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CREATIVITY IN DESIGN EDUCATION: THE EFFECT OF C-K'S C-CONSTRUCTS

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ABSTRACT
The design of buildings is complex and requires the support of multi-disciplinary design teams. Therefore a supportive design approach has been developed: Integral Design. Integral Design combines an engineering design method with an innovation strategy, to support innovative integrated design between engineering and architecture. The innovative Concept-Knowledge theory by Hatchuel and Weil is used in combination with the Integral Design method. This combination enables to illustrate different processes within the conceptual design phase of multi-disciplinary building design. It also makes it possible to see the effect of so called C-constructs to stimulate the generation of concepts. The approach is tested in workshops with students and professionals and the results indicate a positive effect on the number of generated sub solutions. Further research is needed to determine the qualitative effects of the design approach.

Keywords: Multi-disciplinary design, morphological overview, integral design, C-K theory

1 INTRODUCTION

At present building design is understood as a highly complex and to avoid risks the building industry is traditional in their approach to the design process and innovation is rare. Collaborations that cross disciplinary boundaries are essential to innovation and the occurrence of boundary spanning, where ideas from one domain, discipline or functional area are important into another [1], in a way that solves new problems or presents new solutions [2]. The size and specialization of modern professionals makes finding the right conceptual bridge between domains difficult for any one individual to solve the complexity on it his own. Therefore, collaboration is required [1] for innovation to let experts recognize the analogous qualities of ideas from distant conceptual realms, identify ways they can be usefully connected and work to realize them.

Building designs thus need to provide solutions for increasingly complex programs of requirements, especially related to sustainability issues ranging from flexible use to energy saving measures while maintaining and even increasing comfort level of users. Therefore building design involves many designers/experts from different disciplines. However, just putting people with diverse perspectives and from different disciplines in the same room is no guarantee that effective boundary-spanning collaboration will occur [1]. Through the creation of knowledge based on diverse skills, experience and information exchange, the quality of design process and the creative performance of design teams improve. Due to the cognitive diversity among team members in terms of knowledge and skills there is a broader access to information and knowledge, creating more and different insights in to the current design task and its problem field [3].

Synergy between the different disciplines involved in the design process is necessary to attain the best innovative and sustainable designs. It no longer suffices to just merely solve the problems which arise at the level of detailing on the borderlines of disciplines. New approaches are needed to bridge the gap between the worlds of theory and practice in building industry and which looks at designing as a process in which the concepts of function, behaviour and shape play a central role [4]. Such integral design approach can eventually lead to an integral process, team and method – all the required conditions for innovation of the end product; the building [5].

2 METHODOLOGY; INTEGRAL DESIGN

Although research on design started the early sixties due to problems with the quality of products and projects [6], still there is no clear picture [7, 8] and many models of designing exist [9, 10, and 11].

Methodical Design as developed by van den Kroonenberg [12] was chosen as a starting point to investigate the possibility to improve current design approach in the Dutch building industry. Methodical Design is based on Systems theory and is a synthesis of the German and Anglo-American design models of the mid seventies and as such has exceptional characteristics [12]. Starting from the prescriptive model of Methodical design a method, Integral Design, was developed to articulate the relationship between the role of a designer as descriptor or observer within the design team and to reflect on the process [13]. The Integral design method, though based on methodical design, is an extended design method; the cycle [define/analyze, generate/synthesize, evaluate/select, implement/shape] forms an integral part in the sequence of design activities that take place.

A distinguishing feature of Integral Design is the intensive use of morphological charts to support design activities in the design process. The morphological chart is formed by decomposing the main goal of the design task into functions and aspects, which are listed on the first vertical column of the chart, with related sub solutions listed on corresponding rows. The functions and aspects are derived from the program of demands. Possible solution principles for each function or aspect are then listed on the horizontal rows. The use of morphological charts within the integral design method supports step 1 and step 2 of the integral design method's four step pattern. The morphological charts made by each individual designer can be combined into a [team] morphological overview, after discussion on and the selection of functions and aspects considered important for the specific design.

The advantage of this approach is that the discussion begins after the preparation of the individual morphological charts. As each designer uses his own interpretation and representation, in relation with his specific discipline based knowledge and experience, this gives an overview of different interpretations of the design brief resulting in a domain specific morphological chart from each design team member. Importantly, this encourages and allows engineering based disciplines to think and act in a more 'designerly' way than is common in the traditional design approach. In sum, this approach allows a greater freedom of mind of the individual designers and results in more creativity in interpretation of the design problem and generation of sub solutions from the different disciplines. Such a morphologic overview can be used by the designers to reflect on the results during the different design process stages.

