Methodological start-up of student design projects

Citation for published version (APA):

DOI:
10.21125/iceri.2017.0202

Document status and date:
Published: 16/11/2017

Document Version:
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:
- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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Download date: 10. Mar. 2021
METHODOLOGICAL START-UP OF STUDENT DESIGN PROJECTS:
EFFECTS OF A SYSTEMATIC APPROACH

Wim Zeiler

Technische Universiteit Eindhoven (Netherlands) [w.zeiler@bwk.tue.nl]

Abstract

In connection with the Integral design research project for professional in the Dutch building industry, an educational project was developed, the multidisciplinary master project Integral Design. The concept of the integral design workshop for professionals was implemented within the start-up workshop of our masters' project. The framework of the approach will be described as well as the positive effect on the collaboration between the design team members as result of the morphological approach of the Integral Design method. During the start-up workshop professionals participated in the students' design teams and this specific intervention within the design process has been investigated.

Keywords: workshop, project start-up, morphological overview, professional participation

1 INTRODUCTION

Buildings use 40% of all our energy and thus are responsible for a major part of Global warming. To change this buildings are to be designed more sustainable. More and more requirements are made on the operation of the product/building with minimal energy depletion and environmental pollution. Increasingly, the need is felt to achieve early integration of disciplines and parties. The Architecture, Engineering, Construction (AEC) industry became a knowledge intensive industry, which has to create sustained organizational and societal values [Rezgui et al; 2010]. However, many projects were not able to realise their required value due to managerial problems in the design phase [e.g. Hamzeh et al 2009, Hansen & Olsson 2011, Knotten et al 2015]. The increasing complexity of sustainable building design makes it necessary to consider different ways to design [Knotten et al 2015].

The conceptual building design phase is crucial in the overall design process, determining the life-cycle sustainability quality of a building. The increased complexity of building design inevitably calls for more collaboration earlier in the design process [Lee and Jeong 2012]. Early collaboration of architects and engineers should provide the condition for creation of new solutions beyond specific scope of disciplines [Kovacic and Filzmoser 2014]. Architects should become inspired by engineering and science, according to Beckett [2012], leading to concepts and ideas that can be beautiful, useful as well as sustainable. Design teams should no longer work in a conventional manner through the step-by-step improvement of existing features or adding new elements to existing features. Instead the design team should apply more function-oriented design based on demand, which evolves into a concept with features. A functional structured approach facilitates reduction of the uncertainty in the design process considerably. This would also make it easier to exchange information with the various stakeholders.

The "MacLeamy Curve" (see Fig. 1) demonstrates the importance of making design decisions early in the project to maximize influence of positive outcomes and to minimize the cost of changes. The "MacLeamy Curve" illustrates the transformation from the traditional phases of projects towards the integrated design approach. According to the American institute of architects AIA [2007], this design approach leads to optimized project results and increased worth to the owner. However, the needed collaboration in the early design phase is not easy for the architects as engineers 'speak another language', which are often 'too specialized', and they are often 'not willing to compromise on certain issues' [Kanters et al 2014].
Figure 1. “MacLeamy Curve” design approach’s impact on the design process [AIA 2007]

It is important to understand dependencies in the design process in order to handle them [Kalsaas and Sacks, 2011]. Most of these are related to the coordination, negotiations, mutual adjustment and opinion based communication [Andersen 2011]. Relations in a process follow different logics. One of the logics describes an “everlasting movement”, where everything is connected to each other (see Fig. 2). To be able to proceed, you must make a decision, regarding an element or structure, if not the process stops or it will not start. A concrete decision of a solution might then start a pooled or sequential process, yet a decision turning down a solution, might just set of a new reciprocal process. These are the typical processes displayed in a Gant schedule, and they can be planned and managed by the management planning tools [Pinto 2013, PMI 2013, Knotten et al 2015]. The Project Management Body of Knowledge (PMBOK), developed by Project Management Institute (PMI), is one of the most representative of these [Kloeckner et al 2017]. PMBOK presents the process by describing the activities during the project life cycle (initiating, planning, execution, control and closing), making it thus possible to plan very well to execute latter [Fitsilis 2008, Leybourne 2009, Kloeckner et al 2017]. A second logic is to pursue decisions more in a reflective kind of logic dealing with reciprocal, iterative and intensive processes [Knotten et al 2014], see fig. 1. Standard project management approaches [Pinto 2013, PMI 2013] can help to manage pooled and sequential processes, but it is not an effective tool to manage a reciprocal or an intensive process [Knotten et al 2015].

