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STIMULATING CREATIVITY IN BUILDING DESIGN EDUCATION: INTRODUCING EXPERTS AND C-K'S C-PROJECTORS

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Abstract: In order to support creative team design in the conceptual building design phase, a design method was developed: integral design. Integral design uses morphological charts, which are made by the individual designers from different disciplines, and which are than transformed into a design team's morphological overview. The Concept-Knowledge theory by Hatcheul and Weil was used to focuss on specific integral design process steps and to implement techniques to stimulate creativity within the design process. Concept-projectors, as used in the Knowledge-Concepts-Proposition workshops based on the Concept-Knowledge theory, were applied in addition to the steps of integral design process. In 2011 and 2012 this approach was tested in two series of workshops, existing of 4 different sessions, for master students from different disciplines. In one of the sessions of the workshops another invention was tested to stimulate the creativity of the student design teams: the introduction of a professional into the design team. Only the interventions with the Concept-projectors had a significant positive effect and led to a major increase of the number of generated functions and sub-solutions. This showed that the used C-projectors stimulated the creativity of the design teams.

Keywords: *Integral design, morphology, C-K theory, C-constructs*

1. Introduction

Teaching how to design creatively is difficult as there are numerous methods to stimulate designers, however not many established methods that explicitly teach how to generate creative design solutions (Breedveld et al 2011). The ancient Greeks thought that there were divine sources that inspired creative work (Liikkanen and Perttula 2010) and still creativity in the design is often characterised by the occurrence of the so called 'creative leap'. However descriptive empirical studies of the creative event have shed more light on this mysterious and often mystified aspect of design (Dorst and Cross 2001). Creativity focusing on solution generation of individuals and groups has been a research field of psychology with first investigations more than 100 years ago by Galton in 1869 (Badke-Schaub 2007). The big push of interest in the subject of creativity began in 1950 (Rhodes 1961) when J.P. Guilford in his 1950 presidential address to the American Psychological Association pointed out the importance of studying creativity and reviewed the index of Psychological Abstracts for the proceedings 23 years (Puccio 1999). According to Guilford (1950), creativity requires the ability to overcome known routes of thinking, to think divergently, contrary to convergent thinking (Badke-Schaub 2007). The term divergent can be used synymously with 'creative'design (Liikkanen 2010). There are many techniques, tools and methods developed to foster creativity. The most popular method for generating creative ideas, brainstorming was initiated by Osborn in 1939 as 'brainstorm' and subsequently led to his book Applied Imagination (1953). Osborn began hosting group-think sessions and noticed that the quantity of ideas was much greater than those produced by individual persons. Brainstorming has found to enhance idea generation compared to non-brainstorming methods. However, group brainstorming does not seem to be more effective than individual brainstorming (Nystad et al 2003) and therefore the focus stayed on the individual. According to the investment theory by Sternberg (2006) creativity requires a confluence of six distinct but interrelated resources; intellectual abilities, knowledge, styles of thinking, personality, motivation and environment. After more than 60 years of scientific study, there is much that has been learned about creative thinking. Still creativity is a complex and multifaceted phenomenon (Puccio et al 2010) and confusion exists as to exactly what 'design creativity' means (Williams et al 2011). In the past years the research focus has moved from the individual designer to the group as a source of creativity and innovation (Badke-Schaub 2007). Even though there is a broad agreement on the important role of creativity in design, scientific research does not provide much information about the processes which are related to creativity in designing (Badke-Schaub 2007). Therefore it is important to look into the specific context in which the design takes place, because that determines the design process. In our case that is the built environment.

