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EDUCATIONAL BRIDGE BETWEEN STUDENTS AND PROFESSIONAL IN BUILDING INDUSTRY

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ABSTRACT
Within the building industry there is a clear need for more sustainable solutions, with as ultimate goal Zero Emission Buildings. This makes building design more complex. Building design transfers from a mainly architect led process into a multi-disciplinary design team process to cope with the growing complexity of the design tasks. A supportive design method was developed in cooperation with the Dutch professional organizations of architects and consulting engineers. The design method provides overview and helps to structure the communication between design team members. The design method is focused on the creation of solutions in the conceptual phase of building design. After testing the method in workshops as part of a training program in industry, the design method was transferred and applied at the department of architecture for master students for their multidisciplinary Master project Integral Design. In the latest version of the workshops for students we introduced participation of professionals. The partnership with professional societies within the building industry led to the developed design method. This cooperation between professionals and students is an example for a kind of educational bridge for engineering education.

Keywords: Integral design, building design

1 INTRODUCTION

The built environment of the Netherlands uses 40% of all energy for conditioning the buildings. This has to change, sustainable building designs need to provide solutions for sustainability issues ranging from flexible use to renewable energy, energy reduction measures while maintaining and even increasing comfort level of the users. In order to achieve sustainable targets set by EU regulations, the current design practice should be changed to adopt Zero Emission Building, and so should architects change their traditional role in the design process [1]. The design process for a Zero Emission building is quite differently framed from a standard code compliant building and it is essential that an Integrated Design Process is used from the outset of the project to ensure success [2]. A cost-effective Zero Emission Building is however a realistic possibility with an integrated design process [3]. So therefore the focus has to be on the building design process and how to optimize the integrated building design process. As we want to prepare our students for the future this is an essential part of their education in building design. The constant and radical changes which characterizes modern world makes it [4], as Dineen and Collins [5] observed, impossible: ‘to base our future on the certainties of the past. Unable to define what we need to know, we have begun to focus on how we will need to know, on the flexibility and openness which characterizes creative thinking’. In design one has to work with ill-defined problems were the wanted solution and the problem itself develops almost in parallel at the early stages of the design process. Also the amount of relationships and dynamic social interactions makes it increasingly complex. Therefore a method is needed to structure this wicked problem [6].

2 METHODOLOGY: INTEGRAL DESIGN

In the Netherlands such a model was developed in the early 1970s: a prescriptive design model to teach design to mechanical engineering students at the University of Twente [7]. When developing his design method van den Kroonenberg took only the most essential elements of the many different design methods that were proposed at that time. He focused on the need for a methodical ordering of the design activities in an overall design framework and looked at the difference between research and design in analogy with General System Theory [8]. This in the Netherlands familiar model was

extended into an integral design model by us by adding an evaluation step. Methodical Design as developed by van den Kroonenberg was chosen as a starting point as it has as such exceptional characteristics [9]. 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 [10].
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, see Fig. 1.

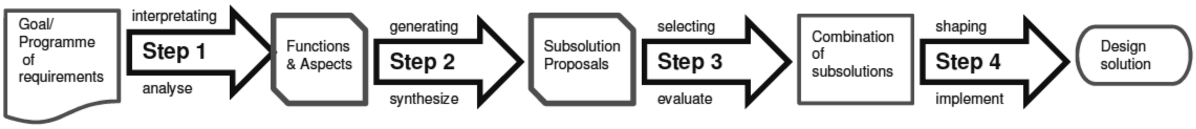


Figure 1. Four-step pattern of Integral Design

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. Such a morphologic overview can be used by the designers to reflect on the results during the different design process stages. Morphological charts were derived from the General Morphological analysis, based on the pioneer work by Fritz Zwicky [11]. General Morphological analysis was developed as a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes, its history and some applications is given by Ritchey [12]. It was Norris [13] who first introduced the application of the morphological approach into the domain of engineering design methods. Morphological charts, which are essentially two-dimensional matrices, originate from the n-dimensional morphological box of Zwicky. It became a popular tool to generate alternatives by using a morphological matrix during focused brainstorming. The morphological charts can also used in conjunction with overall design processes such as 6-3-5, brain writing, reverse engineering and redesign method [14]. As such the use of the morphological matrix offers structure to the chaotic process of brainstorming. However it was intended to be applied more analytical and individual to reach for more objectivity and rationality [15]. The morphological approach has several advantages over less structured approaches. It seeks to be integrative and to help discover new relationships or configurations [16]. Importantly, it encourages the identification and investigation of boundary conditions, i.e. the limits and extremes of different parameters within the problem/solution space. The method also has definite advantages for communication and – notably – for group work [16].
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, see Fig. 2.

