



integral approach can eventually lead to integral process, team and method – all the required conditions in favor of a multi-disciplinary integrated design of the end product. The integrated approach shows high promises to reduce failure costs and improve design quality can eventually lead to integral process, team and method – all the required conditions for design of the end product; the building [3]. Therefore engineering education needs to help engineering and architectural students develop the necessary skills to confidently and successfully handle design tasks [4].

Eindhoven University of Technology (TU/e) has the so called O-O-O-O strategy, in which research (Onderzoek) is applied to practice (Ondernemen) and its results are used in design (Ontwerpen) as part of education (Onderwijs) of students of which many are going to work in practice (Ondernemen).

To test our ideas for the new educational approach we first experimented in a situation as close to design practice as possible: in workshops for professionals. In this paper the main focus is on the use of workshops and their added value for the students as a preparation for building design practice. The methodology, the used design method and its tool, morphological overview, is described in section 2. In section 3, we report on the workshops for professional architects and engineers. Our “Multidisciplinary master design project for sustainable climatic design” uses the same concept as a start-up for the project. Using the professional workshops’ setup brings back experience from practice to the university. In section 4 the results are given of the different questionnaires that were held to gain insight in the appreciation of different aspects of the workshops. Also a comparison is made between the results of professionals and those of the students. After a short discussion in section 5 conclusions are given about whether or not the integral design workshops with their morphological overviews are useful both for students and professionals.

## **2. Methodology**

As complexity and scale of design processes in architecture and in building services engineering increase, as well as the demands on these processes with respect to costs, throughput time and quality, traditional approaches to organize and plan these processes may no longer suffice [5]. This implies defining a process methodology that acts as a “bridge” between architectural elements such as shapes and material on the one hand, and the aspects of indoor climate issues such as overheating and ventilation on the other. Crucial point by using experiments, in relationship to the ‘theoretical’ model of the Design process, is the connection to a ‘realistic’ model which is part of the design-practice.

### **2.1 Integral Design**

Starting from the prescriptive model of Methodical design [6], we developed a way to articulate the relationship between the role of a designer as descriptor or observer within a prescriptive design method and reflect on the process. Methodical design was chosen as a starting point of development because it has exceptional characteristics [7]: it is a problem-oriented model; it is one of the few models that explicitly distinguish between strategies, stages and activities; it is the only model that emphasizes the execution of the process at every level of abstraction. The Integral design model, though based on methodical design is an extended design model; 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 use of morphological charts for design activities in each phase of the design process.

## 2.3 Morphological overviews

The use morphological chart is an excellent way to record information about the solutions for the relevant functions and aid in the cognitive process of generating the system-level design solution [8]. Morphological charts to visualize solution alternatives play a central role in the integral design approach. Although the use of morphological charts based on functional decomposition is quite common in mechanical engineering design, they are rarely used in a multi-disciplinary way besides mechanical engineering. Especially the input of ‘soft’ aspects adds a new dimension to the traditional strict functional approach of morphological charts. A morphological overview is generated; see Fig. 1, by combining the different morphological charts made by each discipline after discussion on and the selection of functions and aspects of importance for the specific design. An example of such a morphological chart from one of the design session is given in figure 1.

