More than a Computational Tool

Design Competence Development using Shape Grammars

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Development of competence has been one of the major issues and goals of modern academic design and engineering education. The research assumes that a rule based reasoning approach could aid in the development of the design competences within the design studio. Support by its application in design and computational courses, the implemented tool is loosely based on the concept of grammatical design and shape grammars. The potential of implementing such methodology is explored by investigating its pedagogical applications as well as evaluating the possibilities of applying such methodology in the studio structure. The argument is supported by examples from the author’s work with beginning and advanced design students from different design schools.

Keywords: Shape Grammars, Pedagogical Grammars, Design Competence, Design Capacities

INTRODUCTION
It has been discussed by various authors that there is a need for, and has been a gradual shift from learning design contents to building up design competence in various contexts.

According to Horváth (2006) the word 'competence' expresses the comprehensive capability to do something in an effective and successful way; it also refers to a purposeful set of behaviors that enable achieving goals. Developing design competences enables future designers to work efficiently in geographically dislocated collaborative design environments. Nowadays, three distinctive views on the development of these competences can be identified:

- The reductionist views: assumes that design competence is nothing more than a set of basic design abilities typically addressed individually (Kovacevic 2008). Design pedagogy consequently is either Skill or Knowledge - based (Van Doorn et al., 2008, Salama, 2005). Approaches to develop design competences typically addressed knowledge and skills disjointedly.

- The ASK model: Inspired by Vinke's definition of competency (2003) as "the ability of an individual to select and use knowledge, skills, and attitudes that are necessary for effective behavior in a specific professional, social or learning situation" attitude" was the third component to be added to form the Attitude, Skills and Knowledge (ASK) model(Bakarman, 2011).
The holistic view: seeing design competences as a synergetic construct of generic human capacities (Horváth, 2006). Accordingly, design competence is assumed to be a combination of five capacities: capabilities, attitude, knowledge, skills, experience (figure 1a). In design education, students should be able to equally develop all the five capacities in a well-balanced education curriculum. They are methodologically strongly connected, providing the problem solving resources for design competence.

**DESIGN COMPETENCE: THE HOLISTIC VIEW CONSTITUENTS**

**Design Capabilities.** are natural capacities talents abilities that enable us to act as designers. They manifest in different forms such as Intelligence, Imagination, Creativeness, inventiveness, artfulness, technicality, pragmatism, and productiveness (Horváth, 2006). These capabilities are innate (Van Doorn et al., 2008), but can be developed through many years of focused learning and practice. The possibility of development is higher if the level innate capability is reasonably high.

**Designer's Attitude.** is seen as the relation between the designer and the design profession (Horváth, 2006). Attitudes influence the performance of the designer in various way, his way of thinking, acting and seeing concerning the design tasks. Van Doorn et al. (2008) concluded that attitude is a combination of five main elements: (i) communication, (ii) reliability, (iii) trust, (iv) motivation, and (v) open mindset. Together they provide the good basis for a designer's attitude, which support designers in Design problem solving.

**Design knowledge.** is a body of specific knowledge relevant and necessary for the particular field of design whether procedural or declarative. The procedural (know how) part of the knowledge goes beyond concrete design cases, involving both formal (codified) design knowledge and informal (tacit) design knowledge stemming from intuition, experience and educated guesses. It involves the integration of different cognitive skills concerned with design thinking and creative problem solving, creating no clear boundaries between "knowledge" and the fourth constituent "Skills"

**Design skills.** are various abilities that enable students to do design actions well (Horváth, 2006). Development of design skills asks for practical training, which involves correct application of design methods, effective use of design tools and creating virtual and physical objects. Unlike capabilities, skills development can be achieved in shorter periods with practical training.

**Design experience.** means the familiarity gained from seeing and doing things in the course of acting as a designer. Experience also means the feeling and reflections obtained in relation to designing and designs.
OUR MODIFIED VERSION OF THE HOLISTIC VIEW

In our research, we believe that professional experience is not a separate element that can be studied or developed disjointedly. Professional experience incorporates all four constituents accumulatively built up, providing expert designers with the specific mastery needed to complete the design task successfully and effectively.

"Clearly, part of the development of expertise lies in the accumulation of experience. Something that distinguishes experts from novices is that the experts have been exposed to a large number of examples of the problems and solutions that occur in their domain"(Cross, 2004)

In education therefore, experience is considered the melting pot for all design capabilities, knowledge, attitude and skills; a third dimension of time and efforts that gradually shape the students design capacities (figure 1b), training them toward the most effective professional practice they can.

DEVELOPING COMPETENCE IN DESIGN EDUCATION

Development of competence has been one of the major issues and goals of modern academic design and engineering education. Our literature study revealed that the holistic approach was adopted mostly in product design courses (Horváth, 2006, Van Doorn et al., 2008, Kovacevic, 2008), other approaches were implemented in architectural design curriculums including ASK and the reductionist approach (Bakarman, 2011, Salama, 2005).

The educational contents and pedagogical approach of these courses were designed accordingly, focusing on each generic capacity respectively.