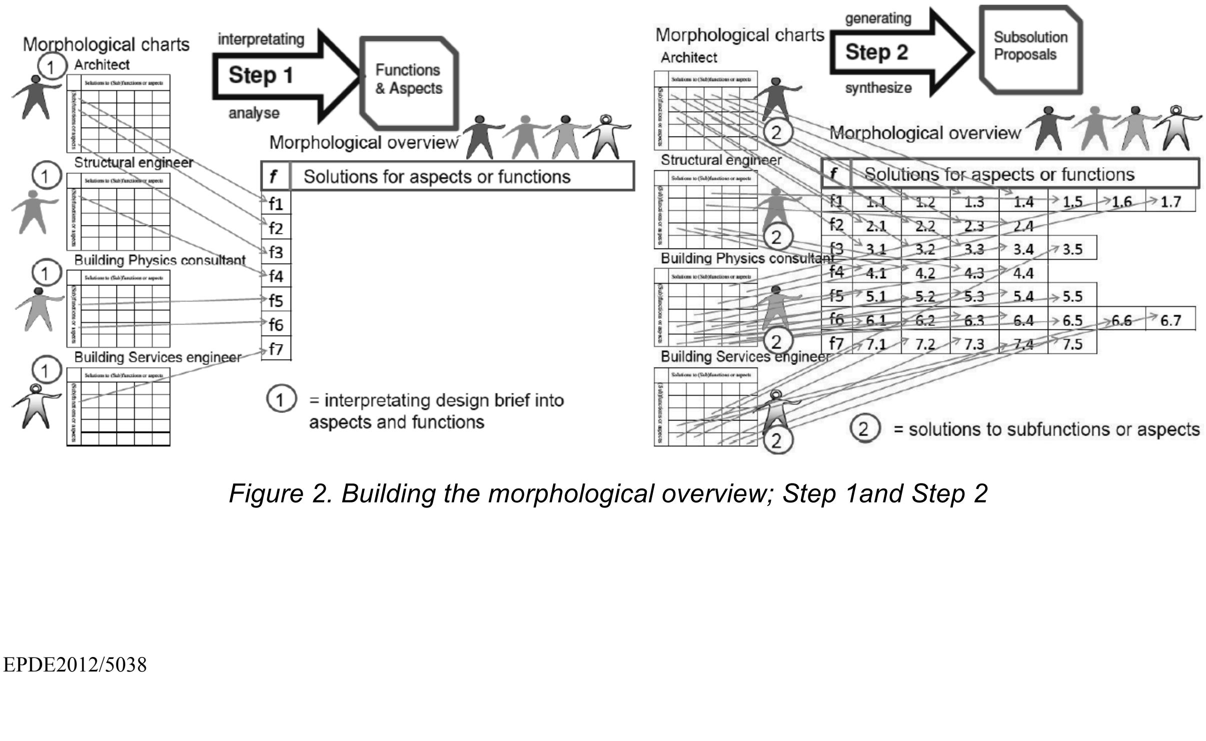


Figure 2. Building the morphological overview; Step 1and Step 2

Although the use of functional description and morphological charts is common practice in mechanical engineering design, they are rarely used in a multi-disciplinary way besides engineering. Especially the input of 'soft' aspects adds a new dimension to the strict functional approach of traditional morphological charts. The description of the morphological overview may read as minor implementation difference of the old morphological matrices.
The morphological charts made by each individual designer can be combined into a [team] morphological overview, see Fig. 2, 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. 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.