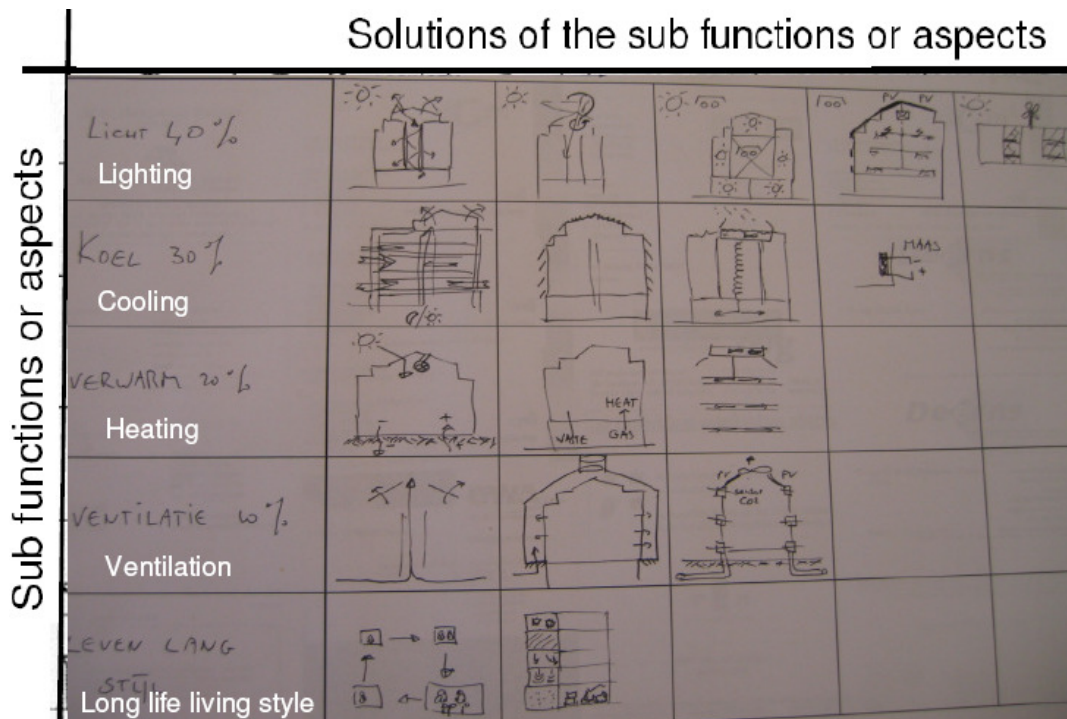


Figure 1: An example of a morphological chart by one of the participants of the workshops

Such a morphologic overview can be used by the designers to reflect on the results during the different design process stages. This is done in two steps, see Fig.2;

- Step 1; The Morphological overviews show the agreed functions and aspects (1) of the different morphological charts. Here the soft elements can be included as aspects

- Step 2: The Morphological Overview with the agreed on sub solutions (2) from the separate morphological charts.

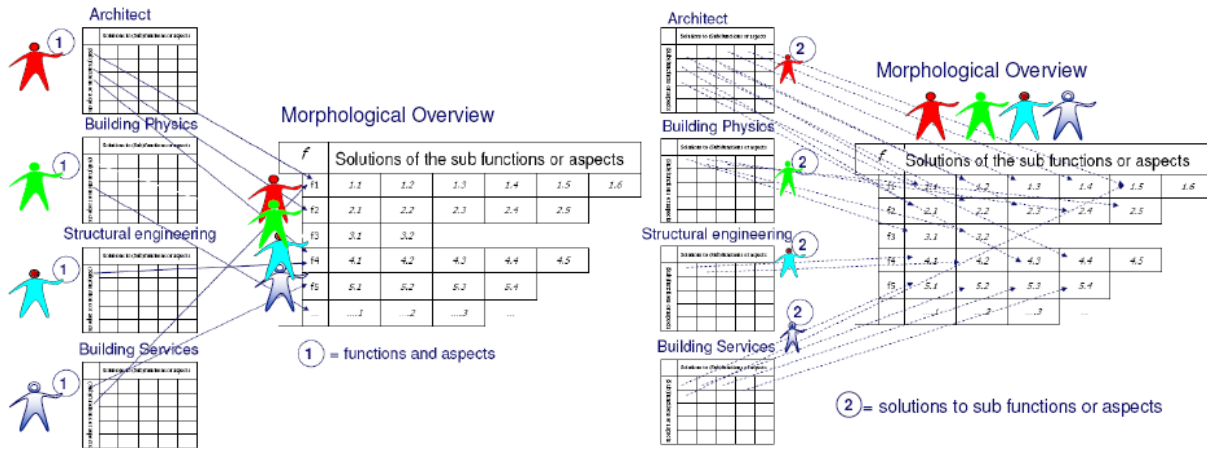


Figure 2: Building the morphological overview step 1 and step 2.

