339: 'Duaal' learning program and Multidisciplinary Master Design Project for sustainable climatic design

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Abstract

The development in (Dutch) building practice necessitates developments in other aspects, besides specialized and professional skills, a new integral approach in education and the introduction of such an approach into building design practice. Eindhoven University of Technology (TU/e) started the 'Duaal traject' (route), in which students merge (combine) working in the practice and studying at the university at the same time. In 2005, the building services chair of the Faculty of Architecture, Building and Planning of the TU/e commenced a multidisciplinary master project 'Integral Design' focused on a sustainable climatic design. In these (this) Multidisciplinary Master projects students of architecture, building technology, structural engineering and building services participated. They, the students begin with a two days learning-by-practice workshop which was implemented and tested in collaboration with experienced professionals from the Royal Institute of Dutch Architects (BNA) and the Dutch Association of Consulting Engineers (ONRI). These workshops by themselves have become part of the permanent educational and professional program of the BNA. This is one of the few projects in which the practical experience is transferred into the educational academic program; normally this process functions the other way around. The results of the combined education of students and professionals is presented and discussed below mentioned.

Key words: dual education, integral design, knowledge sharing, knowledge creation

1. Introduction

Complexity of Building Services has increased during the last decade. Traditionally, the Building Services have made out less than 10% of the budget and rather simple systems. Nowadays, the Building Services have become quite complicated systems and form at least 30% up to 50% (hospitals) of the budget. Practitioners have been 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. Modifications are seemingly inevitable as professionals are able to solve difficulties on an academic level. In the late nineties, there was a strong urge from the industry to the university, to start with initiatives in order to change the worrying situation of the poorly qualified people in the building services industry.

Currently within the context of the Dutch Building Practice, 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 [1]. To reduce these failure costs, collaboration between different design disciplines becomes of considerable importance, as the design tasks which designers are confronted with, become progressively more difficult. The synergy between different disciplines involved is necessary to attain the best designs. It no longer suffices to just merely solve the problems which arise at the level of detailing on the borderlines of the disciplines.

This is caused by different and often changing aspects. One of the complicating aspects in building practice is the different cultural backgrounds of architects and engineers and their different approaches to design [2]. This miscommunication is caused by not speaking a common language as the architect and the engineer feel the necessity to change to improve the design process.

In 1960, the basic improved cooperation between the architect and the engineer was recognized by the famous architect Le Corbusier, see fig.1 [3].

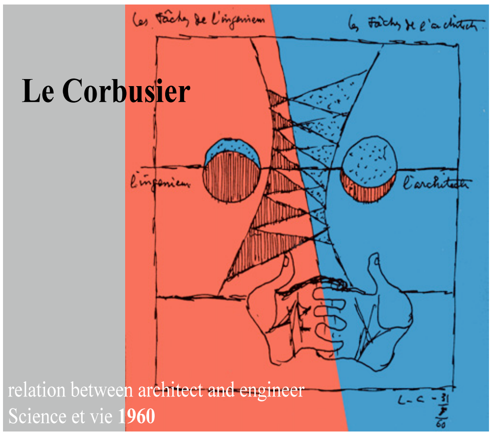

Fig 1. The necessary relation between architect and engineer by Le Corbusier

Le Corbusier explains in a very appropriate way, the roles of the architect and the engineer [4]: “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” [3].
The architect and the engineer shall work together from the very start of a design project and will aim to reach synergy by combining the knowledge and the experience of the respective disciplines.
The present situation in Dutch building practice, where building partners hardly furnish a collective good answer for a variety of questions from society, is determined by a large number of different and often mutually influencing factors that require a broad approach on a variety of levels. To improve this situation, changes on the three levels are required:

1. Process level – to improve design process to fit all involved design disciplines;
2. Product level – to improve the final product (building as a whole, as well as its parts);
3. Culture level – to bridge the gap between ‘Design’ and ‘Engineering’ worlds, in case of the building design specifically between architects and (building services) consultants.

