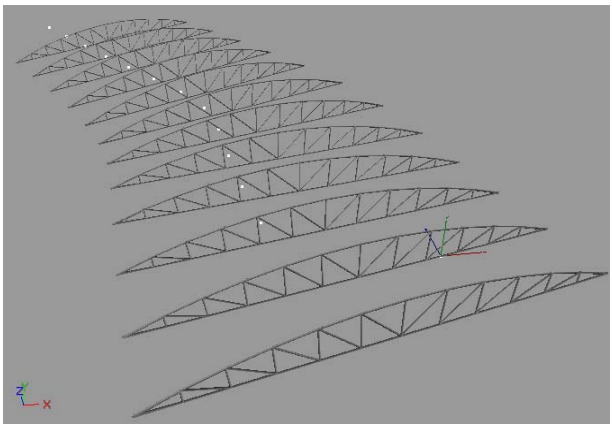

Figure 3. Parametrically created and distributed metal trusses (similar to the structure of the Waterloo Station by Nicholas Grimshaw & Partners)

3.3. VALIDATION METHODOLOGY

The validation experiences in the design studio adopted qualitative methodology combining case study with grounded theory (Creswell 1998). An observation protocol of team work was chosen for the natural and instant verbalization it provides, compared to concurrent and retrospective protocols. The teams consisted of two students working on one computer but with two mice for better digital interaction with it. Exhaustive data collection included a screen session recording and a video-camera recording of the students' activities. The term project is taken into consideration as background information. This was made possible thanks to regular presentations of the project advance, and to a 'web-diary' kept by the students.

A data analysis coding scheme aiming at finding out some cognitive effects of the design teaching approach is developed aiming at a better understanding of the observed design processes. Specifically observed phenomena are: (1) emergence of design ideas, (2) 'use' of referents, (3) contents of the analogical transfer from a referent, (4) moments of 'reflective conversation'.

When a referent is 'used' (referred to), its type is identified:

- from the referents library: visual (picture or drawing), textual, algorithmic model;
- previous experience;
- architectural precedent (just mentioned);

- metaphor (just mentioned).

The role of the 'used' referent for the design idea is determined as well: emergence, support or concretization.

The content of the analogical transfer is especially important for the validation of the possibility for know-how transfer when using modeled referents. The types of content 'looked for' are linked to the three aspects of architectural know-how we have defined earlier in this paper: scientific knowledge, artistic knowledge and methods-of-design knowledge.

The analogical transfer can be successful or not: this was determined by the level of accomplishment of the task it was intended for. Another point of interest is the degree of novelty in the designs where referent-models have been reused. In order to determine this delicate aspect, 'new-design' criteria have to be defined. For the purposes of this study, only one criterion was considered: a reasonable difference in the form between the referent and the design object (which was evaluated by the participants in the study).

At the end of the recorded experiences, questionnaires were given to the students in order to ask for their level of satisfaction with the result of their work, as well as on the interest they find in the library of modeled referents.

4. Observations and data

Ten students (5 male and 5 female) from the third year of architectural education participated in the digital studio. The modeling software used for the project was new to them. During the 10^{th} week of the term, the same students were given 2,5 hours to complete a design task (only in the conceptual stage) working in teams of two. They were encouraged to briefly review the referents library before starting work on the project. In addition to the already introduced models of referents, new ones covering the design task domain (*Summer Theater with an Exhibition Space*) were included.

The recorded material was synthetically transcribed (design actions, conversation, gestures) and then coded according to the identified scheme. Qualitative methodology implies not a statistical analysis, but rather an interpretation of the data, the objectivity being assured by other researchers interpreting the same data.

A general observation on the digital design methods used was that parametric generation of design was successfully used by three (of the five) teams. Two of these teams were working exclusively parametrically (fig. 4 and fig. 5). The remaining two teams were trying to use parametric forms and distributions in the context of their architectural task, but with little success.