The reflection by the design team on the functions/aspects and solutions results in a parallel expansion of the design problem 7 solution space, see Fig. 3.

## Expansion of problem & solution space

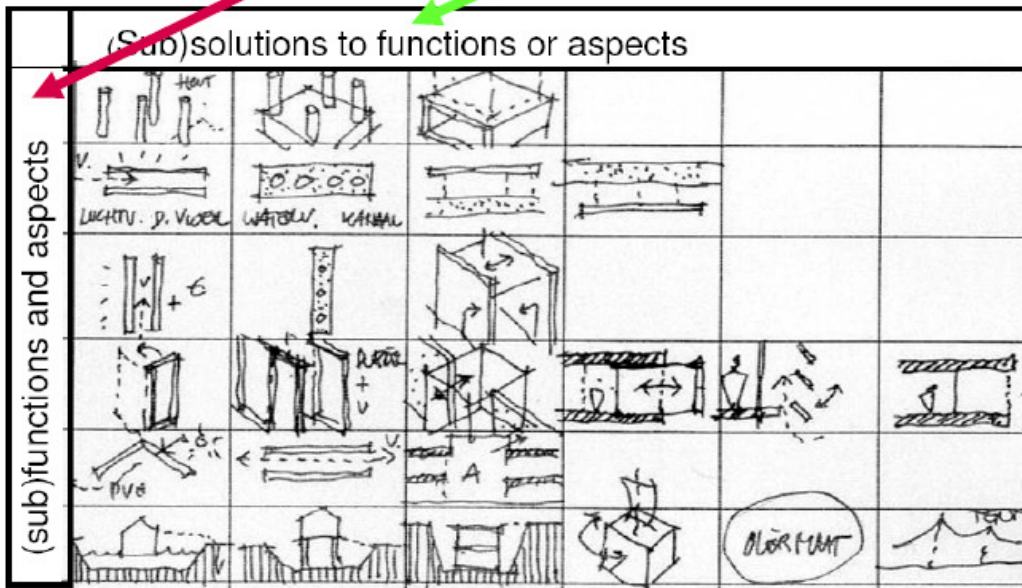


Figure 3: Parallel expansion of problem and solution space

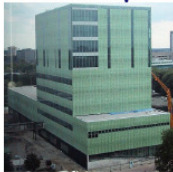
### 3. Experiments: Workshops

#### 3.1 Development of the professional workshops

Since 2005 we organized 5 series of workshops with experienced professionals, architects and engineers, voluntarily applying to participate. The participants of each discipline were randomly assigned to design teams, which ideally would consist of one architect, one building physics consultant, one building services consultant and one structural engineer. Starting with a three day practice-like 'building team' concept, in which all disciplines are present within the design team from the start, the integral design method workshops have evolved to finally a two-day series. The design tasks during the two days are on the same level of complexity and have been used in all workshops. Fig. 4 shows the 4 different design tasks and some results.

#### Design assignments(day 1)

1. Pavilion/parasite

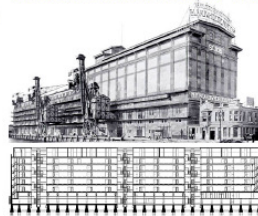


2. Zero energy Office building



#### Design assignments (day 2)

3. Renovation / new functions



4. Zero energy School

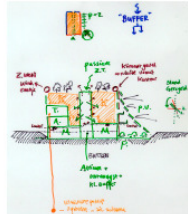


#### Results (day 1)

1. Pavilion/parasite



2. Office building



#### Results (day 2)

3. Renovation / new functions



4. Zero Energy School



Figure 4: Design tasks day 1 and day 2

After each design session the participants present the results to each other and get feedback from the organizers.

The workshops start with a lecture introducing Integral Design and are followed with other supportive lectures about sustainable energy systems, the use of morphological overviews and overall feedback of the results to all participants. Over the past four years the above described approach was tested in a series of 5 workshops, these typically include around twenty participants and lasted for two or three days.

