Concept - Test – Realization - in the architectural design process.

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Abstract

"Building is more than architecture is". Walter Segal, architect

A major part of architecture design is learning how specific architectural designs balance the internal and external constraints. The article explores the meaning of architectural prototyping, as a means of realizing prototypes to experiment with new architectural proposals in real size under real conditions with respect to a system under development. An architectural prototype is primarily used to explore and experiment with alternative material, systems and technology and design styles in order to balance different architectural qualities [1]. The article argues that architectural prototyping provides key insights that may otherwise be difficult to obtain before a design is built [2].
Architects always need to 'being there'. The involvement in the realization of prototypes that reflects essential architectural qualities and realities furthermore lead to a new proposal, which cannot be replaced by something else.
There is no question about the importance of the involvement of experimental work into the educational stage. Experimental learning is necessary to transfer the theory into the practice and to get involved in the process, the difficulties, the details on site, to get responsible and prepared for all the stage of design and simulation before. The students involved in the design and construction process understood the construction' opportunities, possibilities, and also its limitations and developed a feeling for the design idea and how it could be transferred in the building sector.
The educational use of architectural prototypes is illustrated and discussed by three realized experimental prototypes [3]. These real "design built" projects are a prelude to a whole series of full-scale experiments that have already been constructed in an international educational as well as research project between 2012 and 2015. They are an example for a creative academic cooperation between a European and African institution too.

1. Concept - Test - Realization: 1:∞ - 1:10 - 1:1

1.1 Design process - the Built House

Design courses in architecture are often criticized for its overemphasis on formal expressions and its pursuit of the spectacular. Since decades, the original intention of "building" within formal higher education for Architectural education is lost in the education of architects. It shifts towards a theoretical and design oriented teaching system slowly changing the architectural student to become the "designer" widening the gap from what he should also learn - being the "builder". This could be caused by the lack of different tools, where these tools give an output of limited vector based images which have no attribute to real building parameters and real situations of a building.
Simulation and evaluation of various building components or even complete houses through realization of prototypes constitutes a significant and longstanding domain within architectural research. Simulation can be carried out virtually in a modeling laboratory, in a scaled environment or in a real environment physically [4].
Considering the importance of experimental building, research-based teaching and the transfer of research results to industry, all activities of this project are designed to develop, test and realize a full-scale prototype building. This – as a methodology - includes the use of computational tools to increase the productivity of the designer [5]; [6] and to ease the communication and the exchange of information between the involved parties within the design process.

The project is designed as a step by step program administered over three years. The courses are held in parallel in each of the three partner institutions. Each course and year integrates three overlapping and intertwined conceptual phases:

(1 :∞) concept phase - Culture, theory, design and evaluation
(1:1o) Simulation and evaluation phase - Building modelling and Rapid-prototype model-making
(1:1) realization phase - Testing, practice a “one-to-one” prototype

