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'INTEGRAL DESIGN' WORKSHOPS: IMPROVING BUILDING PRACTICE AND EDUCATION THROUGH METHODICAL APPROACH FOR MULTIDISCIPLINARY DESIGN TEAMS

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ABSTRACT
Integral design shows high promises to reduce failure costs and to improve design quality. Based on this assumption, the Royal Institute of Dutch Architects (BNA), the Dutch Society for Building Services (TVVL) and Delft University of Technology (TUD) started a research project on Integral Design in year 2000, which resulted in a series of workshops for architects and HVAC consultants. This project was succeeded by new research within the Knowledge Centre Buildings and Systems (KCBS), in which Eindhoven University of Technology (TU/e) and the Netherlands Organization for Applied Scientific Research (TNO) cooperate. The ongoing research utilizes workshops, in which already over 220 professionals from BNA and the Dutch Association of Consulting Engineers (ONRI) participated, for development and evaluation of integral design methodology in the domain of sustainable comfort systems. Both workshops and 'integral design methodology' are used as part of the education program for continuous BNA-ONRI professionals' personal development.
This paper presents theoretical background for knowledge sharing and knowledge creation within building design teams, implemented in form of 'ID(Integral Design)-methodology'. Additionally, development of workshop experimental setting for measurement of its effects is described.

Keywords: integral design, design methodology, multidisciplinary design teams, design knowledge, workshop, sustainability

1 INTRODUCTION

1.1 Integral approach
The present situation in building (design) practice, where "it is hard for building partners to give a collective good answer for variety of questions from the society" [25], is determined by large number of different and often mutually influencing factors that require a broad approach on a variety of levels. For improvement of this situation, changes on three levels are needed:
1. process level – in order to improve design process to fit all involved design disciplines;
2. product level – to improve the end 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 building design specifically between architects and (building services) consultants.

To realize all these three aims, an integral approach, as defined by Quanjel and Zeiler [25], is needed: "Integral approach 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. This integral approach can eventually lead to integral process, team and method – all the required conditions for design of the end product." [25]
For such high ambition, a true culture change, it is not enough to just 'prescribe' new ways of doing things. History shows that management of design processes through prescriptive methods is not sufficient for large scale (of) design problems/situations [6]. This is partly due to a design problems' peculiarity, being described as 'ill-structured' [31] or even 'wickedness' [26].
The prescriptive methods are often based on experiences of the researchers who develop them. These experiences are either recognized, and as such considered 'open doors', or not recognized and turned

down. Just reading about design methods is not enough to really get grip on the real philosophy behind them. Designers have to be thought how to work with design methods in order to be able to implement them. Because one has to endure himself that something is indeed worthwhile pursuing, a 'learning by doing' course is used in our pursuit for culture change in building design practice. Insights acquired from observing this implementation have to subsequently be used for further improvement of design methods.

1.2 Individual vs. team

Optimal integral design solutions are only possible by uniting various viewpoints of different disciplines involved in building design process on the same subject. In order to achieve integration a single designer has to 'force' himself to look from different discipline based viewpoints while designing. Even if he/she has the ability to deploy most of these viewpoints, he/she usually doesn't have enough specialist knowledge to assess all of them in depth. This is the reason why we assume that a multi-discipline design team view on design, instead of a mono-disciplinary view on design, is a very promising way to pursue building (design) integration. Besides broader knowledge base, the advantage of a design team approach is that different design team disciplines implicitly represent different views on the same aspects of design task at hand.

2 DESIGN PROCESS

2.1 Primary focus

Our aim is to improve conceptual design (process level) by defining an 'integral design (ID) methodology' that increases potential for creation of integral building designs (product level). We assume that positive results on these two levels, which we try to demonstrate in our research, eventually will trigger and support culture change in building design practice. For this to happen, continuous implementation of achieved results in the setting of research-education-practice triangle is crucial. Besides research and development goals, this is the major function of workshops.

The main reasons for focusing on design process instead on design product level are because of *subjectivity of* design task *interpretation* and of design (as product) *evaluation*. (A representation of any stage in design development, from initial sketches, models and drawings to prototypes and final spatial objects is considered 'design as product'.)