A total of 108 designers, average age 42 and on average 12 years of professional experience, participated in a four workshop series. Direct at the end of the workshop the participants were asked to fill in a questionnaire in which questions were asked about the importance of the use of morphological overviews within the design process and about the concept of the workshops themselves. The results of the questionnaires indicate that the participants thought the use of morphological overviews of value to communication and the number of relevant alternatives within the design process. More information about the first three series of workshops can be found in [9,10]. The experiences of workshops series led to step by step adjustments resulting in the final setup workshop which was tested in series 4 and 5, see Fig. 5.

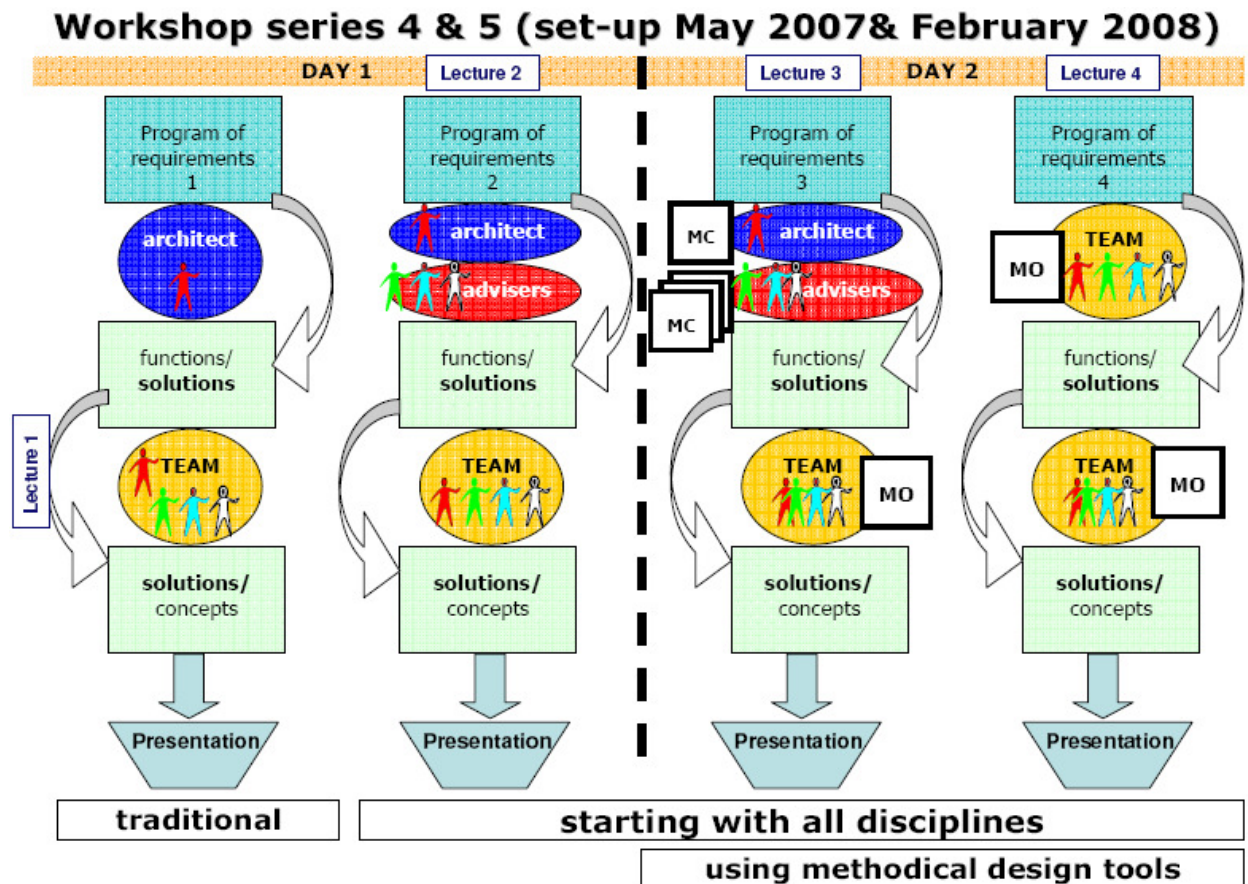


Figure 5: Workshops series 4 & 5, four different design set ups of participants and use of Morphological Charts (MC) or Morphologic Overviews (MO) during the design sessions within two days

