

Dutch academic Building Services design education:

Integral Design to connect industry and university, essential for nZEB design



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Introduction

In the last 50 years, the world has changed enormously: instead of 3.5 billion people on earth, now there are more than 7 billion with more than 5% living in cities with an enormous increased standard of living. The demands for more comfort in buildings as well as more insight in the relevance of Indoor Air Quality towards health, led to more Building Services installations in buildings. This coupled with higher demands in relation to sustainability led to a development of more effective and efficient Building Services installations. In the past, the Building Services made out less than 10% of the budget and were rather simple systems. Nowadays, the Building Services have become quite complicated systems and form at least 30% up to 50% (hospitals) of the budget. The Architecture, Engineering, Construction (AEC) industry has become a knowledge intensive industry which should create sustained organizational and societal values [1]. It is difficult for different disciplines in the design phase to give adequate answers on the built-environment-questions from society. Inadequate design processes result in a productivity loss in the Dutch building design processes of approximately 10% of the total Construction Costs per year [2]. To reduce these failure costs, collaboration between different design disciplines becomes of considerable importance. One of the complicating aspects in building practice is the different cultural backgrounds of architects and engineers and their different approaches to design [3]. As a result, miscommunication occurs caused by not speaking a common language. Already in 1960, the

necessity for improved cooperation between the architect and the engineer was recognized by the famous architect Le Corbusier, see **Figure 1** [4].

Le Corbusier explains the roles of the architect and the engineer [5]: “Under the symbolic composition I have placed two clasped hands, the fingers enlaced horizontally, demonstrating the friendly solidarity of both architect and engineer engaged, on the same level, in building the civilization of the machine age” [4]. The architects and the engineers should work together from the very start of a design project and must aim to reach synergy by combining the knowledge and the experience of all disciplines already in the early stages of the conceptual design. To make this possible, an integral approach is needed which represents a broad view on the world around us that continuously needs to be adapted and developed from sound and documented experiences that emerge out of interaction between practice, research and education.

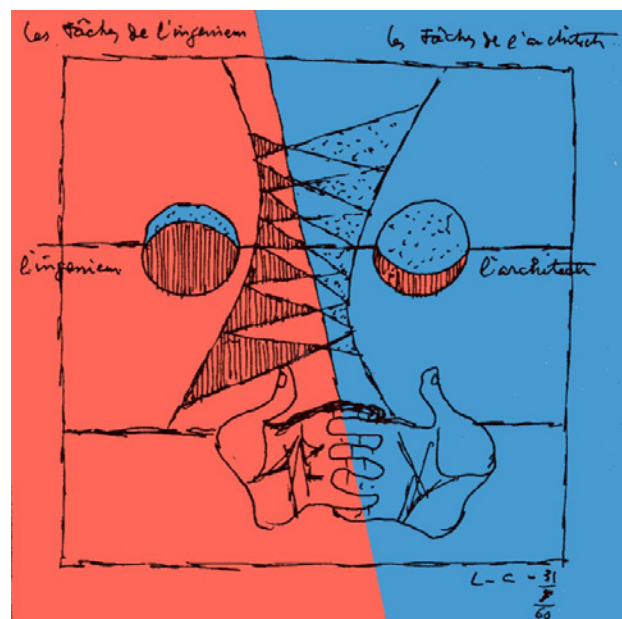


Figure 1. The necessary relation between architect and engineer by Le Corbusier.