It is known that designers/architects tend to reinterpret initial program of requirements [15], being it in rational (through analysis) or intuitive way (by framing design situation) [22,30]. However, in both cases this reinterpretation can't be considered objective. Moreover, a designer often makes different interpretations of the same design assignment each time he/she is confronted with it again. In these types of situations it is hard to compare design results (as products) which are based on different interpretations, even though the designer might be the same. We therefore argue that objective comparison concerning integration aspects within building designs, made by *different* designers, is not possible. Even in case of independent experts' deployment, the measurements regarding evaluation of integral designs remain subjective [9].

2.2 Preliminary phase

Although integral approach encompasses the whole building life cycle (from design, construction and use, to demolition and disposal), for its implementation within design team context and regarding its design part, we limit ourselves to the *preliminary design phase*. The main reasons for this restriction are time factor and decision making.

Because the time reserved for primary design phase in practice is often short compared to the whole design process, let alone building life cycle, it seems appropriate to couple the use of (developing) 'ID-methodology' to a time pressurized context. Any form of course, classes or lessons can be considered as time pressurized context in comparison with actual projects in practice. From practical point of view, since during workshops design assignments are introduced in a short period of time, it is only feasible to ask participants to conceptualize their initial interpretations/ideas.

The most important decisions in building design processes are taken during conceptual design phase [37], even though not all information is available then. This leads to an influence/information contradiction (Figure 1, left), where sequential introduction of different disciplines into design process doesn't support accumulation of information for development of design (as product). The information

becomes too late available in the process, when influence on design is limited. Or, in other words, when positive influence on 'design as product' often has negative implications on 'design as process'.

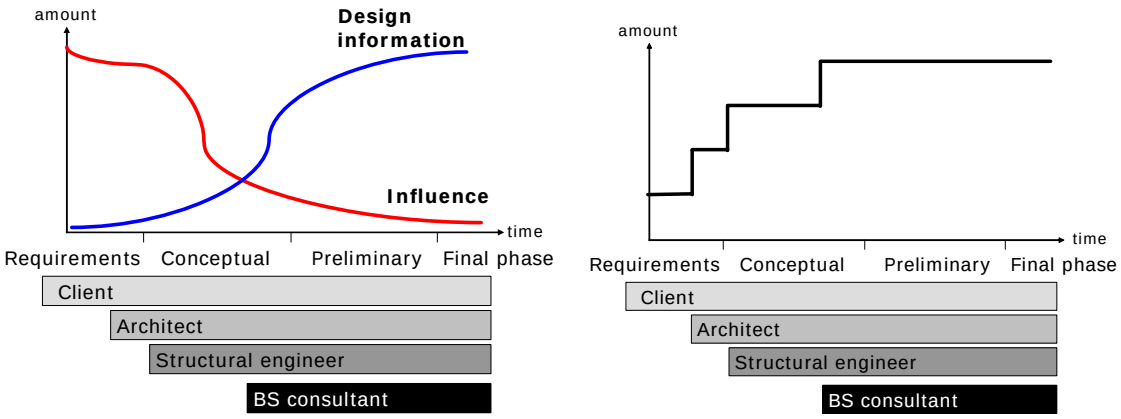

Figure 1. Influence/information contradiction (left) and the availability of knowledge (right)

The accumulation of design information is dependent on two things: development of design (as product) and availability of knowledge that can transform information into design (as product). This combination is the reason why two curves on the left side of Figure 1 are not strictly following introduction of different design disciplines in design process.

Design solutions and design problems are evolving together [30]. Because of this duality, initial requirements and subsequently required essential design information often change according to the in time increased insights about design task. Within traditional design process organisation types some disciplines that have to provide parts of this information at the start of design process, simply aren't there. Instead, one must try to find this information using reference books, databases, case studies etc. However, information always has to be *transformed* into design, and this requires certain skills, which we regard as *implicit* design knowledge. Implicit knowledge is coupled to actual person/designer (looking at design from different viewpoints…), while information is discipline based. Considered separately from persons and their skills, information could also be described as a special form of knowledge. In this sense, a certain discipline can indeed be characterized by *explicit* knowledge that it represents. The previous are the reasons why we focus on term knowledge instead on information. Besides, the emphasis on availability of information implies that precise (objective) definition of design task is needed. Moreover, it indicates that objective definition of design task is possible, which in the past proved as a pitfall leading to defining designing as purely rational (scientific in classical meaning) activity [18,23]. The right side of Figure 1 represents availability of knowledge during different phases of design process. In this example all disciplines contribute the equal amount, but in reality this is dependent on the type of design task, quality of designers etc. The preferred situation is the maximum amount of knowledge available from the start of design process. 'Amount' is qualitatively defined by presence of all design team disciplines, because of inability to actually measure implicit knowledge.