In this final configuration of the workshop series (Fig. 5) stepwise changes to the traditional building design process, in which the architects starts the process and the other designer join in later in the process, are introduced in the design sessions. Starting with the traditional sequential approach during the first two design sessions on day 1, which provide reference values for effectiveness of the method (amount of integral design concepts); the perceived “integral approach” is reached through letting all disciplines start working simultaneously within a design team setting from the very beginning of the conceptual design phase and the application of the integral design model / morphological overview.

The second day of the design sessions allows simultaneous involvement of all design disciplines on a design task, aiming to influence the amount of considered design functions/aspects. Additional application of morphological overviews during the set up of the third design session demonstrates the effect of transparent structuring of design functions/aspects on the amount of generated (sub) solution proposals. Additionally, the third setting provides the possibility of one full learning cycle regarding the use of morphological overviews.

### 3.2 Multidisciplinary master design project for sustainable climatic design

Interaction between practice, research and education forms the core of ‘integral approach’ therefore we implemented the integral design workshop for professional’s pattern and methodology within the start-up workshop of our

multidisciplinary masters' project on TU/e, Department of Architecture, Building and Planning. Students from architecture, building physics, building services, building technology and structural engineering were offered the opportunity to participate. The procedure was the same for the professional workshops; the only criterion for participation was being member of the 'master students group'. To motivate the students there was coupled a contest to the project with an engineering company sponsoring the price money and organizing an excursion and the external jury. The teachers of the TU/e select the best three designs and the external jury then decides on the order of the price winners.

The students were assigned to design teams of different disciplines in such a way as to have all disciplines represented in each team. The students are intensively guided by staff from each discipline involved and the meetings with the individual staff members are according to a strict scheme. After the sessions with the students the staff reflects the meetings together. The whole project took 14 weeks. The different design assignment so far were: an office building with 'sustainable comfort', a zero energy Solution (2005/2006), the design of a 24/7 zero energy university faculty building (2006/2007) and a cradle-to-cradle school in the hart of a large city (.2007/2008).

Zero energy is something which is not possible in practice and only a few demonstration projects have realized the goal of zero energy supply over a year to a building. This can only be realized by applying renewable energy source and an extreme low energy use of the building.

Such complex task requires early collaboration of all design disciplines involved in the conceptual building design. Development of knowledge and skills and the ability to realise this aim is the main task of the multidisciplinary masters' project 'Integral design'. During the first week the professional workshop formula was used to start the design team work. This makes it possible to compare the results and design approaches of the students with that of the professionals [11], but that is not the focus of this paper. As we as educators have to prepare our students to become professionals it is of importance to look into the appreciation of the proposed design tool within building design practice. Therefore we focus on the value of the workshop formula for the professionals and compare that with the evaluation of the workshops by our students.