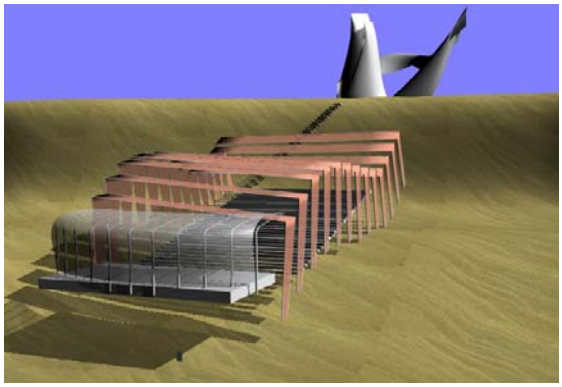

Figure 4. The project of Maude Halle Saint-Cyr and Nicolas Bocobza realized during the observations

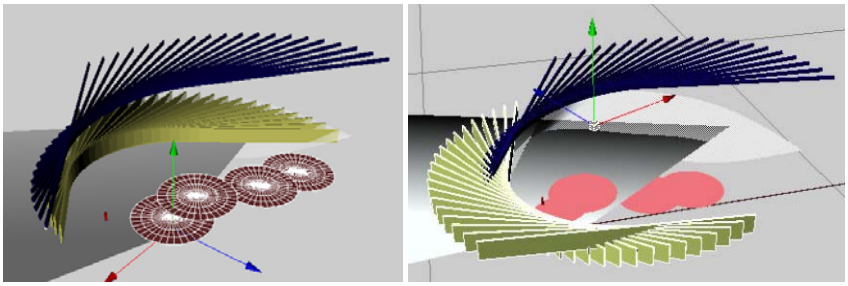

Figure 5. The project offering dynamic configurations (observation project of Jerome Taillandier and Rachid Saghir)

The situation was different regarding the term projects of the same students. There almost all of them (nine) have extensively used parametric and algorithmic methods during the design process. This difference could be partially attributed to the time constraint during the observation experience.

5. Results

After having described the general picture of the students design work, we will represent and discuss each of the observed phenomena.

5.1. EMERGENCE OF DESIGN IDEAS

Only major design ideas were observed. Two main 'patterns' were identified: (1) general definition of the project from the very beginning of the design period, after which only minor ideas emerge while the objective is the representation of the 'project idea'; and (2) identification of the leading principles (or forces) for the project, after which the design is guided by an exploration process. The first 'pattern' was noticed in the teams not working

parametrically, and generated ideas less in number (six for each of the teams) and mainly at the beginning of the design work. The second one was present in the teams using parametric digital methods, and generated respectively 12 and 16 ideas for the two teams.

5.2. USE OF REFERENTS

Out of the 50 major design ideas identified during the work of the 5 teams, 38 were linked to use of referents. As reported by Leclercq and Heylighen (2002), a large part of the objects and phenomena students referred to, were not coming from the provided referents library, but from prior knowledge or experience. Thus, 28 of the referents that have provoked a design idea were from the referents library (11 images and 16 models). Nine metaphors were used, 3 of them being evoked by a model of the referents library.

Students' design methods varied a lot in terms of referent use. Images, project site and metaphors seem to be equally stimulating for ideas. But the process varies from team to team: sometimes they look for ideas, sometimes they search for ways to concretize an intention. This last process is often supported by modeled referents. It is often helped by other architectural precedents or by previous experience as well.

Referring to modeled referents was quite present during the design session. One of the teams got from it an inspiration in support for their design idea; most of the teams were looking for ways of concretization of their intentions. More extensive use of the modeled referents could be seen during the work on the studio project. After the introduction of each part of the referents library, the students were taking the time to explore the models and to eventually integrate an emerged idea into their term project. In the answers to the questionnaire, the models were qualified as very useful and enriching.