Traditionally practitioners in building industry were only educated on a middle level with only a few that have earned a degree of an institute of higher education, but no one on academic level. However, more and more there was a clear need for professionals who are able to solve difficulties on an academic level. Thus, in the late nineties, there was a strong urge from the Dutch industry to the universities, to start with initiatives in order to change the worrying situation of the rather low educational qualified people in the Building Services industry. The MSc Building Services has been established in 2002 as result of a strong initiative from the Dutch Building Services industry, especially the Dutch Society of Building Services Engineers (TVVL), the foundation for stimulating research and education in building services (WOI) and the professional society for building service companies (UNETO-VNI). Both employer and employee have the same professional goals to achieve in the future and have a clear vision of how to share and implement the academic knowledge of the university. In 2011, the MSc Building Services became integrated in the master track Building Physics and Services as part of the MSc Built Environment. The teaching is done by the staff members of the unit Building Physics and Services which exists out of 6 chairs: Building Services, Building Materials, Building Performance Simulation, Building Acoustics, Building Lighting and Building Physics. Through this unique combination of design of systems, simulation and physics, the educational program is broad and technical as well as fundamental oriented.

Methodology

In building design, one should work with ill-defined design problems where the solution and the problem itself develop almost in parallel at the early stages of the design process. In addition, the amount of relationships and dynamic social interactions makes design increasingly complex. Therefore, a method is needed to structure *would-be* design solutions. In the early 1960s, researchers and practitioners began to investigate new design methods to improve the outcome of design processes. Since then, there has been a period of expansion through the 1990s right up to the present day. However, there is still no clear picture of the essence

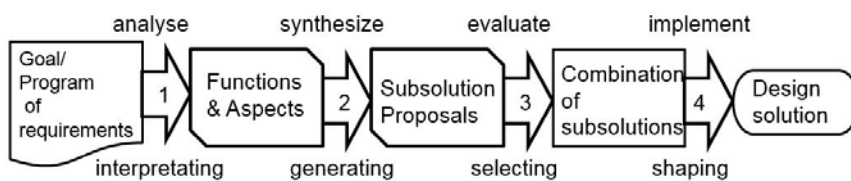


Figure 2. The four-step pattern of Integral Design.

of the design process and many models of designing exist. After studying different design methods, it was decided to use a method derived from the General System theory [6]. This methodical design method has as a distinctive feature the step pattern of activities (generating, synthesizing, selecting and shaping), see **Figure 2**, that occur within the design process.

The methodical design method was expanded to a multi-disciplinary design method, Integral Design, through the intensified use of morphological charts developed by Zwicky [7]. This to support design team’s activities in the conceptual building design process [8,9] and especially the use of a morphological overview built from the individual design team member’s morphological charts. A morphological chart is a kind of matrix with columns and rows which contains the aspects and functions to be fulfilled and the possible solutions connected to them, see **Figure 3**. The functions and aspects derived from the program of demands. An example of a morphological chart created by an architect is depicted in **Figure 4**. In principle, overall solutions can be created by combining various sub-solutions to form a complete system solution combination [10], see **Figure 5**.

	Sub solutions →						
The most important subfunctions and aspects to be fulfilled ↓	1	1.1	1.2	1.3	1.4	1.5	1.6
	2	2.1	2.2	2.3	2.4	2.5	
	3	3.1	3.2				
	4	4.1	4.2	4.3	4.4	4.5	
	5	5.1	5.2	5.3	5.4		
	6	6.1	6.2	6.3			

Figure 3. Concept of a morphological chart

The morphological overview of an integral design team process is generated by combining in two steps the different morphological charts made by each discipline. In the first step of the integral design method, the individual designer has to make a list of what he thinks are the most important functions that has to be fulfilled based on the design brief. This is derived from their own specialist perspective. The morphological charts are formed as each designer translates the main goals of the design task, derived from the program of demands, into func-