## 4. Results

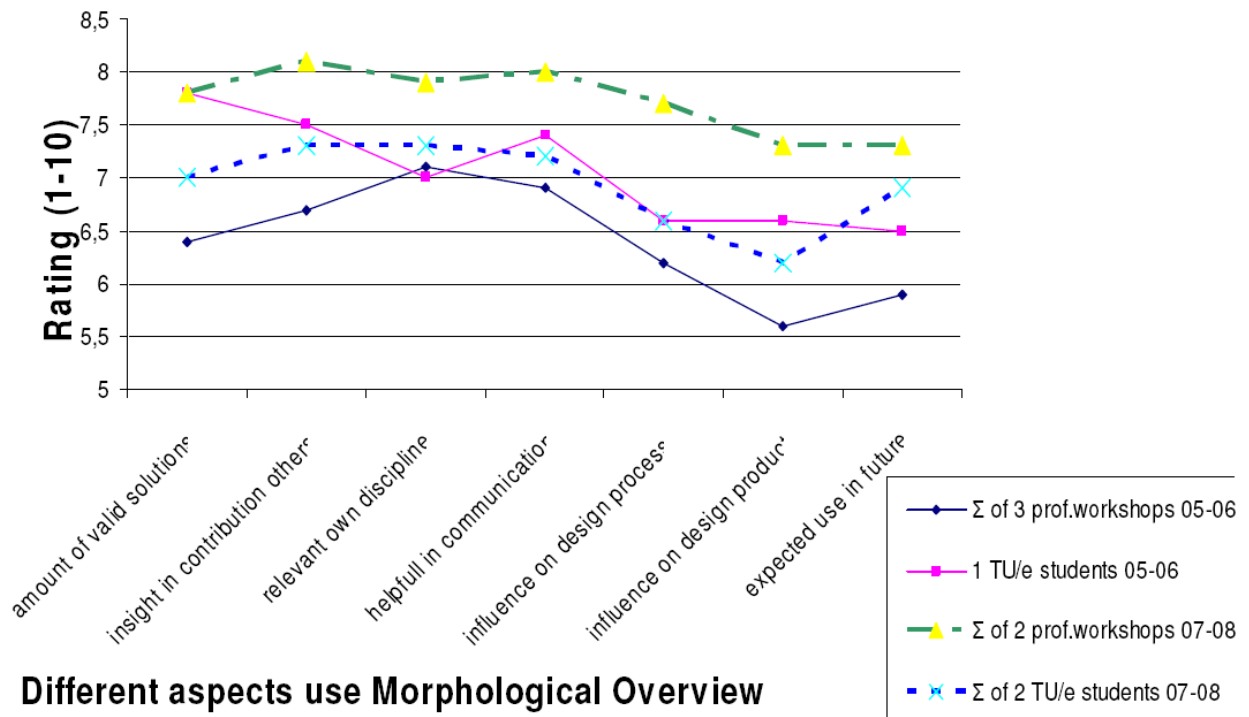
### 4.1 Comparison results questionnaires professional workshops and student workshops

The focus of our research was on building a theoretical workshop model based on extensive testing in a professional setting. As result of this we have only made an overall comparison between the results of the questionnaires held for professionals as compared to that of the students. The number of participants is given in table 1.

*Table 1. Number or returned questionnaires first series workshops of three days and the later series workshop of two days for professionals and students.*

	2005-2006 3-days workshop set-up		2007-2008 2-days workshop set-up	
	BNA-ONRI-KCBS 3 workshop series	TU/e 1 workshop series	BNA-ONRI-KCBS 2 workshop series	TU/e 2 workshop series
Number of participants (during the last day)	54	25	38	42
Percentage reactions (average of last days)	96%	100%	95%	76%

The results of the comparison are given in Fig. 6. Remarkable is that for the 3 days workshops the students are more positive than the professionals on all aspects, where as for the two day workshops the professionals are more positive than the students. Also remarkable is the same pattern in rating for the two days workshops for students compared to that of the professionals: on average there is a difference of nearly 1,3 points but the lines of results are almost parallel. This is not the case for the three days workshops. Again we see the lowest rating for the aspect of the influence of morphological overviews on the design process and for the aspect of the influence of the use of morphological overviews on the final product design. Still there is a high score for the aspect of increased insight in the own discipline (7,0 – 7,9) and that other the others (6,7 – 8,1). Also the participants think that the use of morphological overviews is helpful in communication (6,9-8).



### Different aspects use Morphological Overview

Figure 6. Comparison results questionnaires first series workshops of three days and the later series workshop of two days for professionals and students

## 5. Discussion

Structured introduction of this knowledge enables designers/participants to transform it into design concepts. In the workshops the Integral Design approach with its morphological overviews proved to be supportive to the experienced professionals from BNA, Dutch Royal society of architects and ONRI, Dutch society of engineering consultants.