5.3. CONTENT OF THE ANALOGICAL TRANSFER

The content of the intended analogical transfer (when using referents) was covering mainly scientific knowledge and methods-of-design knowledge when modeled referents are used. The tendency was to witness more artistic knowledge and 'experiential' transfer, when images were discussed or architectural precedents mentioned. These results are supported by the data coming from the term project. In fact, both scientific knowledge and methods-of-design knowledge were used by the students for project exploration.

The level of success of the transfer of know-how embodied by the referent was quite high. The reuse of modeled referents was sometimes hampered by technical difficulties (not knowing the functions of the software used). The situation was much better during the studio project when

the time constraint was not present, and where students could ask the tutor for help. In fact, three times during the observations, one of the team members was asking to watch the explicative video in order to find out how to use a modeled referent, but the other member of the team declined the request because of the time limits.

A known danger of reuse of models is imitation, or directly copying from the referent. The study of the students' projects according to the established 'new design' criteria, gave a satisfying result. This is especially well observable when methods-of-design knowledge are transferred (Figure 6).

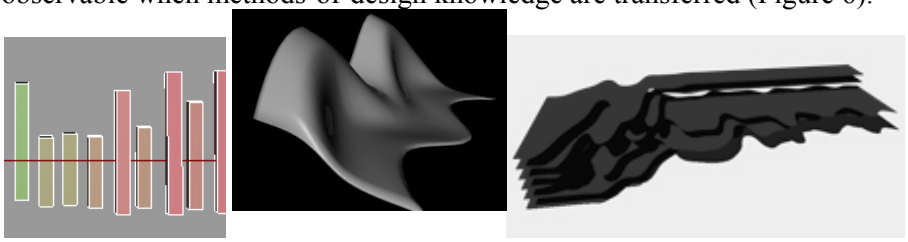

Figure 6. Comparison between a referent model in the library (left) and two students' variations (middle and right)

In the example on Figure 7, the exploration made with one of the referent models gave place to a main design idea of the studio project of the student.

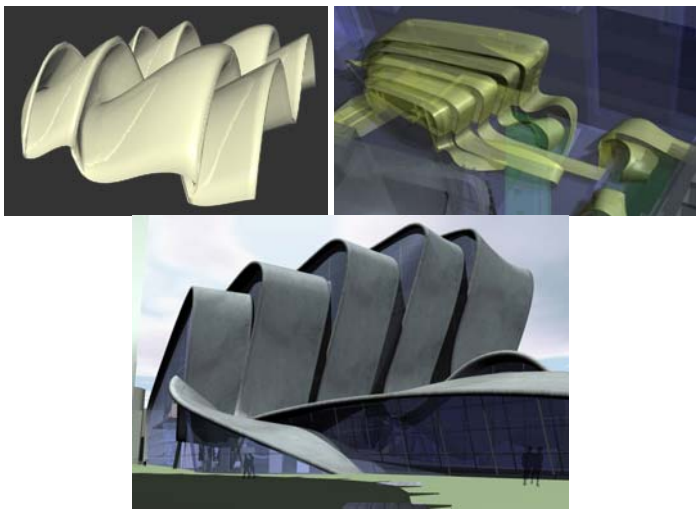

Figure 7. Form generation influenced by music: (top left) exploration based on a modeled referent; (top right) idea for the project; (bottom) the final project (work of Jerome Taillandier)

The degree of novelty should be considered in a slightly different way when scientific knowledge is transferred. Some formal aspects of the newly designed object may remain similar. In the project shown on Figure 8,

visibility and acoustic parameters determine the relatively similar slopes of the audience's seats in the concert hall. The advantage taken from the modeled referent here is the possibility to realize the project according to the encoded knowledge, and at the same time, to be able to vary the available parameters within permitted limits in order to find an optimal solution.