To realize all three aims, an integral approach is desired 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. Transformation is taking place towards an acquaintance society which causes structural changes in the learning and work demands of professionals [5]. Nowadays, knowledge is crucial for the success of problem solving and task performance [6].
Due to the dynamics in the knowledge economy, continuous learning is expected by (suggestion: delete knowledge) professionals [7, 8]. Yet, there is little understanding of what is required to design adequate on-site learn-work environments that directly facilitates learning with the learning and knowledge resources of any organization [9, 10]. It is advisable to analyze all different aspects of building design in a more integral ways to achieve an integral approach to building design. This integral approach can eventually lead to integral process, team and method – all the required conditions in favour of design of the end product.
In paragraph 2 we discuss our Duaal learning traject Building Services with “The employee combined work with study”, the duaal traject. In paragraph 3, we report on the workshops for professional architects and engineers. Our “Multidisciplinary master design project for sustainable climatic design” which brings back the experience from the practice to the university is described in paragraph 4. The experiences of all three forms of educational interaction between the university and the industry are given in paragraph 5.

2. Methodology: Duaal learning traject Building Services

In 1998, the Dutch government launched the dual education as an experiment in universities. About 28 university courses were involved in this experiment. A ‘Duaal traject’, is defined as a study route in which students combine working in the practice and studying at the university simultaneously [11, 12].
The Faculty of Architecture, Building and Planning (ABP) of the Technical University Eindhoven contributed also to this experiment with their course Building Services.
The MSc Building Services has been established in 2002 as a result of the Bologna declarations. With the introduction of the bachelor-master structure in Europe [13], the faculty board of ABP decided to exclude the students of the bachelor and only to incorporate the master Building Services to offer the means of a duaal education. Students can pursue this course either as full time student or duaal student.
The program of the course, Table 1, is fundamentally the same for both regular students and duaal students. Main focus of the educational program is sustainable climatic design. The course load is given in ECTS (European Credit Transfer System) credit points. 1 ECTS equals 28 hours of study. This includes preparing for and attending classes, reading books, writing papers, studying for tests and exams etc. In ECTS, 60 credits represent the workload of a year of study.

Table 1: MSc BS 120 ects program 2008/09

Code	Subjects	ects
7Y400	Design methodology	3
7Y320	Building safety	3
7Y410	Intelligent buildings	3
7S532	Heat and moistures	5
7S750	State of the art building performance simulation	3
7S892	CFD for building eng.	3
7Y700	Sustainable building systems	3
7Y900	Health and comfort	4
	Free subjects	16
7YS15	Master project 1	14
7YS25	Master project 2	14
7YS35	Master project 3	9
7YY40	Final project/thesis	40

However, the educational program comprises specific features that are exclusively fitted to for the needs of the duaal students, the companies they work for, and of course, the essential academic level. Significance of these particulars

is the structure of classes and projects accordingly. The students accomplish most of their projects on subjects related to their work in the companies.
(Young) employees with a bachelor background are allowed to participate in the course. The duaal employees obtain enough time to follow lectures at the university (minimum one day a week). Both employer and employee have the same professional goals to achieve in the future. Both have to work on a vision of how the academic knowledge of the university will be shared.
An important focus is in which manner duaal students and their supervisors solve potential conflicts of interest between the academic requirements, and those of the practice/industry. Such problems are avoided by letting the duaal students and their industrial supervisors select a subject of special common interests; they formulate the general and specific objectives, the methods and the contents of the rapport. A supervisor of the university evaluates the proposal in advance. If the proposal involves enough challenges and has attained the academic level of complexity, an expert of the university will coach the duaal student during the project. This procedure is followed for 3 projects (2 of 14 ects and one of 9 ects) and a final project (40 ects). Two examples of final projects are given.