3 DESIGN (TEAM) KNOWLEDGE

3.1 Object knowledge

Based on above considerations we propose that, and in contrast to traditional sequential building design approach, building design team should start working on a design task from the very beginning of primary design phase. Such building design team should consist out of an architect, a structural engineer, a building physics and a building services consultant. Even though the mentioned disciplines do not represent all stakeholders within building design processes, they are considered to be the ones that contribute most in defining properties of design object (as product) – namely building (parts). In contrast to clients, constructors and managers, design team's disciplines posses *object design knowledge*. 'Object knowledge' is knowledge on the characteristics and properties of artefacts and their materials [34]. Van Aken's distinction between object, realization and process design knowledge proves to be very helpful in explaining what we are trying to do: integrate *explicit* discipline based

'object design knowledge' through implementation of 'process design knowledge' (represented in our case by developing 'ID-methodology').
To be able to relate knowledge of different disciplines, we have adopted the view of designing as *the* most central activity in engineering [21]. However, it has been confirmed [29] that at present most of building design team disciplines actually don't act as designers during (traditional) design processes – meaning that there exists an artificial separation between 'design' (as a generalist; architect's) and 'engineering' (as a specialist; consultant's) activity. This duality forms an obstacle that has to be overcome. If we consider relations between different disciplines within design teams as a form of social system, the question is if (in our case design) activities can be imposed on 'design team system' through external (meaning outside intrinsic design activities) management. Certain approaches suggest that each system, if we look at its constituting entities, can only *organize itself* [1] – resulting in what is called emergent behaviour [17]. This self-organization is also systems' strongest point. It doesn't need any complicated prescriptive rules, at least if management is left to the system itself. External intervention is considered contra productive. This would mean that system's knowledge could be structured through self-searching/-organization. The specific things we are keen to understand and improve within 'design team system' is how to, firstly, *communicate* discipline based object design knowledge (by making it explicit) and, secondly, how to realize *transformation* of this knowledge into integral design concepts; taking into account self-organization of design teams.

3.2 Communication

In order to enhance building design processes, communication between various disciplines has to be improved. Currently, cooperation between design disciplines is unsatisfactory; better organization of building design process is necessary [13]. Communication between different members of a design team is generally a notoriously difficult problem, especially at the early stages of design process [10]. It is important to stress that communication in the first place needs to be transparent; not only internally for design teams themselves, but also for external stakeholders. Designing falls under service providing, meaning that design team designs for the client and not for themselves.
Communication within groups can generally be discerned in social-emotional and task neutral [2]. Similar distinction is made in literature on design teams, where distinction between task and team work, or content and process activities has been made [11,33]. In our 'ID-methodology' development we are primarily interested in task related communication. Given the fact that in our setting design teams have restricted amount of time to work on design tasks, we assume that this will automatically lead to more task related communication. Some research results support this assumption by showing that time pressure prevents teams from engaging in 'social niceties' [8].