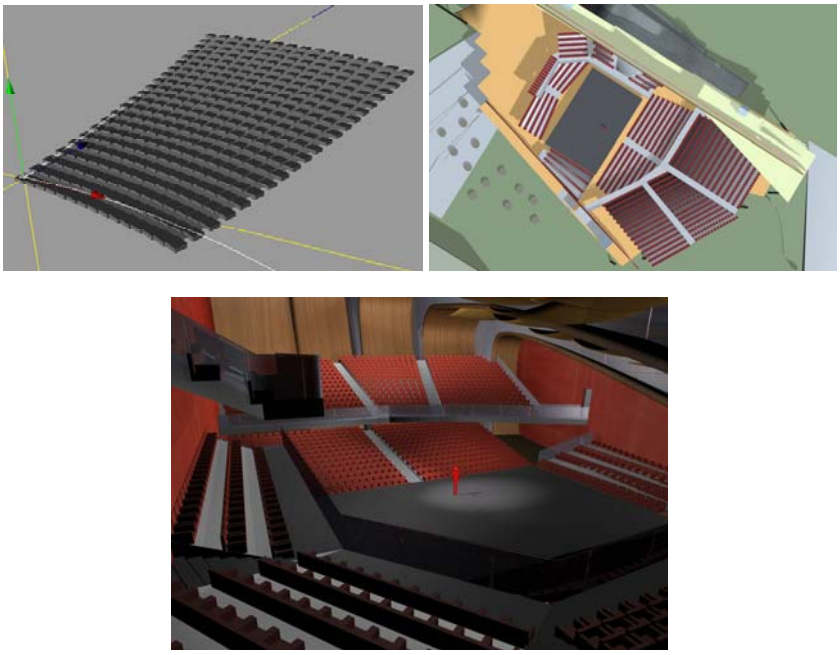

Figure 8. Concert hall: (top left) modeled referent, (top right, bottom) new project in plan and in perspective (work of Jerome Taillandier)

5.4. MOMENTS OF 'REFLECTIVE CONVERSATION'

The moments of reflective conversation were the most surprising part of this study. They were almost exclusively the result of parametric and algorithmic explorations of the design object or parts of it. Sometimes, the exploration was initiated by a reference to a model; other times simply by the application of an already learned digital method. The common point is the dynamic, interactive and continuous modification of the design object, assisted by computer algorithms. The teams working with parametric methods had most of their ideas emerged in this way.

6. Discussion

The referents library was a precious help for the students as well as for the tutor during the studio work. It was noticed that some of the models played a role similar to this attributed to metaphors – design inspiration; while others

were transferring design know-how as architectural precedents are supposed to do. The new moment is the possibility to reuse this encoded know-how and to be able to exploit it as a basis for design exploration. This way, functional, structural and performative aspects of the future building, can be considered from the very beginning of a design process; and even more, can participate in the form generation of the architectural space.

Whilst all students stated that modeled referents were extremely helpful to their studio learning, their ways of using them during the design observation session differed a lot. The processes varied from (1) merging the model into the current project and changing its structure or parameters; to (2) internalizing the modeled referent thus making the encoded know-how completely 'operational'. One explanation to this difference (other than time passed for learning) could be the background of the students. Some of them come to architecture after a scientific profile of education, others – from art or even from humanities. Another link could be possible with the cognitive learning type of the students. Thus, learning in an analytical way could require different support than learning in a holistic way; and similarly to visual or verbalizing cognitive styles.

There are some aspects of the methodology of this study that have to be further developed. For example, a more precise validating method should be defined to study the observation that know-how transfer is not on the same level from a picture or from a modeled referent. In the future, the study can go into more depth into the cognitive learning processes and their implication to the referents library development and use.

Generally, we can conclude that algorithmically modeled referents are very useful for digital design learning. They are most creatively used when internalized to a certain extent by the student. From this moment on, they can offer the advantages of design exploration based on the knowledge coded in them, and thus, stimulate a process of 'reflective conversation' with the situation. This way, they are worth a thousand pictures.

Acknowledgements

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