3. Workshops: learning by doing education

Integration of activities of different disciplines involved in building design such as architecture, building services, building physics and construction are mandatory. Research on communication in construction teams Emmitt and Gorse [14, 15] shows that face-to-face (interpersonal) communication is the most effective communication medium. Currently, cooperation between (Dutch) building design disciplines is unsatisfactory; better organization of building design process is apparently necessary [16]. Therefore, the starting point was to bring those disciplines together, in a design team setting. Communication between different members of a design team is generally a notorious difficulty, especially in the nearly stages of the design process [17]. It is important to stress that in our opinion, communication must be transparent; not only internally for design teams themselves, but also for external stakeholders. After all, designing is a form of service provision, meaning that a design team designs for a client and not for the design team members themselves.
We believe that a suitable environment for integration of activities of building design teams is a workshop setting. The first series of workshops were organized during 'Integral Design' project [18] that was conducted by the Dutch Society for Building Services (TVVL), BNA and Delft University of Technology (TUD). The main conclusions of this project, such as the suitability of workshops for integration of design team activities and necessity of constitution and knowledge of design team members, formed the basis for further development of BNA-ONRI-KCBS workshops within PhD-projects initiated by Knowledge Centre Building and Systems (KCBS) in which TNO (Dutch Institute for applied science) and TU/e (Technische university Eindhoven) cooperate.
Since 2005, together with BNA and ONRI, we organized 5 series of workshops with experienced professionals from both organizations who voluntarily participated.
The participants of different disciplines, that were involved, were randomly assigned to different design teams that ideally consisted of an architect, a building physics consultant, a building services consultant and a structural engineer. A three days rotation of practice like 'building team' concept was set at the beginning. All disciplines were present within the design team initially. Later, the integral design method workshops have evolved to a two-day series.
The ongoing series of workshops are still organized in cooperation with BNA and ONRI. All participants are experienced practitioners who voluntarily attend "learning-by-practice 'Integral design' workshop". The only selective criterion we use is the requirement to be a member of either BNA or ONRI. The participants are randomly assigned to design teams that ideally consist of an architect, a building physics consultant, a building services consultant and a structural engineer.

4. Multidisciplinary master design project for sustainable climatic design

In addition to the aforementioned structure of the MSc Building Services program, an outstanding major project is the "Multidisciplinary master design project" itself. The basis of this project which serves as a (combined work and study) learning-by-doing workshop approach, is implemented and tested by experienced professionals from the Royal Institute of Dutch Architects (BNA) and the Dutch Association of Consulting Engineers (ONRI).
Interaction between the practice, research and education forms the core of 'integral approach'; we implemented the same workshop pattern and methodology within our multidisciplinary masters' project on TU/e, Department of Architecture, Building and Planning. The preliminary pattern of this project, initiated by the Building Services chair of Building Physics and Systems unit, took place in the 2005/06 academic year. All students of architecture, building technology, building services and structural engineering took part in the current three patterns.
The students from architecture, building physics, building services, building technology and structural engineering were offered the opportunity to participate. The procedure was the same for BNA-ONRI-KCBS workshops; the only criterion for participation was the 'membership' of 'master students group'. The

students were assigned to design teams of different disciplines randomly, to have all disciplines represented in each team. The whole project took 14 weeks. The specific aspect of the office building design assignment was to realise 'sustainable comfort', a Zero Energy Solution, bearing in mind that in the current situation, 40% of primary energy consumption is due to built environment. Such a 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 BNA-ONRI-KCBS workshop formula was used to start the design team work.

5. The results

5.1 Overview duaal educational traject

Since September 2002, twenty-five duaal students have started with the MSc Building Services. Seven duaal students received their diploma. Although it is not easy to combine work, study and most times a family live, only a few students decide to end their study prematurely; most dual students are ambitious and well motivated and therefore, finish their studies.

A noticeable outcome has been the priority these duaal students achieved from high qualified companies. These companies have simple access to the university and vice versa. This was one of the main goals of the duaal education experiment.