The design of buildings is meant to shelter humans from the outdoor environment and thereby facilitate core processes of organizations or to facilitate for humans a comfortable way of living. As a result the built environment is using 40% of all our energy for conditioning of buildings. However more and more the effect of the related energy consumption is endangering the environment as became apparent through the effect of global warming. The design of buildings becomes increasingly more complex. The complexity and scale of design processes of buildings increases and traditional approaches may no longer suffice (van Aken 2005). Buildings can no longer be designed by an architect alone: the whole design team's knowledge and interpretation is needed to cope with the complexity of the design problem and to come up with a adequate design solution. It requires multiple disciplines with a shared theoretical understanding and an agreed interpretation of knowledge according to Gibbons (Dykes et al 2009). Synergy between the different disciplines involved in the design process is necessary to attain the best innovative designs. 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, behavior and shape of artifacts play a central role (Vermaas & Dorst 2007). 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 (Seppänen et al 2007). We choose a popular Dutch design method to develop an integral design method to be used in a multi-disciplinary building design setting. The main aim of our integral design approach is to support design teams. This support should improve their conceptual design collaboration in order to stimulate creation of new design solutions. As such we analysed the effect of applying design theory and design tools to increase creativity within multi-disciplinary design teams. In anolgy with Le Masson et al. (2011) we looked at influencing the interplay between creativity issues and design theory. The main question of current research was about the effect of two interventions, introducing professionals to student design teams and the introduction of C(Concept)-projectors from the Concept-Knowledge (C-K) theory of Hatchuel and Weil, on the integral design method to further stimulate the creativity of students.

The main body of the paper starts (Section 2) with the introduction of the integral design method. In section 2.2 the C-K theory of Hatchuel and Weil is used to explain the interaction between knowledge and concepts which take place in the transformation process within the integral design process of morphological charts into a morphological overview. To test the derived design approach, we originally held workshops for professionals in building design practice (architects and consulting engineers) as well as for students. Section 3 describes the introduction and further development of the workshops for students, especially the introduction of the participation of a professional in the student design teams, as well as the use of C-projectors. By applying C- projectors derived from the C-K theory it was possible to stimulate the transformations from knowledge to concepts and this led to the further expansion of the solution space. Section 4 presents the results of the two interventions within the student workshops. In section 5 there is a discussion about the interventions to the integral design approach and its results, followed by conclusions in section 6 about the added value of the interventions to support creativity within the integral design approach.

2. Methodology: integral design and C-K theory

In the earlier 1960s design methods, developed to support designers (Margolin 2010), were based on the application of 'scientific' methods derived from operational research methods and management decision-making techniques in the 1950s (Cross 2007). Although the systematic presciptive approaches were helpful, they were hard to apply for design, which is considerd to be an too ill-structured activity (Simon 1969). Up to today, there is no clear picture about the most effective way to support designers (Horváth 2004). This resulted many models of designing (Pahl et al. 2006, Howard et al. 2008, Tomiyama et al. 2009).

2.1 Integral design

In the Netherlands a specific design method was developed by Van den Kroonenberg, methodical design (Zeiler and Savanovic 2009), which had exceptional characteristics (Blessing 1994). In the Netherlands methodical design is the most popular design method in mechanical construction industry. Therefore we used the methodical design method and transformed it into a method more suited for multidisciplinary building design: integral design (Zeiler and Savanovic 2009, Savanovic 2009). A distinguishing feature of Integral Design is the intensive use of morphological charts (Zwicky 1948) to support multi-disciplinary design activities in the design process. A morphological chart is formed by decomposing the main goals of the design task, derived from the program of requirements, into functions and aspects, which are listed on the first vertical column of the chart. After this step the related generated sub-solutions are listed on corresponding rows. The morphological charts, made by each individual designer, can be combined into a design team's morphological overview. After discussion the meaning and importance of the functions and aspects mentioned in the individual morphological charts, the design team members decide which functions and aspects must be put in the morphological overview. These selected functions and aspects are listed in the first column of the morphological overview. In the next process step, the relevant sub-solutions can be added from the separate individual morphological charts into the team's morphlogical overview.

The advantage of the integral design approach is that the discussion about the intepretation of the design brief, begins after the preparation of the individual morphological charts. So there is no situation of influencing each other at the beginning of the design process. As a result, each designer uses his own interpretation, in relation to his specific discipline based knowledge and experience. This leads to an overview of different interpretations of the design brief, represented by the domain specific morphological chart of each design team member. In sum, this approach allows a greater freedom of thought to individual designers and results in more diversity in interpretation of the design problem and generation of sub-solutionss from the different disciplines. Such a morphological overview can be used by the designers to reflect on the results during different design process stages. The integral design approach with its tools was tested in workshops. In the initional workshops particpated around 150 members of the Dutch society of Architects (BNA) and the Dutch Building Services engineers society (TVVL). These workshops led to series in which in total of 107 designers participated. After each workshop the set-up and the results were evaluated and adjustments made (Savanovic 2009).