As one of the important aspects is the added value to insight and communication in multi-disciplinary design teams, we think that our approach is not only useful within the building (design) industry, but also in mechatronic/ergonomic design, industrial design and inclusive design. Contexts in which mechanical engineers work together with people from different disciplines with a more ‘soft’ or reflective approach to design. Also the experience of testing educational settings in practice instead of only in academic settings and how experiences from professional education and professional practice can flow back into academic education could be useful to mechanical engineers.



## 6. Conclusions

In this paper we discussed the connection between industry and university in the field of building design education. First we described the multidisciplinary workshops to professional (architects and engineers). The professional workshops were organized for research into a new design education concept for architectural and engineering master students. This led to a set-up of student workshops as the starting point of a multi-disciplinary master design project. Secondly, our multidisciplinary master student project was highlighted.

Our workshop formula, based on the integral design approach with the use of morphological overviews is appreciated both by professionals and students. Our presented approach of combining education for students and professionals is meaningful in the field of building design. Besides the good ratings of the questionnaires by the participants of both the student workshops and the professional workshops, the best proof of success may be the fact that the workshops have become part of the permanent professional educational program of BNA (Royal Institute of Dutch Architects) since 2006.

An additional 'proof' for success is the fact that the largest Dutch building services consulting company asked us to provide training for their employees within the company, based on the concept of the workshops. This was after several employees of this company had participated in the professional workshops. This workshop was held in company on March 31, 2008. Sixteen professionals attended this workshop and their overall rating of appreciation was 7.5 on a 1-10 scale. So we presume that by using our integral design workshops with the use of morphological overviews, we prepare our students good for the multi-disciplinary design problems they have to face in practice.

## 7. Acknowledgments

This research was done with the help of the Royal Institute of Dutch Architects (BNA) and the Dutch Association of Consulting Engineers (ONRI). The Foundation 'Stichting Promotie Installatietechniek' (PIT), supported the research financial.

## 8. References

- [1] USP Marketing Consultancy (2004) Vernieuwing in de bouwsector, wie durft? (Dutch), English translation: Innovation in building sector, who dares?, juni 2004, <http://www.businessissues.nl/?ContentId=2748&BronId>
- [2] Vermaas P.E. & Dorst K. (2007) On the conceptual framework of John Gero's FBS-model and the prescriptive aims of design methodology, *Design studies*, doi:10.1016/j.destud.2006.11.001
- [3] Seppänen O., Steenberghe T. van & Suur-Uski T. (2007) (editors), Energy Efficiency in Focus – REHVA workshops at Clima 2007, REHVA Report No.2.
- [4] Adems R.S, Turns J. & Atman C. (2003) Educating effective engineering designers: the role of reflective practice, *Design Studies* 24 (2003) 275-294.
- [5] Aken J.E. van (2005) Valid knowledge for professional design of large and complex design processes, *Design Studies*, 26(4), pp 379-404.

[6] Kroonenberg H.H. van den (1974) Methodisch Ontwerpen (Dutch), English translation: Methodical design, De Ingenieur, 21 november 1974, nr.47

[7] Blessing L.T.M. (1994) A process-based approach to computer supported engineering design, PhD thesis Universiteit Twente.

[8] Weber R.G. & Condoor S.S. (1998) Conceptual Design Using a Synergetically Compatible Morphological matrix, Proceedings Frontiers in Education Conference, FIE98, Tempe, Arizona, 4-7 November 1998

[9] Zeiler W., Savanovic P. & Quanjel E. (2008a) Integral Conceptual Building Design Workshops, Proceedings TMCE2008, April 21-25, Izmir

[10] Zeiler W., Savanovic P. & Quanjel E. (2008b) Morphological Prescriptive Reflection Overview in Building Design, Proceedings TMCE2008, April 21-25, Izmir

[11] Savanovic P. & Zeiler W. (2007) Integral Building Design Workshops: A concept to structure communication, 4th DEC symposium, Las Vegas, DETC2007-34377