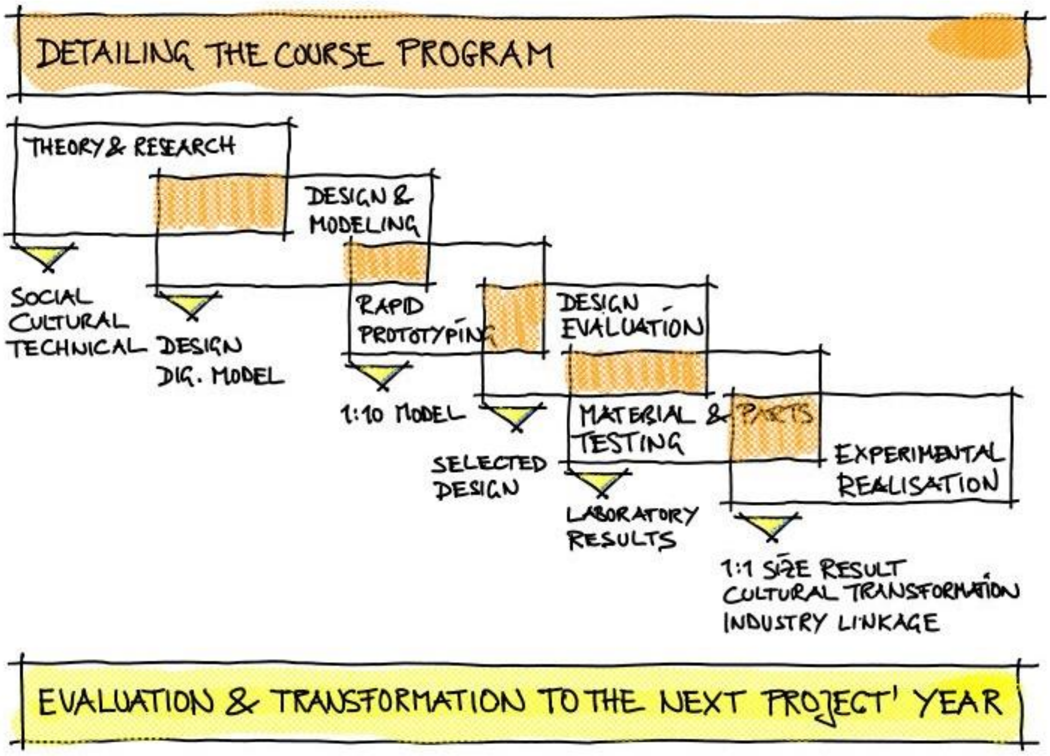


Fig. 1: Project phases and output transformation over the three years

The project related courses held each year basically maintain the same structure, whereby the thematic focus each year lies on a different aspect of the finalized building. Although the basic course-structure will be repeated each year, the project evolves as a series of progressive and partially overlapping phases and steps that build upon each other, driving a long-term institutional learning process (Figure 1).

2. 1:10 - phase: concepts and simulation

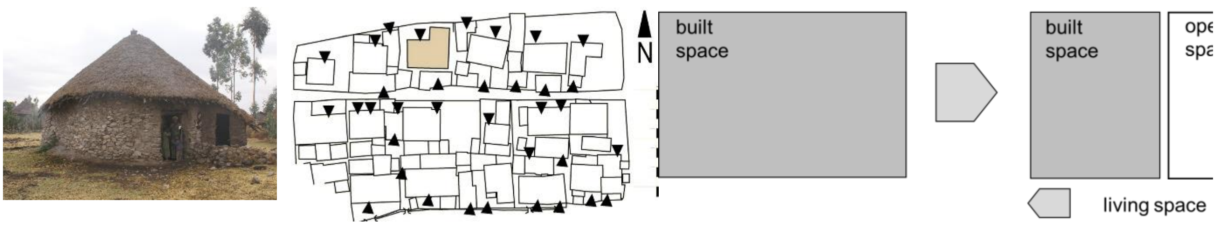
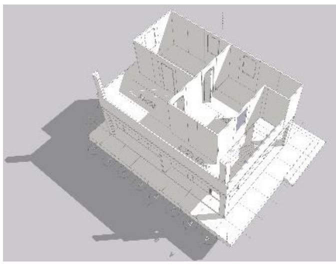
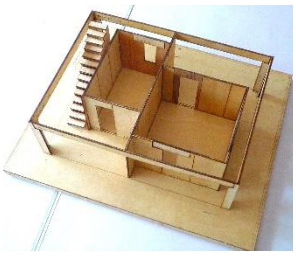


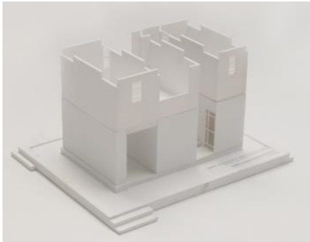
Fig. 2: Concept phase - discussing the culture, neighborhood design and social standards in Africa

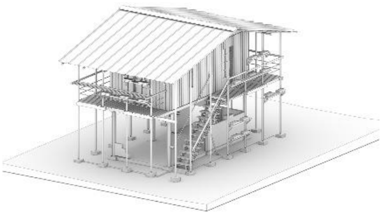
During the conceptual phase the participants’ task consists in creating a physical model by applying contemporary design and planning technology. They work on a “Building Information Model” parallel to their design progress (see Figure 2) and their field work for tests and implementation of the construction. Applying BIM is a kind of multi-dimensional model and Information integration technology [7], [8], [9], [10]. The digital representation of the design were evaluated for structural behaviour with connected tools. All the quantities and work description and ordering lists were generated out of the model: imagine this situation; the students went out to local basic building markets for buying materials with their generated lists out of the BIM description.

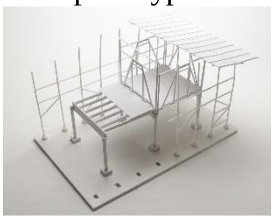
Based on their work with the digital model the participants get an idea about the later realization, i.e. to explore the spatial and environmental issues for assembling designed parts into the whole building, the students will produce an l: l0 physical model by rapid prototyping (Figure 3). Through this process, students get a deeper and wider understanding of the impact and potential of their previously conceived design [12], [13].