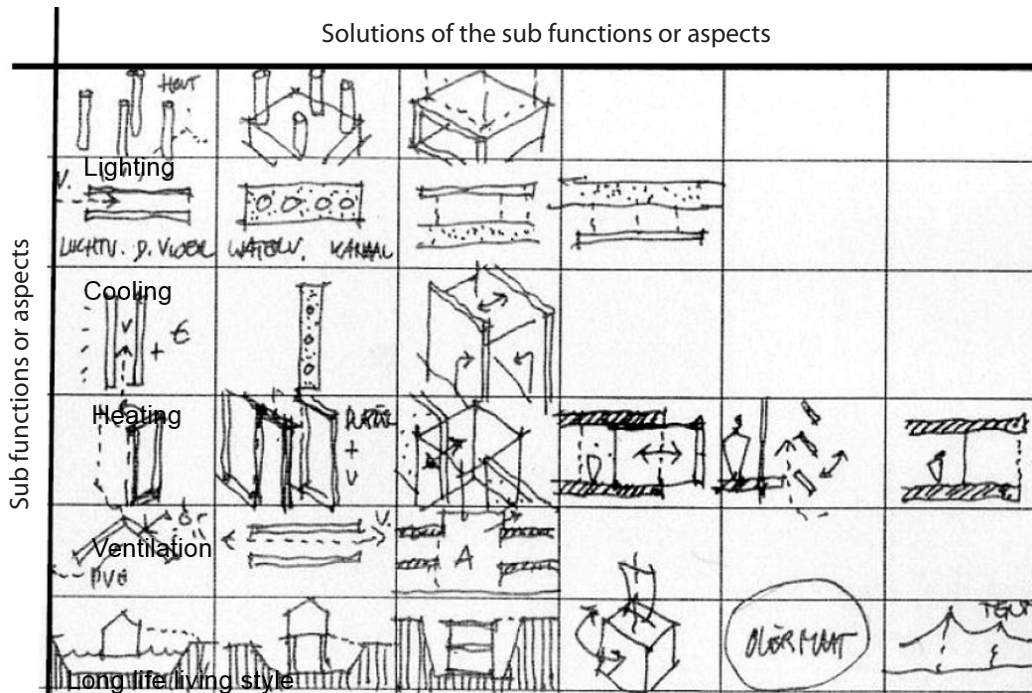


Figure 4. An example of a morphological chart by an architect.

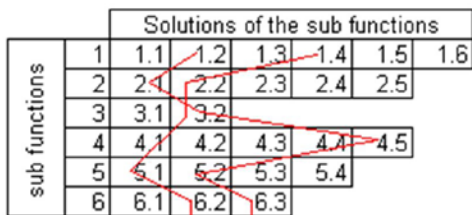


Figure 5. Morphological chart and the possible solutions on the horizontal rows of the chart, with the lines representing 2 possible solution combinations

tions and aspects and is then put into the first column of the morphological chart, see Figure 6. In the second step of the process, the designers add the possible part solutions to the related rows of the functions/aspects of the first column. So, functions and aspects are discussed and then the team decides which functions and aspects will be placed in the morphological overview. Then, after this first step, all participants of the design team can contribute their solutions for these functions and aspects by filling in the rows within the morphological overview.