3 APPLYING C-K THEORY TO CONCEPTUAL INTEGRAL DESIGN

Design is process existing knowledge and information about the actual needs of the client and as such a distinction can be made between the known [knowledge] and the unknown [concepts]. This distinction determines the core propositions of C-K theory [14]. C-K theory defines design as the interplay between two interdependent spaces having different structures and logics: the space of concepts C and the space of knowledge K. Within this research space K represents all explicit representations of a design team's knowledge [15]. See Fig1.

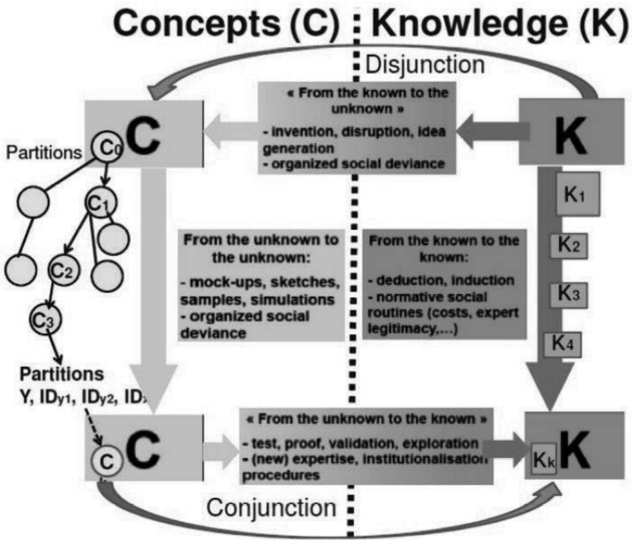

Figure 1. The C-K design square [14]

From here, two types of synthesis are possible: either the representations are combined, using the K→K operator, or are transformed, using the K→C operator. Adding new properties [K→C] to a concept, the set is partitioned into subsets, see for example C1 in Fig. 1; subtracting properties includes the set in a set that it contains [16], see par example Co in Fig. 1. After partitioning or inclusion, concepts may still remain concepts [C→C], or can lead to creation of new propositions in K [C→K], see par example the C_k to K_k conjunction in Fig. 1. A design solution is given by a concept C_k which after a transformation, from the unknown to the known, becomes a true proposition in K.
In the next stage of our research the use of so called C-constructs, sometimes called C-projectors, of the KCP (Knowledge Concepts Proposition)-method by Hatchuel and Weil was investigated to stimulate the creation of new concepts in the Integral Design workshops [17]. The intended effect of the C-projectors is the expansion of the solution space in C, after which, by means of research and evaluation, is the expansion of space K, through the transformation of C-K. Applying C-projectors to the Integral Design approach enables to expand the knowledge domain which was formed by the design task related morphological overview, by stimulation of new transformation between space C and space K. From these new connections it may be possible to derive new concepts. These C-constructs are domain strange concepts, which can be used as a source of inspiration and the start of further research to make a connection with existing domain knowledge in space K, and after evaluation determine the possibility of concepts resulting from these new connections. As such the discipline blind spots which occur after the combining of the individual morphological charts are one of the mechanisms to create C-constructs. Another mechanism is the introduction of an 'impossible' optimal solution direction. The C-construct stimulates the subconscious of the designers and they come forward with new concepts. After a positive evaluation these concepts can become part of K and than the C-K transformation is completed. The morphological Integral Design approach combined with the transformation by C-constructs between space C and space K, leads to schematic of Fig. 2.