Design problems are complicated or even wicked as there may be many ways of solving them [Voss and Post 1998, Jonassen et al 2006, Kiernan et al 2017]. This poses difficulties for design teams and highlights the requirement to reach consensus on a variety of matters. Arriving at consensus can be challenging for teams and is affected by cognitive diversity [Badke Schaub et al 2010, Détienne et al 2012, Ostrosi et al 2012, Kiernan et al 2017]. In addition many teams fail to optimally use their distributed information due to a poor understanding of each other, their task, and an overemphasis of agreement seeking at the expense of information elaboration [van Ginkel and van Knippenberg 2008]. To understand groups’ effective use of distributed information there is need to identify factors that are conducive to the elaboration, exchange, discussion and integration of information and perspectives [Kooij-de Bode et al 2010]. There is a need to explore how teams reach agreement during the
conceptual design phase of complex design and innovation problems to better inform how design educators can engage students in teams.

Figure 2. Team task complexity, adapted from Bell & Kozlowski [2002] and Knotten et al 2015.

2 METHODOLOGY

The traditional role of the architect must be transferred into a more intensive interaction with other disciplines and stakeholders in already the conceptual design phase. However this is difficult to achieve and this is why the Dutch professional organizations of architects and consulting engineers started together with TU Delft the project Integral Design in 2000. This lead to research with workshops organized with professionals to test a specific design method based on Methodical Design [Zeiler and Savanovoc 2009] and the extensive use of Morphological Charts and Morphological Overviews [Savanovic 2009]. This research project was continued at the TU Eindhoven [Zeiler 2015, 2017] and implemented it in the educational program of the Faculty of the Built Environment of the TU Eindhoven.

A good project start-up is crucial: therefore we introduced a start-up meeting workshop at the beginning of the project, where the participants got to know each other, understood and agreed upon the goals of the project were. In step 1, the individual design team member’s based on his interpretation of the design brief formulates the most important functions or aspects to be fulfilled in the first column of the morphological charts. Than in the second step he fills the rows with the possible sub-solutions connected to them. So in the first step of the integral design method the individual designer has to make a list of what he thinks, based on his own specialist perspective, are the most important functions or aspects that have to be fulfilled in relation to the design brief. This is then put into the first column of the morphological chart. 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.
Individual morphological charts can be combined by the design team to form one morphological overview, see Fig. 4. 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. Tuckman [1965] has described the development of cooperation within groups. Groups develop themselves in a certain order into a team: forming, storming, norming, performing and adjourning. It is a good model for the promotion of cooperation within a team [Nieuwenhuis 2010], which can be used to illustrate the steps of morphological approach (see Fig. 4).

3 EXPERIMENT: MULTI DISCIPLINARY PROJECT WITH START-UP WORKSHOPS

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. The concept of the integral design workshop for professionals was implemented within the start-up workshop of our multidisciplinary masters’ project. The different design assignment all 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 and as such let the students experience the added value of the design method. Master students from architecture, building physics, building services, building technology and structural engineering participated in these projects. The basis of this project, which serves as a learning-by-doing start-up workshop for master students, is a method with extensive use of morphological charts combined to a morphological overview of the design team. The master project Integral design was initiated by the chair of Building Services in the 2005/06 academic year and since then was held every year. During the start-up workshop professionals participated in the student’s design teams and this specific intervention within the design process has been investigated. The frame work of the approach will be described as well as the positive effect on the collaboration between the design team members as result of the morphological approach of the Integral Design method.
Figure 5 Program and set-up of start-up workshop session 1 and 2

Workshop ‘Masterproject Integral Designnn – MIO’ assignment 1

**Design task: an office building for climate makers with passion**

Wishes:
- A pleasant and healthy working environment for employees is central
- Sustainable and energy neutral
- Promotion of solar-energy
- Kind for nature and humans
- Avoid typical complaints of mechanical cooled buildings
- 5500 m² gross floor area

Different functions with different requirements

Figure 6. Program of requirements design assessment 1 during the startup workshop

4 RESULTS

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. The design teams existed in principle of 4 students from different disciplines. During the last 7 years, in total around 170 students participated in the research. In the startup workshops the students had to practice with the same exercise during all the years which made the outcome comparable. This was the same exercise as had been used during the research with professionals [Savanovic 2009]. Unfortunately in the conceptual phase of the design it is not possible to accurately evaluate the quality
of the mentioned functions/aspects or sub–solution. Only a quantitative analysis is possible by counting the number of mentioned functions/aspects and sub solutions. The number of functions and sub-solutions mentioned by the designers in their morphological charts and the design team’s morphological overview were counted, for an example see Fig. 7.

<table>
<thead>
<tr>
<th></th>
<th>Number of Functions/Aspects</th>
<th>Number of Sub-solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphological Chart Designer 1</td>
<td>11</td>
<td>38</td>
</tr>
<tr>
<td>Morphological Chart Designer 2</td>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>Morphological Chart Designer 3</td>
<td>10</td>
<td>41</td>
</tr>
<tr>
<td>Morphological Chart Designer 4</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>Morphological Overview Design Team</td>
<td>13</td>
<td>54</td>
</tr>
</tbody>
</table>

Figure 7. An example of the transformation of the individual morphological charts into a morphological overview, indicate the functions/aspect in the morphological overview and where they came from.
The number of functions and sub-solutions mentioned by the designers in their morphological charts were counted and the average numbers of functions and solutions as mentioned by the design teams are represented in Fig. 8. The same was done for the sub-solutions mentioned by the design teams in their morphological overviews.