3 EXPERIMENTS

The Integral Design approach has been tested in a series of 5 workshops, typically including around twenty participants and lasting for two or three days. A total of 107 designers participated in the workshop series. Here only a brief selection of all the results is given. More results and information are presented by Savanovic [10]. From the analysis of the workshops it could be concluded that the number of functions and aspects considered as well as the number of sub solutions offered, was significantly increased by applying the Integral design method with its Morphological Overview.
In connection with the Integral design research project for professional in the Dutch building industry, we developed an educational project, the Multidisciplinary master design project. Interaction between practice, research and education forms the core of the 'integral approach'. Therefore the concept of the integral design workshop for professionals was implemented within the start-up workshop of our multidisciplinary masters' project. The basis of this project, which serves as a learning-by-doing start-up workshop for master students, is the Integral design method with its use of morphological overviews. The different design assignment all were related to the design of zero energy buildings. Such complex task requires early collaboration of all design disciplines involved in the conceptual building design.
Students from architecture, building physics, building services, building technology and structural engineering were offered the opportunity to participate. Based on the multidisciplinary master design project workshops [10], the first two assignments were the same and the workshops had one afternoon session on the first day and one morning session on the second day. The teams formations for the different assignments were changed from teams of two [session 1] to teams of four [session 2] and teams of five or six [session 3]. Also the teams were formed so that all students worked together only once. During 2011 in the sessions 1 and 2, 29 students participated and in session 3 and 4, 27 students participated (5 Building Services, 6 Structural Design, 3 Building Physics and 13 Architects). The average age of the students was 23 and they had no professional experience. 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. The teams existed out of different disciplines and were changed after each session. On day 1 the students had to perform the design task 1 in teams of two and design task 2 in team of 4 students. After this, during the morning of the second day, they had to perform design task 3 together with one professional expert in each group.

4 RESULTS

In the 2011 version of the Multidisciplinary master design project, students performed different design assignments in sessions 1, 2 and 3. Central element of the Integral Design process is the use of morphological charts by individual designers were are than combined into one morphological overview by the design team. By making combinations within the morphological overview of possible sub solutions and combining them to overall solutions, the teams generate their solutions. Figure 3 shows some example of the generated morphological overviews and figure 4 presents the related generated solutions based on the chosen combinations within the morphological overview.

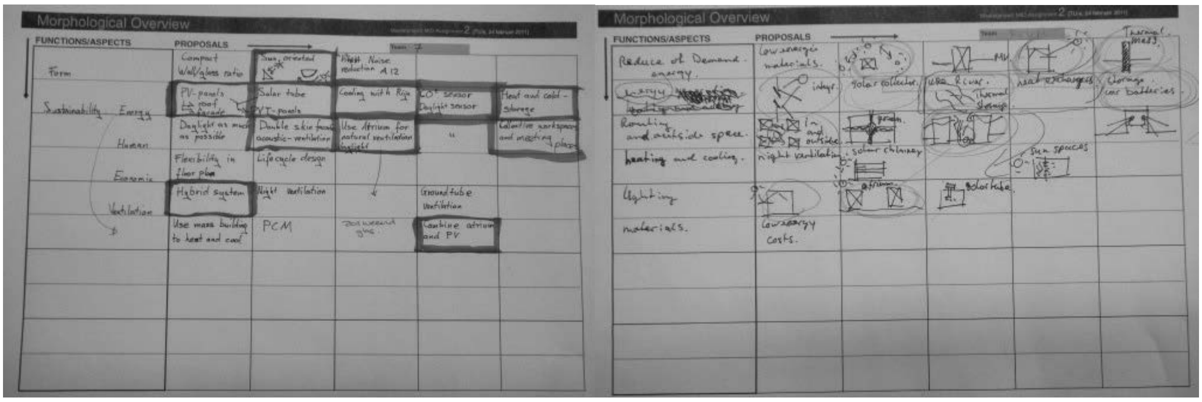


Figure 3. Some examples of the morphological overviews generated by the design teams