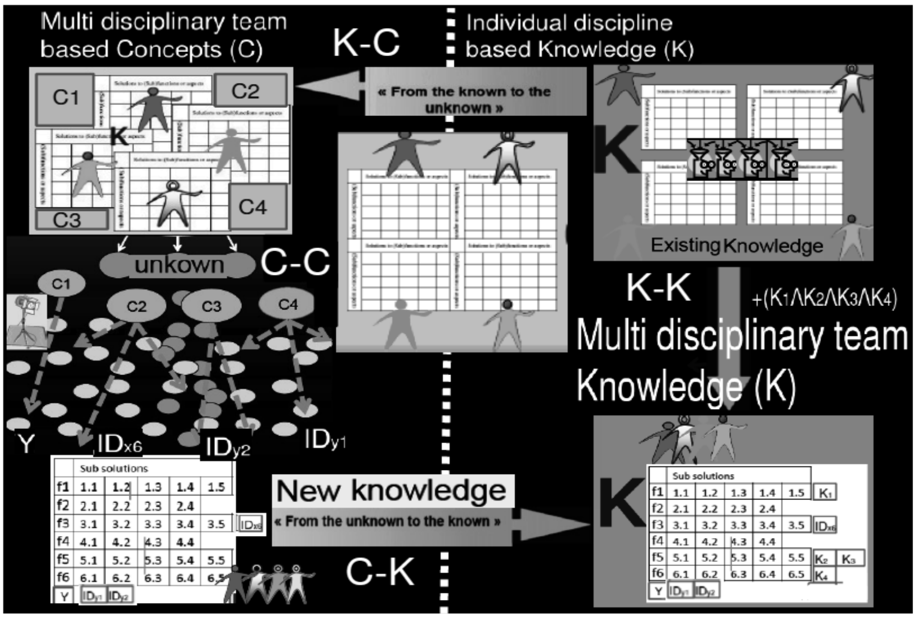

Figure 2. Morphological representation of the C-construct transformation process within C-K space

The next step is for the team to take the knowledge and ideas from the morphological overview and translate them into a proposed design solution. This step can take two forms: either the design team combining known sub solutions into RE-designs [K-K] or the design team starts transforming object-design-knowledge into new concepts [K-C]. The Integral Design model combined with the C-K theory enables the focus on the distinction between redesign [K-K transformation leading to RE] and integral design concept generation [K-C transformations leading to ID-concepts]. To illustrate this an example is presented in Fig. 3, where after step 2 there is a transformation of known sub solutions or from a specific aspect or function to a new concept of function [Y] or to a new concept as possible sub solution [ID_x]. The elements ID_{x6}, IDy_1 and ID_{y2} represent conceptual sub solutions as a result of the concept generation K-C, see Fig. 3.