One of these adjustments was to combine the Integral Design approach with C(Concepts)-K(Knowledge) theory, which enables us to focus on the distinction between redesign (K-K transformation) and integral design concept generation (K-C transformations). C-K theory can help to manage design processes because it helps to clarify them and then to overcome them by providing means of action (Hatchuel et al 2011). Normally in traditional design the focus is on K-K relations. In addition, C-K theory offers specific value in the conceptual building design stage, where it can be used to focus on K-C, C-C and C-K transformations. In essence, in the current research Integral design-concepts are seen as essential for the creation of new, innovative building designs. These concepts can be tested, interpreted by simulation and verified by experiments. Through this process the concepts become knowledge and plausible solutions. Integral design-concepts represent the potential for the definition of new object design knowledge, which can then be exploited to solve new design tasks in the building design domain. In the next stage of the research the use of so called C-constructs, some times called C-projectors, of the KCP-method by Hatchuel and Weil was investigated to stimulate the creation of new concepts in the Integral Design workshops (Elmquist en Segrestin 2008, 2009). 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, via 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, see Figure. 1.

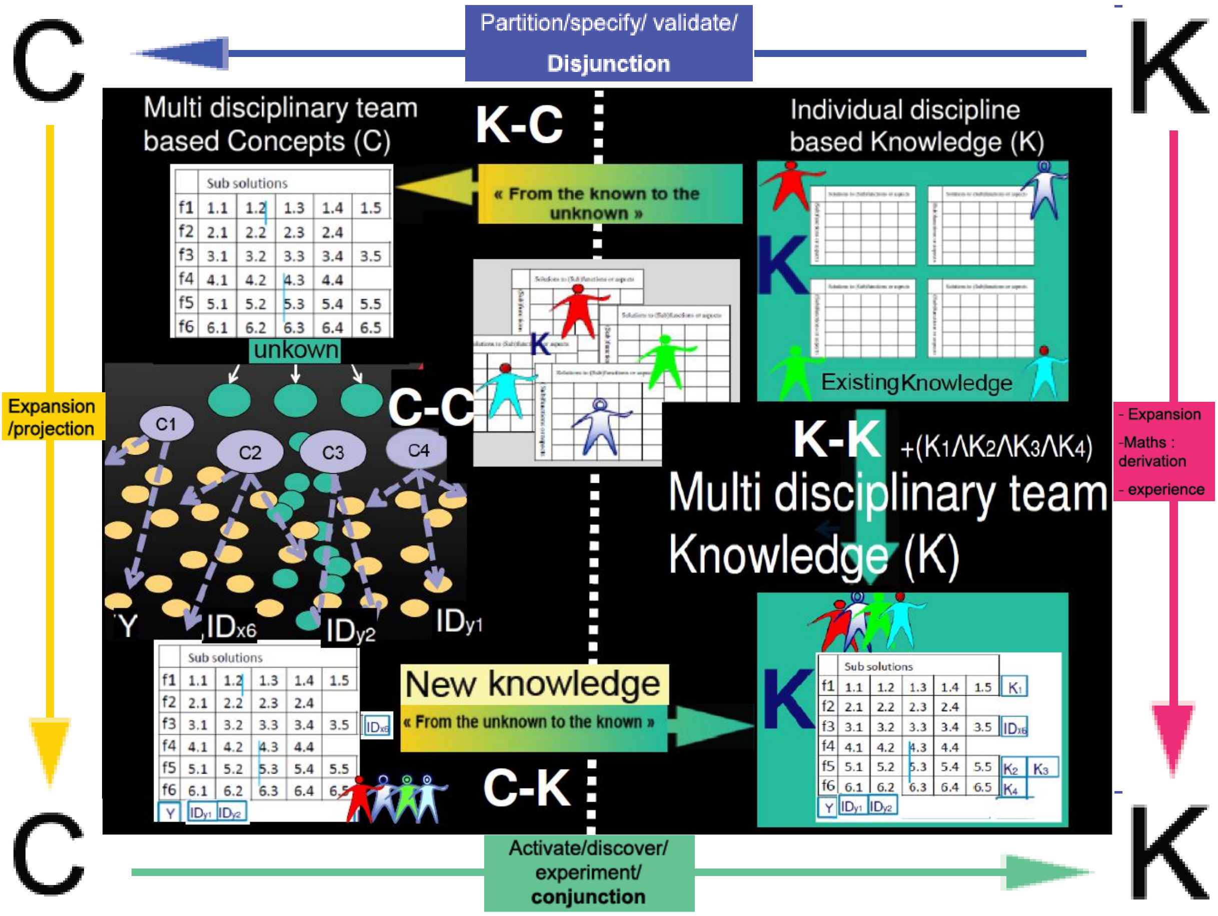

Figure 1. Morphological representation of the C-constructs transformation process within the four operators of C-K theory (Hatchuel and Weil 2003)