Different tools including conventional and creative Studio methods, questionnaires, interviews and special projects were used and implemented with the involvement of different universities and industrial companies.

In this paper we followed our modified version of the holistic view. We concentrate more on studying the implementation opportunities of CAAD tools in developing aspects of the students’ design competence.

The research assumes that a rule based reasoning approach could aid in the development of the design competence especially Procedural Knowledge, Skills and Attitude within the design studio. Support by its application in design, the implemented tool is loosely based on the concept of grammatical design and shape grammars.

Why CAAD & grammar?

Computational models and methodologies aided the researches in the field of design studio teaching with its unexplored theoretical prospective. Computational design is based on more than just algorithms; behind the conception of generative design systems there are many design theories, methods and models as well as reasoning systems that contributed to offer more than images, data or software. Addressing the vagueness and indeterminacy of the design process outstood and motivated the search from the design education perspective. Knowing more about natural design reasoning processes would pave the way for modes of enhancing teaching it in the design studio. These generative systems developed design methods that are able to effectively transmit a comprehensive codex of design knowledge, including procedural knowledge about how to design and how to reason about designing. This consequently helped developing very useful models that interpret design and problem based reasoning in a very comprehensive and understandable way.

Shape grammar has been brought into design education in various forms supported by its success in analyzing and synthesizing design (Knight, 1999). In many instances it has been introduced as a generative design methodology during design computation classes, and in other occasions it has been highlighted as a design methodology in specific design projects through design studio work. Supported by its potentials in the design studio, the research assumes that shape grammars could aid in the devel-
Reasoning for Design Knowledge development
Building up the students capabilities especially knowledge base process first was suggested to be handled on two levels with both reasoning operations:

- Building Expertise/Declarative knowledge: A Pop-up (or Bottom-up) cognitive system of reasoning that corresponds to Similarity-based (Precedents-based) ones. This could be achieved by exposing students to specifically crafted cases of design (Kalay, 2004) to expand their visual experience and provide them at the same time with the base knowledge on which they will draw in further academic years. This will be harvested later in more advanced studio levels, by teaching students the use prototypes, precedents, analogies and metaphors in solving design problems under the similarity-based reasoning method, thus providing them with a starting point from which to develop their new designs.

- Developing Skills/Procedural Knowledge: Implementing a top-down instructive cognitive system of reasoning in the design studio that may corresponds (roughly) to the rule-based systems, may help leading students during their design work to the process of designing in a concise and stepwise manner. According to the very special nature of the design problems, the implemented methods should be re-drafted to ensure that it will remain open (probably less defined).

DEVELOPING COMPETENCE: THE GRAMMATICAL APPROACH

The application
In order to explore the effect of grammatical design on competence development, the research reviews the outcomes of four years of design and grammar teaching.

The argument is supported by examples from the author’s work with students in both:

- The Beginning design studio: Three shape grammars workshops were carried out as part of the coursework of first year students (Ibrahim et al., 2010, Ibrahim et al., 2011, Ibrahim et al., 2012). The application of these workshops took place in four universities from three different countries (Strathclyde University, Glasgow; Beirut Arab University, Beirut; Alexandria University, Alexandria; Cairo University, Cairo). During the four years, these workshops were conducted with objectives specially tailored to fit with the design studio ILOs.

- Shape Grammars course: Unlike the beginning studio, this pedagogical experience was with advanced students in a more specific subject: introduction to shape grammar (Cairo University, Cairo). The course was originally planned to develop the students' generic and analytical capacities. The author was able to conduct more grammatical experiments, analytical and synthetic projects, enriching the teaching experience with different category of focused examples.

Design Capabilities development
The students' development of capacities like systematic thinking, creativity or balanced comprehension for example could not be precisely addressed, measured or judged due to their abstract nature. Typically, it requires many years of focused learning and practice.

One of the preliminary approaches to ensure a more efficient capabilities development in design schools is a well-designed admission policy. Within this selection stage, students with higher level of innate capabilities are been selected to increase the probabilities of effective development.
For grammars, what is more promising is that developing capabilities could be achieved via design exercises that focus on a part of the entire design process.

To some extent, shape grammars' scenarios capture the layout of the design process and adjust students to it. According to Kalay (2004) and Lawson (2006), there are three major components of the heuristic architectural design process that was formulated in the 1960s. In this cyclic non-linear network process, Kalay (2004) (figure 2a) proposed another parallel phase of "communication" that tops the three intertwined phases of "Analysis", "Synthesis" and "Evaluation". The operations of cognition, production and evaluation are embedded in the shape grammars scenarios (figure 2b) especially the synthetic process in a way that enables students to develop a good understanding of and control over their own design capabilities.

**Designerly Attitude development**

**Motivation.** "when in flow, the individual operates at full capacity" (Nakamura and Csikszentmihalyi, 2002)

Research has shown that performance and motivation can mutually affect each other. With high motivation, people tend to work harder on the task at hand and therefore tend to be more successful in performing the task (Atkinson, 1999).