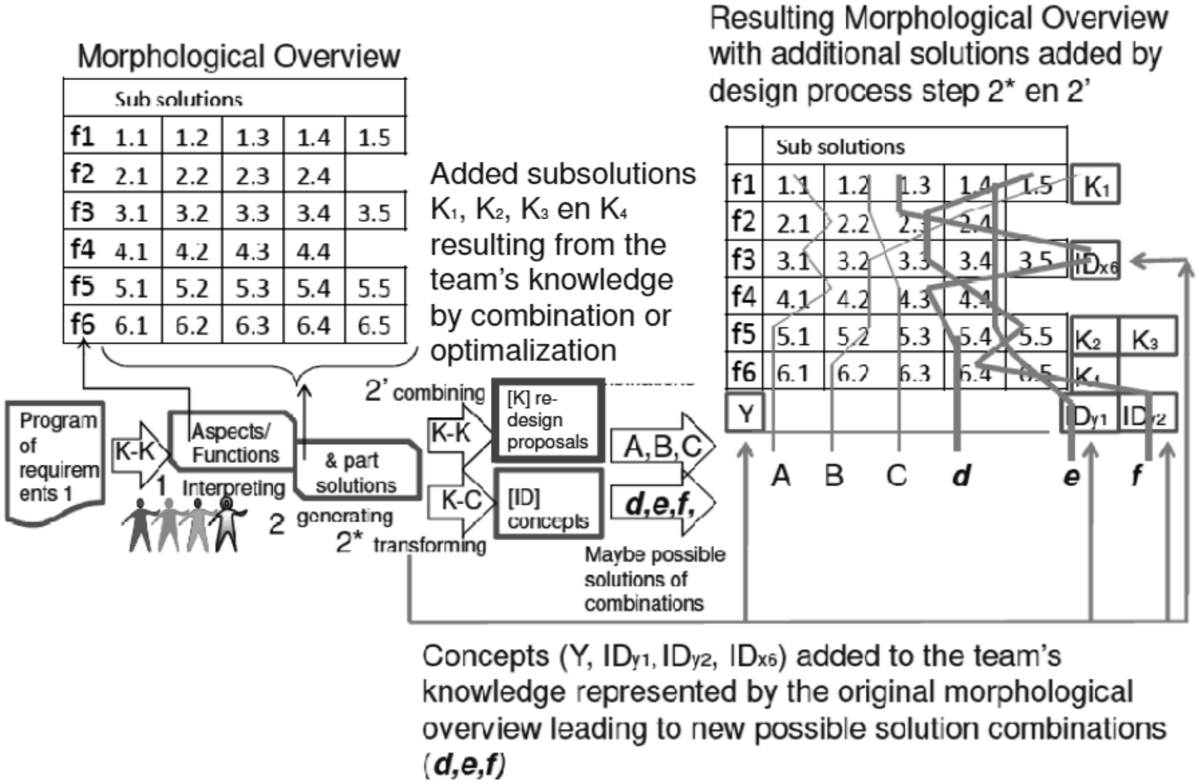

Figure 3. The ID-method steps according to the C-K theory operators

This distinction is crucial to generate creative solutions to the highly complex contemporary design problems that society faces. In this research the main area of interest lies in the conceptual phase of the design process. Here, the focus is on K-K and K-C relations. Nonetheless, C-K theory also offers value in subsequent building design stages, where it can be used to focus on C-C and C-K relations. In essence, in the current research ID-concepts are seen as essential for the creation of new, innovative building designs, which increase the possibility to ultimately realize sustainable building solutions. Perhaps more importantly, ID-concepts represent the potential for the definition of new object design knowledge, which can then be exploited to solve future design problems in the building design domain.

4 EXPERIMENTS WITH FOR STUDENT WORKSHOPS INTEGRAL DESIGN

To test the application of C-constructs, workshops were used within the master project Integral design [MIO]. In this multidisciplinary master project students from the faculty of Architecture Building and Planning with different disciplines background [architects, structural engineers, building physics, building services and building technology] have to design together a building which always has to become a net zero energy [NZE] building. The focus of the workshops was to teach the students the use of morphological charts and morphological overview. This was done by giving starting with a lecture about the Integral Design method and its specific application of morphological charts and morphological overviews as design tools. The workshop was divided into four sessions. The participants of the workshops were master students of the faculty of architecture, building and planning and had an average age of 22 and no working experience. During the sessions 1 and 2 29 students participated and in session 3 and 4 27 students participated. In session 3 and 4 six professionals participated, in each student design team one, which were on average 50 years old and had around 25 years experience. Besides 2 or 3 engineering design disciples present in the design teams they had 2 or 3 architectural students. The members of the design teams started individual, making the morphological charts and after that worked together to make the morphological overview.

In design sessions 1 and 2, the teams were given the same design task as used in the Integral design research by Savanović [2009]. The design task for the 3rd design session was to a 60 stories net zero energy [NZE] apartment building on a specific location. The design teams for this session were formed based on the actual tams of the Master project Integral design [MIO-project]. The students

were divided in design teams in such a way that to avoid a learning effect during session 1, 2 and 3 all students worked only once with the same students. In session 1, 2 and 3 the participants started individual working on the different design task and made their own morphological chart.
After this first part of the session, the teams put together the morphological charts to make a morphological overview as a team. The individual part of the sessions 1, 2 and 3 took 20 minutes and the team part lasted 40 minutes. In the first individual part of the sessions there was no communication between the participants. Only in the second part of a session they were allowed to communicate, this to make sure that there was no influencing of the individual morphological charts.
In session 3 each student design team was joined by an expert. After session 3 a lecture was given about C-K theory and the possible application of C-constructs. C-constructs were presented to the design teams and they had to try to use these to stimulate their conceptual thinking process. The design team had to try to generate concepts with the help of some C-constructs that were given to them in session 4, the focus was on the possible effect of introducing C-constructs. In the 4th design setting, students with an expert worked on the same assignment from session 3, the Net Zero Energy apartment building, but their task was now to try to use the C-constructs as a stimulus to come to new ideas. Starting point for this session were the team's morphological overviews of the 3rd design session. The teams stayed the same compilation as in session 3. The focus of the 4th session of the workshop was on the expansion of the design team's knowledge box, their Morphological Overview, so to stimulate thinking out of the box by applying C-constructs to make the step from existing knowledge to the unknown world of concepts. C-constructs were presented to the design teams and had to try to use these to stimulate their conceptual thinking process.