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. Another C-construct mechanism is the introduction of an ‘impossible’ optimal solution direction, for example a weightless high rise building or an always energy producing building. The C-construct stimulates the subconscious of the designers and they come forward with new concepts. After a step by step development of the concepts and 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. 1. 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 concepts are seen as essential for the creation of new, innovative building designs. This because 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.

3. Experiments with a new set-up for student workshops Integral design

To test the application of C-projectors, workshops were used within the masterproject integral design (MIO) in 2011and 2012. In this multidisciplinary master project students from the faculty of Architecture Building and Planning (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 (Zeiler and Savanovic 2012). The workshops started with an afternoon setting consisting of two sessions and followed the next morning by another two sessions. The focus of the workshops was to learn the students the use of morphological charts and morphological overviews. This was done by starting with a lecture about the integral design method and its specific application of morphological charts and morphological overviews as design tools. The students were split up in design teams that during session 1, 2 and 3 all students worked only once with the same students. This to avoid a learning effect in teams as they otherwise starting to know each other better. In session 1, 2 and 3 the participants started individually, working on the different design task and making their own morphological chart, see Fig.4. In all design settings the teams were given the same or similar design tasks as used in the Integral design research by Savanovic (2009). After this first part of each session the teams made from the morphological charts a morphologocial overview. The individual part of the sessions 1,2 and 3 took 20 minutes and the team parts lasted 40 minutes. In the first individual part of the sessions, when they had to make their individual morphological chart, there was no communication between the participants. In session 1 the teams existed of an architectural student and an engineering student. In session 2 the teams existed of four students. In session 3 the students were again rearranged now in teams of 4 students. In addition each student design team was strenthenged by an expert who joined the design team. After session 3 a lecture was given about C-K theory and the possible application of C-cprojectors. After which the design team continued in session 4 with the design assignment of session 3 and tried to generate concepts with the help of some examples of C-projectors that were given to them. Starting point for this session were the morphological overviews of the 3th design session. The teams stayed the same compilation as in session 3. The focus of the 4th assignement was on applying C-projectors to make the step from existing knowledge to the unknown world of concepts. 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 2011 the sessions 1 and 2 29 students participated and in session 3 and 4 27 students participated. In 2012 22 students participated in the sessions 1 and 2 and in session 3 and 4 20 students participated. In addition in session 3 and 4 six professionals participated, one in each student team, which were on average 50 years old and had around 25 years experience.

4. Results workshops integral design

The number of functions and sub-solutions mentioned by the designers in their morphological overviews were counted and are represented in Table 1. This makes it possible to compare the average number of functions and subsolutions mentioned in morphorlogical overviews for all different teams configurations and MIO workshop sessions. Here we present only the results of the second, third and fourth sessions of the MIO workshops, as the first session was a first learning session for the students after which they got thorough feedback. As the number of groups is relatively small we decided to take the results of the student workshops of 2011 and 2012 together as the setting of the workshops was identically. Fig. 2 gives the avarage results of the different design sessions.

Session	Functions	Sub-solutions	Teams
2009 PhD MO	8.4	30.3	6
2011 MC 2 Stu	5.1	16.3	8

2011 MO2 Stu	7.1	27.3	8
2012 MC2 Stu	8.7	28.7	7
2012 MO 2 Stu	10.5	43.2	7
2011 MC3 Stu	5.5	18.5	6
2012 MC3 Stu	7.9	30.3	6
2011 MC3 Pro	7	16.2	6
2012 MC3 Pro	7.2	13,8	6
2011 MO3	7.8	30	6
2012 MO3	9.5	36.3	6
2011 MO4 CK	12.6	42.7	6
2012 MO4 CK	10.8	48.5	6

Table 1. The overview of the average number of mentioned functions and sub-solutions in the different design sessions