3.3 Knowledge transformation

Besides communicating object design knowledge to each other, design team members/disciplines have to be able to use it for designing. Theoretical background on how design knowledge could be transformed into integral design concepts is found in "C-K theory" [14]. C-K stands for concept-knowledge relation. This theory defines design as a process generating co-expansion of two spaces, space of concepts C and space of knowledge K: "A design concept is a proposition that can not be logically valued in K... Concepts are candidates to be transformed into propositions of K, but are not themselves elements of K (properties of K can however be incorporated into concepts)… If a proposition is true in K, it would mean that it already exists and that we know all that we need about it (including its feasibility). Design would then immediately stop. There is no design if there are no concepts. Without the distinction between the expansions of C and K, design disappears or is reduced to mere computation or optimization." In our view, optimization through merely (re)combination of already existing object design knowledge leads only to redesign (Figure 2, RE).
We focus on possibility of expanding concept space with integral design concepts (Figure 2, ID) and on producing new object design knowledge (Figure 2, nODK). A concept not being true or false (within K), the design process aims to transform this concept and will necessarily transform K [14]. At the end of process of generation and integration of concepts, transformation of existing object design knowledge within design team into new object design knowledge takes place, allowing design team members to acquire new insights in this 'learning by doing' approach.

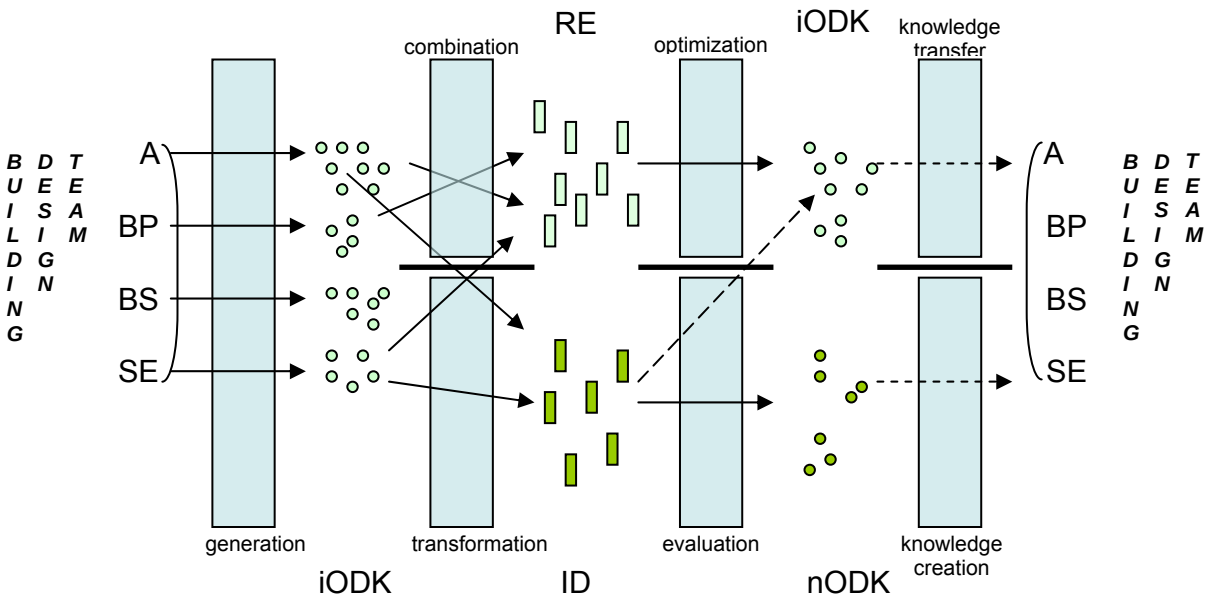

Figure 2. Combination vs. transformation, knowledge transfer vs. knowledge creation; 'ID-methodology' design model

In our case K is defined by initial object design knowledge that participants bring into design team (iODK). Making this knowledge *explicit* enables designers/participants to use it for creation of design concepts. What we are curious about is if these concepts are *integral* (ID), some would even call them innovative, or just plain combinations (RE). The problem regarding innovative concepts / knowledge is that they are mostly related to the present state-of-art. We, on contrary, are focusing only on *knowledge within design team itself*. Now, if we assume that communication aspect can be measured, for example using Bales' Interaction Process Analysis categorization [2], the question is how we can measure (design) knowledge? Our operational definition is the one of only explicitly presented/communicated object design knowledge. Implicit knowledge is considered not directly transferable to other design team members and, as such, isn't treated as a research subject. If we were concerned how designers utilize implicit knowledge, in other words if we were researching *individual* design thinking, it would indeed be one of the essential aspects. Instead, we are interested in how explicit object design knowledge is transformed/integrated within building design *teams*, assuming that different design disciplines are (on average) of the same standard, because of their similar level of education and daily practice.