5 RESULTS WORKSHOPS INTEGRAL DESIGN

In all sessions combining morphological charts into a morphological overview leads to an on average increase of the number of functions and solutions as mentioned by the design teams, Fig. 4.

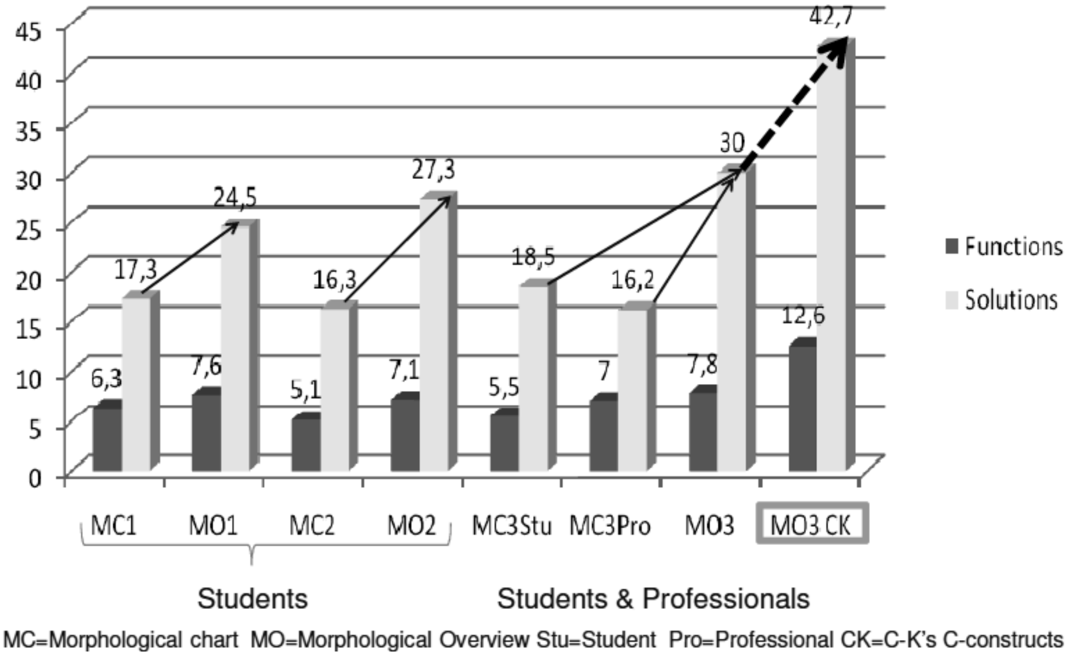

Figure 4. The average number of functions and solutions in the morphological charts and overview

Overall there is an increase of the number of solutions mentioned in the morphological overview after session one compared to session two [on average 24.5 compared to 27.3], which indicates that the students learned to improve the process of combining the individual morphological charts into the team's morphological overview. There is only a rather small difference between the students making the morphological charts in session 3 [MC3Stu] compared to that by the professionals [MC3Pro]. Quite remarkable is also the effect of adding a professional to the students teams in session 3, MO3 [7.8 functions and 30 solutions], compared to the outcome of session 2, MO2 [7.1 functions and 27.3solutions], which led to an increase of 10% overall. To focus more on the effect of the application of C-constructs as used in the 4th session of the workshops, the outcome of the average number of functions and solutions, mentioned in the morphological overview, were compared as a percentage of the average numbers of the morphological charts, see Fig. 4. Compared to the morphological overview of session 3 there is a significant increase in additional mentioned functions [from 7.8 to 12.6= +61.5%] as well as an increase in proposed solutions [from 30 to 42,7= +42.3%].

6 DISCUSSION AND CONCLUSIONS

The Integral design method with its use of morphological overviews in combination with the C-K theoretical focus on concept generation is an important step to reach true collaborative building design. With the use of morphological overview of the Integral design method and the C-K theory to focus on specific transformations par example from knowledge to concepts or from concepts to knowledge is it possible to make the conceptual design phase more transparent. This improves the quality and productivity of the architectural design process. The focus in this paper was on the implementation the use of morphological overview of the Integral design method and the C-K theory to focus on the effect of the so called C-constructs. The results indicate a clear positive quantitative effect of the use of a C-construct; however it is not possible to tell something about the qualitative effect. This is because; the solutions within the conceptual stage are not specific enough. More research is necessary with a more specific focus on the effect of C-constructs on the quality of design proposals.

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