Original duaal learning is proposed and introduced for students who wish to combine study and work. In this fashion, students obtain better initiatives on what exactly they wish to do in their future, and they have better understanding on the concepts that companies demand. But, instead of young students, (young) ambitious employees of companies prefer to combine work with an academic course. The side effects of such preference forced the companies to seek collaboration with the academic institutes. This opportunity gives both universities and companies a more meaningful prospect. This also leads to some interesting cooperation within duaal students projects.

5.1.1 First example duaal student project

The first example is a final project worked out by a duaal student who is in the service of an engineering consultant for installation technology: The project involves the reliability of active showcases to be used at the Dutch Maritime Museum located at Amsterdam. This Dutch Maritime Museum is the only Dutch national museum without climate control. The building was built in the year 1656 and has remained up till now in the original state. Because of the monumental value of the building these conditions can not be improved. For this reason the museum has decided to expose the vulnerable objects, after an extensive renovation, in active climate show cases. Less sensitive objects will be shown in the exhibition rooms without show cases. Within the framework of a graduate project measurement and supplementary simulations have been carried out. The optimum system configuration for the air supply in the show cases has been obtained by mounting an air supply plenum, equipped with perforated plates, at the bottom of the show case. The measurement proves a very stable situation when the interior temperatures of the show cases are a little lower than the surrounding temperature.

5.1.2 Second example duaal student project

The second example is a final project worked out by a duaal student being an employee of a power company. This project concerned the design of a Ground Source Regeneration System. Most heat pumps installed in the Netherlands use the ground water from aquifers as heat source. If a collective heat pump system is installed, the amount of energy that is extracted from the ground is significant. When this ground source energy extraction takes place for a long time, the ground water in that area will cool down. A heat pump fails to function if the source becomes too cold, so this should be prevented by adding heat to the ground source. This process is called "ground source regeneration".

In this project, two regeneration systems have been designed for typical Dutch dwellings, discerned by their ventilation system. One dwelling has a mechanical exhaust ventilation system and one is equipped with balanced ventilation and heat recovery.

In order to investigate the performance of the regeneration systems, capacity estimations have been performed. To validate the estimations, simulation models are created in the Matlab/Simulink environment. These models simulate the heating demands of the selected dwellings and give insight in the performance of both regeneration systems.

5.2 Results professional workshops

Over the past four years, 5 series of workshops have been conducted. These typically include around twenty participants and lasted for two or three days. All designers of the series 1 to 4 were congregated six months after their workshop participation in order to get their 'second opinion' on the proposed approach and also to assess the effects that the 'ID-methodology' had entailed on their practices. The 5th workshop was held in February this year, so the questionnaire deadline of six months was not reached yet. A total of 107 designers participated in these four workshop series, in which 74% of the designers were present during all days. The average age of the participants, in both members of either BNA or ONRI was 42 and they had an average of 12 years of professional experience. At the end of the workshop, the attendees were asked to fill in a questionnaire and were asked about the importance of the use of Morphological Overviews within the design process and about the concept of the workshop itself.

The responses provided important insights into practitioners' impressions of (mainly the usability of) the method. The results from the workshops indicated that the integral design method had been received positively by professionals in practice.

Table 2: Comparison between ratings direct at the end of the workshops and after a working period of six months.

	average *Direct after Series*	*average* After 6 month's
Number participants	107	69
Percentage returned questionnaires	94%	53%
	Rating(1-10)	Rating(1-10)
- overall rating workshop	7,2	7,1
- workshop met expectations	6,7	7,0
- workshop fit for professional education	8,3	8,4

5.3 Results Multi-disciplinary master project

The results of the first multidisciplinary master project pattern are presented and discussed here. At the same time, a comparison is made with BNA-ONRI-KCBS workshops for professionals, mirroring the encountered differences between students and professionals to literature-based differences between novices and experts.

The work of design teams was photographed, in 10 minute intervals. This way, the progress in time of the number of proposed alternatives was registered. Changes in the amount of proposed alternatives of design teams could be traced through the quantitative observations. As an example, average progress of a number of generated alternatives is presented as developed by professional design teams during the workshop series 2 in 2005, see figure 3 and 4.