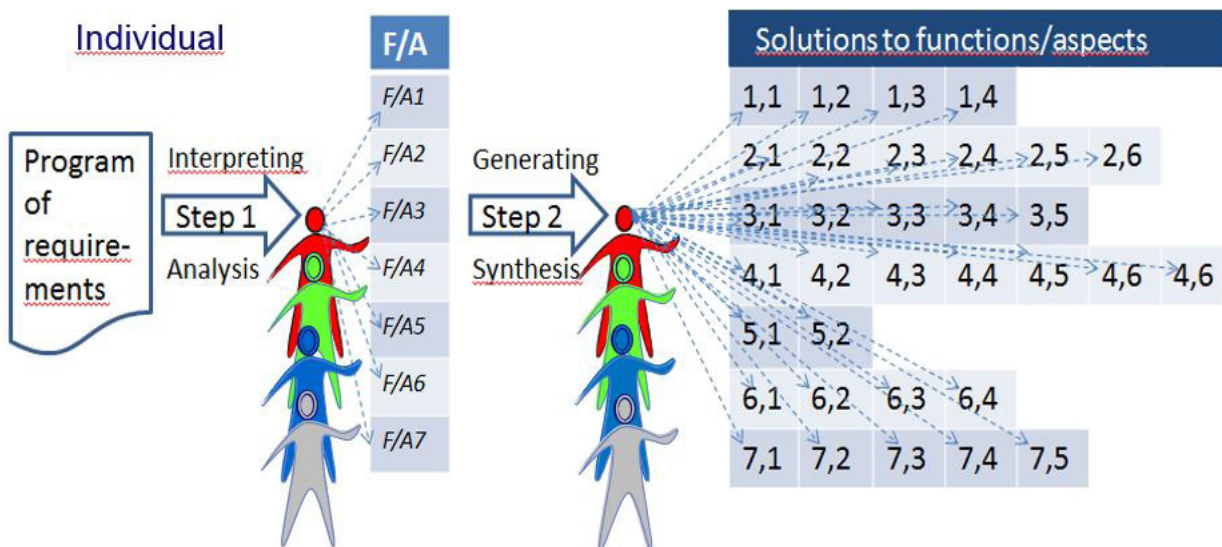


Figure 6. The first two design steps of the design process cycle, interpreting the design brief and list the functions in the first column of the morphological chart and add the related sub solutions [11].

Based on the given design task, each design team member perceives reality due to his/her active perception, memory, knowledge and needs. The morphological charts represent the individual interpretation of reality, leading to active perception, stimulation of memory, activation of knowledge and defining of needs.

These individual morphological charts can be combined by the design team to form one morphological overview, see **Figure 7**. Putting the morphological charts together enables ‘the individual perspectives from each discipline to be put on the table’, which in turn highlights the implications of design choices for each discipline. This approach supports and stimulates the discussion on and the selection of functions and aspects of importance for the specific design task.

Integral Design: Workshops learning by doing education starting in industry

Since 2000 together with the Dutch Royal society of architects (BNA), the Dutch Association of Consulting Engineers (NLingenieurs), the Dutch Society of Building Services Engineers (TVVL) and different Roofer associations in total 14 series of workshops were organized in which in total more than two hundred experienced professionals, with at least 10 years of experience, from these organizations, voluntarily participated. After extensive experiments with different set ups for implementing the Integral Design approach, in which well over one hundred professionals participated, it was concluded that a good way to test our design approach was a workshop setting for professionals. Therefore, workshops were arranged as part

of a training program for architects and consulting engineers (structural engineers, building services engineers and building physics engineers) [8], as well as for architects and contractors [10]. These design exercises were derived from real practice projects and as such were as close to professional practice as possible. The design tasks during the two days are on the same level of complexity and have been used in all workshops. In the workshops, stepwise changes to the traditional building design process type, in which the architect starts the process and the other designers join later in the process, were introduced in the set up of the design sessions. In the final series of the research focussing on the interaction between architects and engineers during the conceptual design phase, three different design set ups of participants were tested in four sessions [8].

In connection with the Integral design research project for professional in the Dutch building industry, we developed an educational project, the master project integral design. 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 assignments were related to the design of zero energy buildings. These complex tasks require early collaboration of all design disciplines involved in the conceptual building design. Master students from architecture, building physics, building services, building technology and