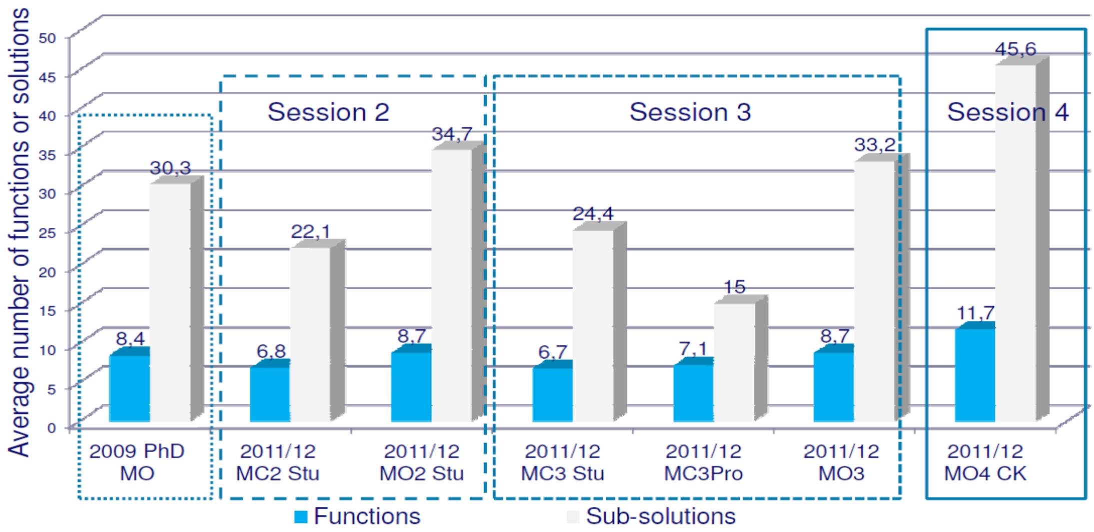

Figure 2. PhD= PhD research by Savanovic (2009), MC=Morphological Chart, MO= Morphological Overview, Stu=Student, Pro=Professional, CK=application of C-K's C-projector. Average combined results of the 2011 and 2012 MIO workshops, compared with the results from the PhD research from Savanovic (2009), 2009 PhD MO

On average the student teams (2011/2012 MO2Stu) produce slightly more functions and sub solutions than the professional teams (2009 PhD MO). Adding one professional to a student team (2011/2012 MO3) slightly decreases the student design teams' performance level compared to the all student teams teams (2011/2012 MO2 Stu). The number of on average mentioned functions stays the same with 8.7 but the number of generated sub solutions decreased from 34.7 to 33.2 (minus 4.3 percent). Applying the C-projectors lead to an increase in the number of mentioned functions from 8.7 to 11.7 (plus 34.5 percent) and an increase in the number of mentioned sub-solutions from 34.7 to 45.6 (plus 31.4 percent).

5. Discussion

The design tasks for all four sessions were quite simular to those of the former research by Savanovic (2009). The spread within the results of the individual design teams is quite wide, which might due to the limited numer of design teams (six) in each design session. The difference between the outcome of design teams, depended of the synergy between the participants, as well ofcourse depended on the individual talent, social capabilities and experience of the participants.

As the sub-solutions are proposed in the conceptual design phase there is no possibility to make statement about the quality of the mentioned sub-solutions. Therefore we only included quantitative results in relation to the effect of the interventions that we made to the design process.

As stated by Le Masson et al. (2011) there is an interplay that links creativity and design theory. That interplay leads to new ways of managing design, new ways of managing knowledge, processes and organizations for design activities. In our case we used the framework of integral design in combination with C-K theory to stimulate creativity within multi disciplinary building design teams/

6. Conclusion

Integral design method enables to merge different perspectives of all designers and consulting engineers, involved in the design process. In the conceptual phase of integral design, morphological overview represents the design team's interpretation of the design task and the related design knowledge. and as such it defines the problem and solution space of the design task. The integral design method is based on experimental workshops for professionals and was now used to teach multi disciplinary building design to students in workshops during their master project integral design. We researched how for student design teams, interventions to the integral design method could improved the quantitative outcome of the design process. Two interventions were tested to stimulate the creativity of design teams within the integral design process: the application of C-projectors and adding a experienced professional to the student teams. Only the C-projector's intervention had a significant positive effect on the increased number of generated sulutions and as such had a stimulating effect on the creativity of students within the integral design process.

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