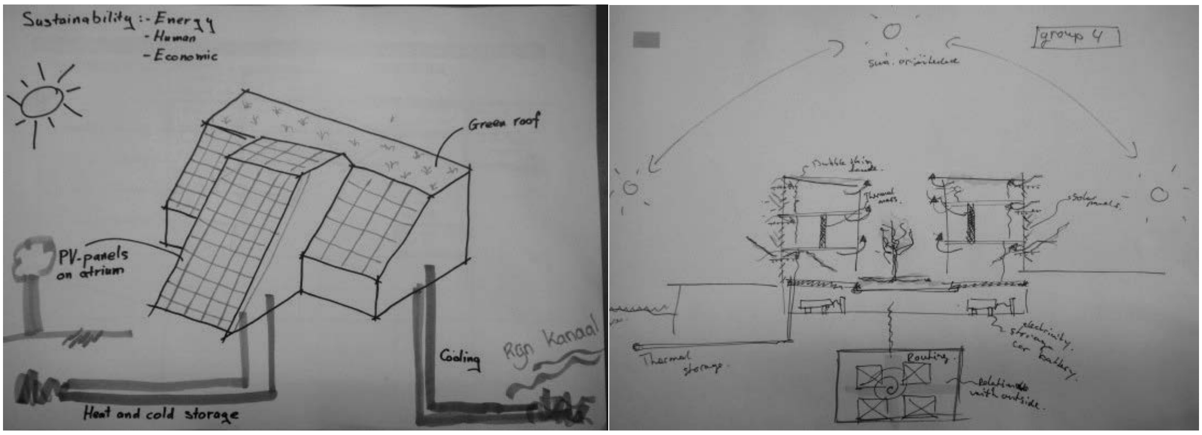


Figure 4. Some examples of presented design solution related to the presented morphological overviews in Fig.

All the assignments were related to aspects of nearly Zero Energy Buildings and had a similar level of complexity to make the results of the different sessions comparable. In session 3 the student design teams were joined by a professional. After session 3, all participants were asked to fill in a questionnaire, which made it possible to compare the outcome of students as well as of professionals, see Fig. 5.

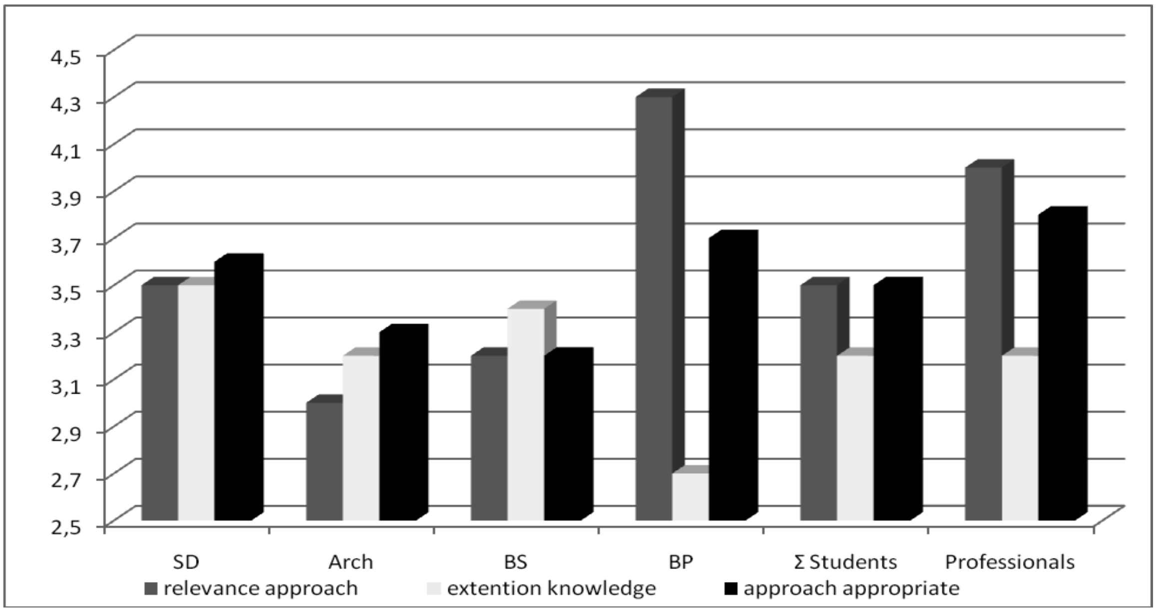
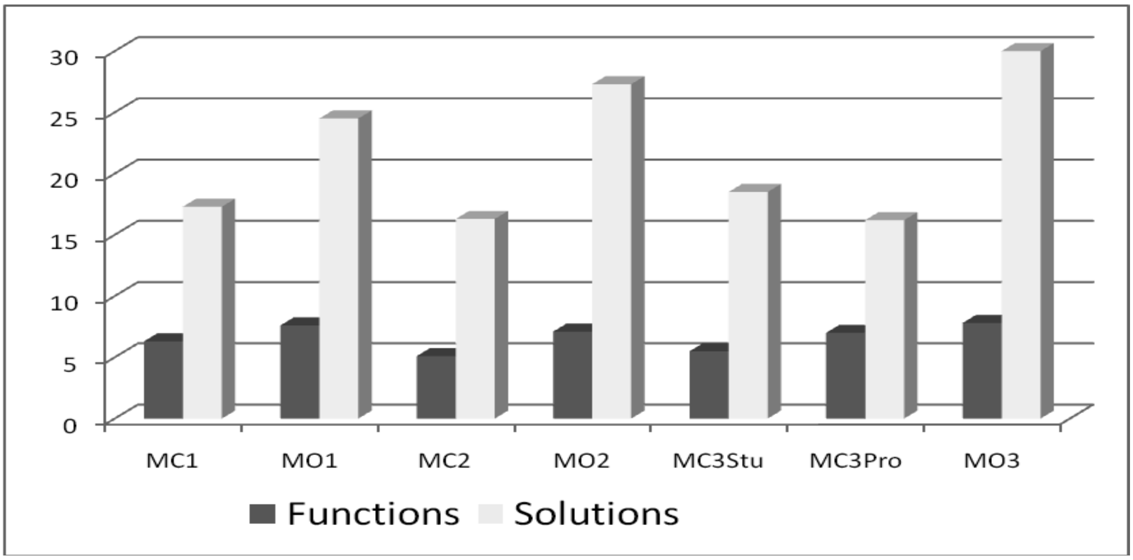