The essential aspect of design (thinking) is often referred to as creativity [7]. Although we are aware of significance of creativity in design thinking, we are not interested in how this process is unfolding, but if, when and how often it takes place within building design teams setting. People can be credited with creativity in two senses, described as P-creativity and H-creativity: P stands for psychological and H for historical [4]. The P-creativity represents creation of ideas which are new to the person that 'comes up' with them, whether this person immediately realizes their significance or not. These ideas are 'new' no matter how many other people may have had the same ideas already. H-creative ideas are fundamentally novel with respect to the whole of human history, and people usually have them in mind when they're speaking of 'real' creativity and 'real' innovative proposals. In case of design teams we consider transformation of object design knowledge, introduced by different design team disciplines, as design teams' P-creativity process. In other words, with application of 'ID-methodology' we are concerned how to stimulate design teams to produce, for themselves new, integral concepts. Seen in this way, *design within our integral approach represents realisation of potential for creation of new object design knowledge through integration of discipline based explicit object design knowledge into integral design concepts*.

By observing if proposed 'ID-methodology' for building design teams enhances emergence of integral design concepts (ID), we can say that (within specific context of a particular design team) potential for creation of new object design knowledge is realized. This new knowledge increases the possibility of arriving to 'satisficing' final solutions in subsequent design phases of a given situation (within specific design team, regarding given design task and using 'ID-methodology'). *The number of integral design concepts produced by design team is then the measure for this potential.*

4 INTEGRAL DESIGN METHODOLOGY SETTING

4.1 Workshop formula

A suitable environment for integration of activities of a building design team is believed to be workshop setting. The workshops are seen as a self-evident way of working for designers, that occurs both in practice as during their education. They are however not predominant way of working in practice, where most of time different disciplines work separately. The actual designing, in the full design team line-up happens only occasionally and mostly at the very beginning of the project. Even then the purpose of (workshop) meetings is often just to get better acquainted with each other. Besides full design team line-up there are a number of other advantages of workshops with regard to standard office situations, 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, repetition of the same assignment and comparison of different design teams and their results. The openness of participants for new methods is also bigger than during daily routine, something that can't be emphasized often enough.

Until now 12 workshops involving design teams were organized, with more then 220 participants. In all except one, workshop participants worked as design teams. A total of 65 teams were observed / worked with. The development of workshop setting was also a 'learning by doing' process. Instead of making a theoretically 'optimal' configuration, the approach we used was rather adaptive. Starting with 'standard' practice-like building team setting for the first sessions in 2001, workshops have evolved to two full-day series. The first workshops were organized during 'Integral Design' project [24,25] that was conducted by the Dutch Society for Building Services (TVVL), the Royal Institute of Dutch Architects (BNA) and Delft University of Technology (TUD), which involved mainly architects and building services consultants. The main focus of that project, which was initiated in 2001 and ended in 2003, was to raise the awareness of different disciplines about each others positions and problems in relation to building design. During this project a total of seven workshops were organized. The first one was an explorative session, which confirmed suitability of workshops for integration of activities of a building design team. Based on this result a workshop concept was developed in which the participants, members of BNA and TVVL, had to change their roles. The architect acted as building service consultant and vice versa. The awareness of position and needs of 'the other' was believed to be most evident if one had to play the role of 'the other'. A series of six identical workshops provided us with an important, and at the same time very surprising insight that either the level of knowledge about not only 'that other', but also about one's own field of expertise, was generally not that high; at best, it couldn't be understandably communicated to the other party in design process. This left us with conclusion that a way for structuring and confronting the respective (object design) knowledge of design disciplines needs to be found.

Hugely oversimplified, these were the most important conclusions regarding direction of further development of 'Integral design' workshops. Much more information is available in Quanjel's report [24], which unfortunately is only available in Dutch.