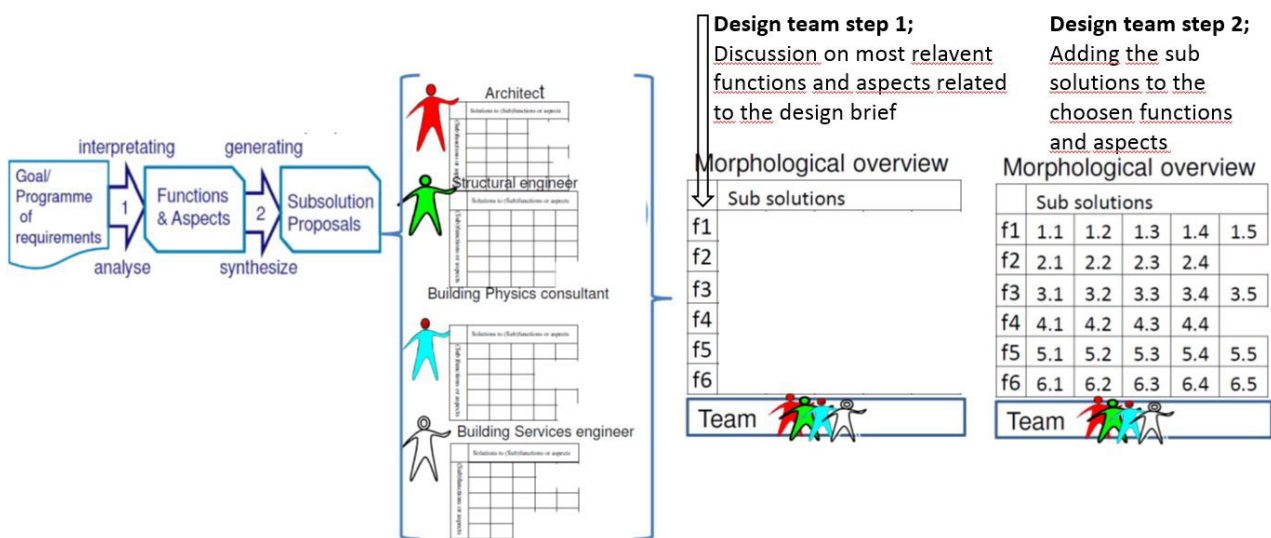


Figure 7. The second phase generating the morphological overview from the individual morphological charts [11].

structural engineering participated in these projects. The master project Integral design was initiated by the chair of Building Services in the 2005/06 academic year and since then, it has been held every year. The master students from architecture, building physics, building services, building technology and structural engineering were offered the opportunity to participate. The specific aspects of the office building design assignments were to realise ‘sustainable comfort’, a net Zero Energy Solution on different locations. Bearing in mind that in the current situation, 40% of primary energy consumption is due to built environment such a task is highly complex. It requires early collaboration of all design disciplines involved in the conceptual building design. Development of knowledge, skills and the ability to realise this aim are the main tasks of the multidisciplinary masters’ project ‘Integral design’.

The participants of the workshops were master students of the faculty of architecture, building and planning (architects, structural design, building technology, building physics and building services) and had an average age of 22 and no working experience. Since 2005 around two hundred and fifty students participated in MIO projects. The workshops were developed since they had their final form.

The results of the workshops

Central element of the Integral Design process is the use of morphological charts by individual designers which were 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. The number of functions and sub solutions mentioned by the designers in their morpho-

logical charts were counted and the average numbers of functions and solutions as mentioned by the design teams are represented in **Figure 2**. The same was done for the sub solutions mentioned by the design teams in their morphological overviews. Here only a brief selection is given of all the results of the preliminary professional workshops Integral Design. More results and information were presented by Savanovic [8]. There was a clear increase in the number of mentioned functions (+62%) as well as the number of mentioned sub solutions (+105%) in the workshops for professionals as well as in the workshops for students functions (+30%) and sub solutions (+57%), see **Figure 8**.

Discussion

Given the existing disparities in the construction industry, King [12] stated that, to do something meaningful in terms of moving to low carbon society, there is a need for a consistent framework within which knowledge can be applied as embodied in a design team. By structuring the interactions of designers from different disciplines in the conceptual phase of building design, it is possible to support members of every discipline to handle tasks and to supply information from other disciplines. The Integral Design methodology was tested through workshops with industry professionals from the Royal Institute of Dutch Architects (BNA) and the Dutch Association of Consulting Engineers (NLIingenieurs). After this, it was implemented in the educational program of the university.