Figure 5. Results comparison results questionnaires 2011, professionals – students, scale from [1-5]

Remarkable is that the professionals are the most positive group on whether they think the approach appropriate, as well as for the relevance of the approach. The result also shows that the architectural students are the least positive group when evaluating the Integral design group process. The number of functions and sub solutions mentioned by the designers in their morphological charts were counted and are represented in Fig. 6. The same was done for the sub solutions mentioned by the design teams in their morphological overviews. Fig.4 shows that there is no significant difference in the average outcome of the morphological charts between the different sessions of the workshops. 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.



MC=Morphological chart, MO=Morphological Overview, Stu=students, Pro=Professionals

Figure 6. The average number of functions and part solutions mentioned in the morphological charts and morphological overview of the design session 1, 2 and 3

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 could be an indication 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 small 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 27,3 solutions]. Overall the professionals generate more functions [on average 7] as compared to students [on average 5.6] but generate fewer solutions [16.2 compared to 18.1]. In table 1 the difference between the different disciplines is presented. This indicates that the architectural students generate the most functions as well as the most sub solutions, however the difference are relatively small (less than max. 15% for the functions and less than max. 11.7% for the sub solutions).

Table 1. Generated number of functions and sub solutions per discipline in session 3

	Functions	SD-Functions	Solutions	SD-Solutions
Average MC3 A	5.9	1.7	18.8	6.6
Average MC3 BP	5	1.0	18.0	4.4
Average MC3 SE	5.2	0.4	16.8	1.9
Average MC3 BS	5.4	1.3	16.8	6,0
Average MC3 Pr	7	2.8	16.2	10.2
Average MO 3	7.8	1.5	30.0	9.4

5 DISCUSSION AND CONCLUSION

Education should prepare students to become professionals therefore the professional workshop formula, developed with participation of the professional organizations within the Dutch building industry, was used to start the students' master project integral design team work. The results of the workshops in their final form held for professionals and students were compared and showed that the professionals were more positive about the workshops than the students [17].

The primary goal of this research was to find a way to integrate architecture with different engineering disciplines into an integral design process for Net Zero Energy Building design. Right at the beginning of such integral building design project, a design method was offered to integrate in a meaningful way engineering knowledge and experience. The results show that the Integral Design-method is relevant for increased insight between design team members, which makes it easier to create Net Zero Energy Building-concepts. Applying the Integral Design method lead to an increase of the number of functions and aspects thought of as well as to an increase of the number of generated sub solutions which in result stimulates the creation of new concepts to achieve Net Zero Energy Buildings.

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