Figure 8. Average results workshops Integral Design for students compared with that of professionals from the research by Savanovic [2009].

Here only a brief selection is given of all the results and a comparison with the professional workshops Integral Design. More results and information were presented by Savanovic [2009] and Zeiler [2015, 2017]. Compared with the results of professionals the students generated on average more functions/aspects as well as sub-solutions than the professionals in their morphological charts. There was however no significant difference between students and professionals in their morphological overviews. 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 (+28%) and sub-solutions (+57%) (see Fig. 8). In both cases there was a positive effect: an increase of number of functions/aspects and sub-solutions mentioned by the team’s morphological overview compared to the numbers of the individual morphological charts. However, there were also a few teams where one of the individual design team members had more functions/aspects mentioned than were taken over in the morphological overview, but these were exceptions.

5 DISCUSSION

Our research is focused on the conceptual design phase. However, as the sub solutions are put forward in the conceptual design phase, there is no possibility to make a statement about the quality of the mentioned proposals. In this face there is often not enough information, this being gathered during the design process. Therefore, we only included quantitative results in relation to the effect of the intervention that we made to the conceptual phase of the building design process. The only thing about quality might be that the more functions and aspects are mentioned the broader the analysis of the design brief might be done.

The results of individual designers can show large differences, see Fig. 9, depending on all kinds of aspects relating to personality, social capabilities, attitude etc. of the individuals within the teams. As a result also the outcome of the design teams show a large variation, see Fig. 10. Therefore, we selected students from our University who all had similar educational background and experience, as well as were about the same age. Nonetheless there is still a big difference in the manner people are able to express, discuss and share their thoughts in design sessions. It would be interesting to research more diverse design teams. As can be seen from figure 9 and 10 the number of mentioned sub-solutions shows individually as well as that of teams large differences (min. 4 max. 52 average 20.1) individual designers and (min. 12 max. 71 average 31.4) for design teams.

So clearly the difference between the individual designers have a large effect on the absolute outcome of the process. However, in almost all cases (around 95%) the quantitate outcome of the design team is higher that of the individual designers and especially the design team’s discussion will improve their
understanding of key issues from each discipline involved in the design process and thus also improve the quality of the mentioned functions/aspects and sub-solutions in the morphological overview.

![Figure 9. Comparison of the number of sub solutions in their morphological charts by individual student designers during 2011-2017](image)

![Figure 10. Comparison of the number of sub solutions in their morphological overviews by different student design teams during 2011-2017](image)

6 CONCLUSIONS

A new design approach, Integral Design, was developed to support all the disciplines involved in the building design process by structuring the communication and solution generation process in steps and structuring the information flow about the tasks and solutions of the different disciplines. The method enables, within the conceptual phase of the building design process, a structured approach at the start of the building design process. All the requirements of the design task become more transparent to all designers from different disciplines and they become more a design team with a common goal.

The presented intervention to the conceptual phase of the building design process had a positive effect on the number of proposed sub-solutions and also on the amount of functions and aspects considered in this early but of crucial importance phase of the design process. This indicates that the effectiveness and productivity of design teams can large improved by adding structure to the process to the design team. Making the interpretations of the design brief transparent enables easier exchange of information and reduce misunderstandings. This will also improve team members understanding of each other’s tasks and results in better communication and combined efforts to further generate more part solutions. This way students, architects and engineers, will be better prepared for their future professional collaborative role in sustainable development by means of integral design approach.
The conceptual design phase can be analysed and used to further improve the design team's process. The use of morphological charts and morphological overview enables to reflect on their collaboration process. Results showed that Integral Design was a good way of presenting and sharing the knowledge and experience of each design discipline/member. The main lessons from the paper are that Integral Design with its use of morphological overviews stimulates collaboration and exchange of ideas and perspectives between architects and engineers in the very important early stage of the conceptual design phase. It helps them with their communication and collaboration. The morphological approach is a good method for supporting the education of a new generation of architects and engineers with their new roles in the highly complex tasks of designing sustainable cost effective nearly Zero Energy Buildings.

ACKNOWLEDGEMENTS

This research was done in cooperation with the Dutch engineering consulting companies: Deerns, Smits van Burgst, Valstar Simons, RHDHV and Nieman. The project was financially supported by the professional organisations UNETO-VNI and OTIB as well as the foundations WOI and PIT. The earlier research which formed the basis was supported by the Dutch Society of Architects BNA, the Dutch Society for Consulting Engineers ONRI-NL and the Dutch Society for Building Services Engineers TVVL.

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