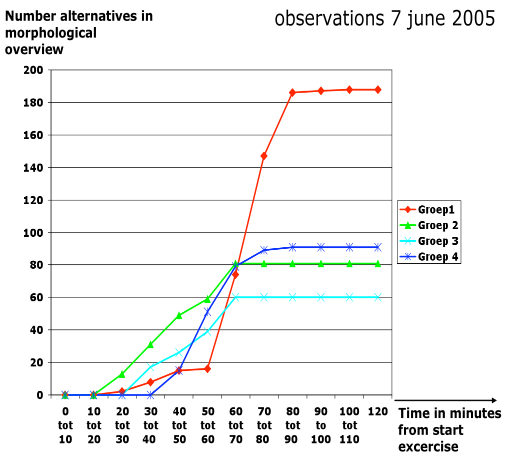

Fig 3. The number of alternatives produced by professionals during the workshop series 2

The number of alternatives that any design team could produce is directly related to the number of functions and aspects they observed. The strange boost within group 1 compared to the other groups was interesting. This was suggested to be due to a strong reflection within group 1 after a short break which took place 60 minutes after the start.

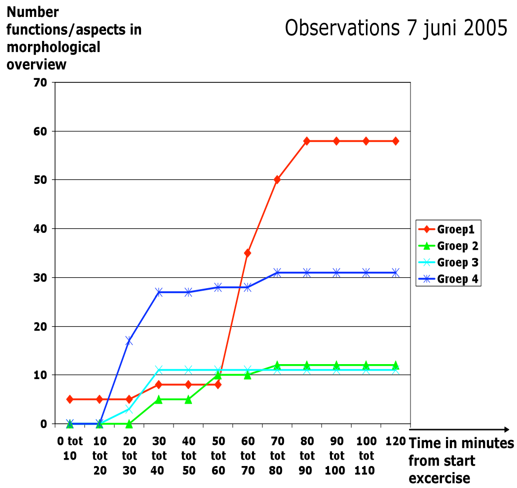

Fig 4. The number of produced functions/ aspects and alternatives by professionals during the workshop series 2.

The numbers of defined functions/aspects by design teams are indicated on the Y-axis. It is remarkable to realize that the total number of functions that design teams defined as relevant to the design assignment, was similar for both practitioner and student design teams. The number of proposed alternatives and the way design teams generated them was, on the contrary, completely different. The practitioner design teams tended to define functions first, and then to proceed with producing relevant solutions. This pattern was even more obvious with 4-discipline design team [19]. The quality of generated alternatives/proposals was not assessed. Evaluation was aimed only at if use of morphological overviews led to the expansion of 'field of possibilities' [20].

6. Conclusions

In this paper, three cases were discussed in which the connection was made between industry and university in fields of education. Firstly, the concept of a duaal education followed by employees in building services branch was presented. Secondly, we described the multidisciplinary workshops to professional architects and engineers for BNA and ONRI. Thirdly, our multidisciplinary master project was highlighted.

The dual educational program, the workshops and the multidisciplinary projects provided us with many insights, some of which were discussed in this paper. 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 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 professionals 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 openness of participants for new methods is also greater in comparison to their daily routine, that in not often emphasized. 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 professionals' education model is built.

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 makes it possible to work in a structured and transparent way using the framework of the Integral Design matrix. Ongoing tests of methodology are being conducted through workshops with industry professionals from the Royal Institute of Dutch Architects (BNA) and the Dutch Association of Consulting Engineers (ONRI). Over 100 professionals participated in these workshops.

Our presented approach of combining education for students and professionals is of a greater value in the field of sustainable climatic design. Besides the good ratings of the questionnaires by the participants of the workshops, the best proof of success may be the fact that the workshops have become part of the permanent professional educational program of BNA since 2006. An additional 'proof' 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 workshop was held on March 31, 2008. 16 professionals attended this workshop that was evaluated with an overall rating of 7.5 on a 1-10 scale.

7. Acknowledgments

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