One of the key conditions of motivation is to establish a balance between challenges (perceived action opportunities) and skills (perceived action capacities). (Nakamura and Csikszentmihalyi, 2002). Accepting and encouraging the use of intuitive decisions and abilities is helpful in integrating more complex yet adequate design challenges. This is why instead of dictating the design subjects, many grammatical studios (including ours) adopt a different approach to achieve such balance, allowing students to select their grammar projects subject upon their own choice, supported only by a preliminary research.

Once selected then finalized, their choices reflected their own interests, personalities and most of all revealed an essence of enjoyment and motivation within the teamwork (figures 3 and 4).

**Communication.** "Architects don't explain their services well.. In general architects are not good at putting over what they do.. They've (Architects) got a vision in their head which we can't see, it might be a fantastic vi-
sion... but it's no good if we can't see it” a client inter-
view, (Nicol and Pilling, 2005)

As the grammar’s concept is mainly about mak-
ing tacit knowledge explicit (Bruton and Radford, 2003), A pedagogical grammar therefore could bene-
fit from manifesting this implicit knowledge in a more explicit way; helping students communicating ideas
and solutions with clear graphical or verbal presenta-
tion.

In one of the workshop, students were required
to formulate the consistency of their design ap-
proach, so they varied in their ways of expressing the
language using narrative or graphical presentation
or a mix of both of them. Some stated the general
(and sometimes specific) design preferences embed-
ed in their project, described as a like and dislike list
of strategies (figure 5a), design aspects, geometrical
forms, etc. others offered a step by step recipes for
their formal or conceptual design process (figure 5b).

They were also required to rationalize, to make
modifications based on a thoughtful and rational
evaluation of the original language's choice of ele-
ments and rules. This means that the decision of ac-
cepting or rejecting the language (or part of it) is not
taken upon personal preferences; it is only built on a
logical basis. This debate creates a kind of interesting
conversation between both students' languages.

An example for good communication of ideas
could be seen in the same workshop. In figure 6,
Laura mentioned that her language involved the for-
mal expression of movement in design, giving an
example from her projects. Paulina was required
to evaluate then transform her friend’s language;
she questioned her rationale, asking “If it's about
movement, why dance space (in an ongoing project)
strictly defined?”

Open mindsets. Design is a creative process. This
means that designers should experience the world
from an open perspective, treating all experience as new, as something that cannot be taken as
granted (Van Doorn et al., 2008).

Within the design studio, the author bene-
ficiated from the grammars' non-determinacy to
demonstrate this open perspective concept in an-
other workshop.

Students were given 2D shapes, they were then
asked to draw at least 4 different readings for the
shape and its basic elements with at least one 3D in-
terpretation of which. To extend and modify the ex-
isting design they have to extract its basic elements
and work with basic geometric operations to create their new designs (figures 7 and 8).

They were trained to change perception several times and enjoyed proposing different ways of seeing. After the workshop, each group was asked to present their final ideas. Their attention was drawn to the interesting fact that there were no two identical designs presented, even though they all began from the same shape. It was easier then to demonstrate that design problems are often complex ill-structured problems and there is no single answer to them.

**Knowledge development**

The knowledge repository (Procedural). As synthetic grammar depends on the selection of vocabularies and rules that promise to solve certain design problems, the selection lays on the designer’s experience, his knowledge repository and more on the level of "expertise" accumulatively acquired and developed during the solution of similar problems in education and practice. Developing this kind of expertise is one of the main aims of the architectural studio, especially on the undergraduate level; this development is normally planned to occur over a comparably extended period of time (figure 9). It is easier for advanced students to begin experimenting with grammatical designs at the final year, and is thus too early for the beginners to build their synthetic grammar implementations upon their limited and insufficient level of expertise.

**Design Skills development**

The analytical skills. To develop analytic grammars means to be able to extract common features of a wide range of designs, a very critical and systematic process of comparison and analysis that should at the end reveal the hidden variety of common vocabularies, details of conditioned or non-conditioned rules, as well as their sequence of application (figure 10). Such analytical skill is thought to be less developed in novices than in graduates or post graduate students.
Such process not only motivated the students' ability to see and make respectively, it also developed flexibility in design, an analytical awareness as well as confidence to take design decisions (figure 11). The analytical skill allows them to build their proposals on a creative assimilation of the existing information and the circumstances of the current situation.

**Design (formal) skills.** The grammar development and application stages expose some of the main design strategies, principles and even simple compositional operations. The implicit teaching of these issues makes the methodology more relevant for teaching composition and visual correlation. It is also thought to be very significant for the studio's project based approach, as the implementation stage of synthetic shape grammars involves a playful "making" process (figures 12, 13 and 14).

**CONCLUSION**
The goal of this paper is to gain insight into the possibilities of using shape grammars to support the stu-
Our experiences showed that:

- Shape grammars has the potential to improve and develop many design capacities especially knowledge & skills.

- with focused and continuous training, workshops and grammatical projects can contribute significantly to the development of attitude and capabilities as long as the implemented grammar model remains open and less determined.

Our final conclusion is that grammar, if combined with other conventional and creative pedagogical tools and projects, could provide us with a comprehensive & livable model. A model that targets the diversity of the constituents and aspects of the students’ design competences in a more effective way.

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