Putting the morphological charts together makes possible to ‘put on the table’ the individual perspectives from each discipline about the interpretation of the design brief and its implications for each discipline. This enables, support and stimulates discussion on the

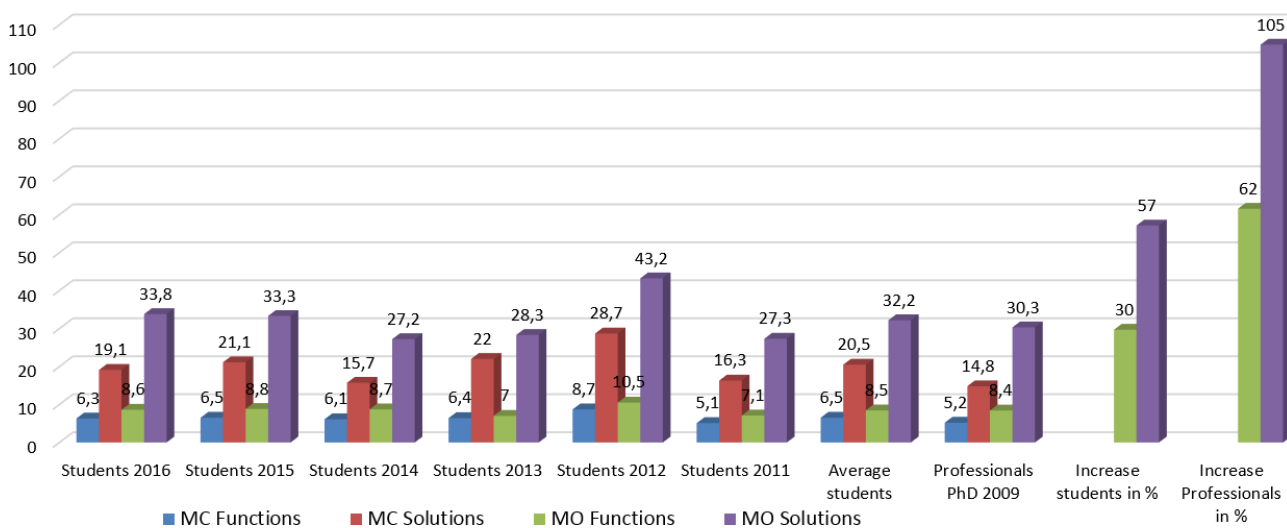


Figure 8. Results workshops Integral Design for professionals and students.

selection of functions and aspects of importance for the specific design. In step two, the functions and aspects are discussed and decisions are placed by the team in the morphological overview. Structuring design (activities) with morphological overviews as the basis for reflection on the design results stimulates the communication between design team members. Thus, integral design helps the understanding within design teams and stimulates collaboration to come forward with new design propositions. Through visualizing the individual contributions within a design team, morphological overviews based on the individual morphological charts stimulate the understanding of different perspectives within design teams.

Workshops are a self-evident way of work for designers that occur both in the practice and during their education. There are a number of advantages that workshops have with regard to standard office work, while at the same time retaining practice-like situation as much as possible: the possibility to gather a large number of designers in a relatively short time, manipulation of design team formation, repetition of the same assignment and comparison of different design teams and their results. The suitability of workshops for integration of design team activities, together with suitability of morphological overviews for structuring knowledge of design team members, forms the basis on which the education design method is built.

Our presented approach of combining research for education for students based on experience with professionals is quite unique. Interaction between the practice, research and education forms the core of our integral approach; we implemented the same workshop pattern and methodology within our multidisciplinary masters' project at the university.

Conclusions

The unique aspect of the academic HVAC educational program at the Technische Universiteit Eindhoven is the context within the Faculty of the Built Environment and the close relation with Building Physics within the master track Building Physics and Services. Furthermore, the close relation with industry and their interaction within the educational structure through the research and education in relation to Integral Design is a strong aspect.

The workshops and the multidisciplinary projects provided us with many insights, some of which were discussed in this paper. Building design processes can be improved through improving process communication

understanding, sharing and collaboration. The use of the morphological chart is an excellent way to record information about the solutions for the relevant functions and aid the cognitive process of understanding, sharing and collaboration. ■

Acknowledgments

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