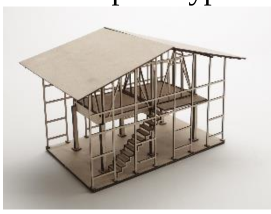

SECU 3D CAD model

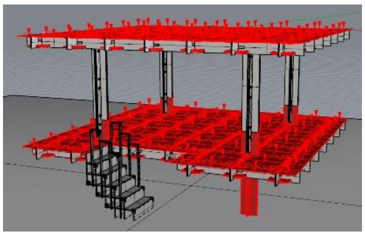

SECU lasercutting prototype 1:10


SECU 3D printing rapid prototype


SICU BIM model


SICU 3D rapid prototype


SICU 3D lasercutting model


MACU : full parameterized model (here: Rhino)


MACU variant: rendering

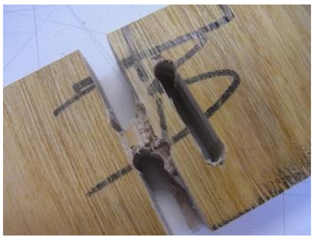

MACU plywood tension testing (CIB Weimar) 2014

Fig. 3: Testing phase: digital model BIM + 1: 10 and Rapid prototyping (laser cutting, 3D printing) for evaluating the design concept

The embedded and wider use of BIM and Rapid prototyping technology creates a wider and proofed view for the realization of an experimental house by simulation and evaluation. It promotes a shift towards customization of design methods through development of procedural logic and skillful modeling techniques.
During this course, students are sorted into transnational project-teams intended to last across the semesters, sharing ideas, problems, observations and achievements through an online platform, moderated by selected and trained staff in each institution. It allows course-participants in each location to take part in, compare and discuss the progress and experiences made in the other locations and to evaluate their own learning progress.

3. 1:1- phase: the full-scale implemented prototypes

The final products, as a consequent implementation of BIM approach, are construction proposals and design alternatives for affordable housing in Africa. It shows a more individual and flexible construction system where modern system of planning and design are used for the complete planning and construction process. The projects focus to contemporary construction technologies like prefabrication and modular design, attempting to shift industrial standardization towards mass customization and evidencing advantage to affordable building practices.
All three projects were realized parallel to the detailing and evaluation process. Doing this, the involved parties reflected on the theory and explore the reality with the related needs, constraints and

limitations. First of all, the participants learn by reflecting their theoretical and testing work in the courses before realizing it. They engage with the building industry, the availability of local and contemporary materials and technology.
The result of the project are three innovative and experimental building' prototypes for emerging cities or rural places addressing the high demand for housing in the African countries (Figure 4) ([14], [15]: SECU - Sustainable Emerging City Unit, SICU - Sustainable Incremental Construction Unit and MACU - Mobile Automated Construction Unit.
The given core issues are the material, the modular construction, design and modeling principles and criteria for cultural and social identification with a maximum level of flexibility to create individual space and diverse urban patterns. The modular system allows that using prefabrication, standardization and optimization. All elements are developed and evaluated in the digital Building Model and physical Rapid Prototype model as described before.

SECU 2012 SICU 2013 MACU 2014

Fig. 4: Realization phase 1:1 - three houses driven by various intentions e.g. out of highly prefabricated building elements or innovations in the digital fabrication, 2012-2014

4. The impact and value

The project leads to the following positive outcomes:
First of all *adopting the state of the art of planning technologies and conceptual design systems* by the intensively use of rapid prototyping, integral communication platform, Building Information Modeling.
Handling of tasks with multiple scales: Coming up with the general idea, to transform it into detailed and structured digital representation results, to test and evaluate it with physical models and to bring it to realization.
Critical research challenges in this domain are the control of information organization, the translation from digital to physical reality without losing the initial idea and the problem of scaling up a design into a real prototype; the effort for realization is high and the academic institutions are not equipped and specialized for these tasks. The use of BIM and the shift to testing and implementation at the above described prototype already done to a large extend but not consequently. Further steps will come up addressing beside principal design and construction question the level of involvement and identification by the user. The project will continue with the realization of a more complex prototype in 2016: an architectural intervention for the rural urbanization by a holistic neighborhood design with an integrated urban infrastructure concept [16].

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