4.2 'Methodical design' model

The basic framework for structuring knowledge of design team members was found in 'Methodical design' [35], a model which is problem oriented and distinguishes, based on functional hierarchy, various abstractions and/or complexity levels during different design stages and design phase activities. This framework proved its potential within (mechanical) engineering domain [3], and makes it possible to explicitly think and act on a specific abstraction level. A distinguishing feature of 'Methodical design' is the use of morphological overviews, both for the overall description of design stages as for separate design activities. Morphological overviews were first used by Zwicky [39], and

are listed as one of 'Design methods' in the book by the same name [19]. Jones states that "morphological charts are intended to force divergent thinking and to safeguard against overlooking novel solutions to a design problem", and that "experienced designers in mechanical and structural engineering have quickly learned to use it with enthusiasm and success in areas in which they have some knowledge of problem structure and feasibility." The fact that workshop participants are also experienced designers is the main reason we assume that also within field of building design this method can be applied. Since, according to 'integral approach', the basis for culture change is formed by relation research-education-practice, we also implement findings from workshop based research into master education program within Department of Architecture, Building and Planning at TU/e. As such, we were able to confirm one of other Jones' statements: "graduate design students who have tried the method have found considerable difficulty in defining *functions*" [29].
Emphasis on working with functions is based on experienced designers' preference for function-oriented strategy [12], instead to phase-oriented that is often recommended by (engineering) design methodology [23]. Besides, definition of functions during interpretation of design task makes it possible to assess client's needs on a higher, but better workable, abstraction levels than program of requirements (which is often too detailed) provides. Based on definition of functions, various design complexity levels can be separately discussed and, accordingly, possible solutions generated. This way interaction with the client is aided, and at the same time design process is structured. The process of continuous interpretation and solution feedback transparently narrows field of possible solutions leading to well thought-out integral building concepts, while actively involving the client in design process [27].

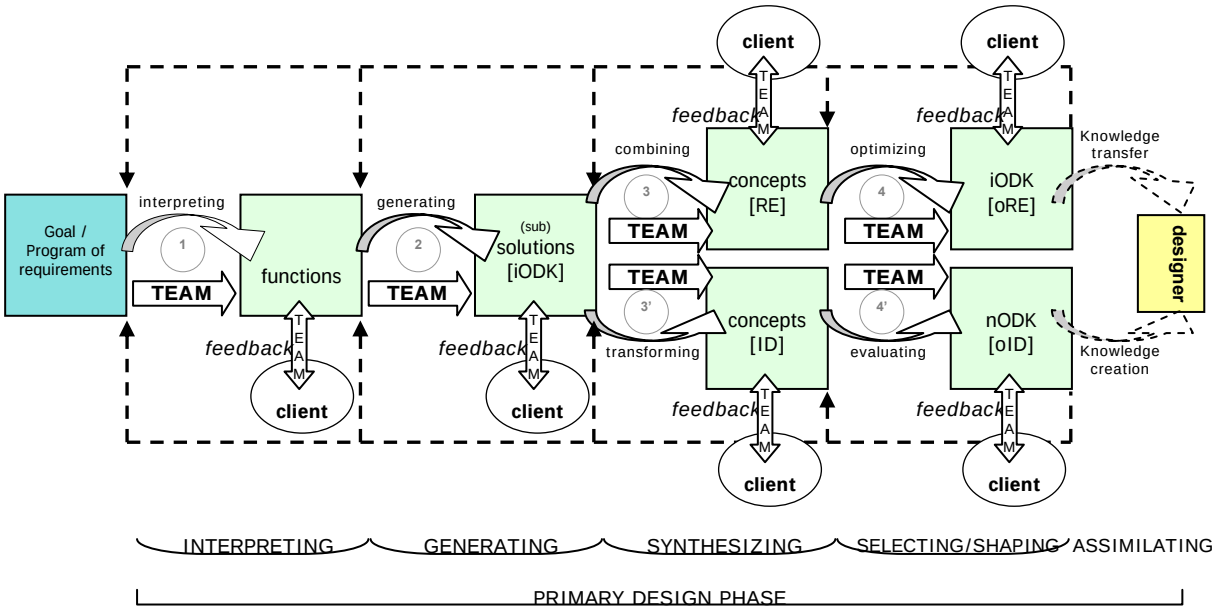

Figure 3. 'ID-methodology' design model; continuous feedback between design team and client additionally structures design process

Using morphological overviews as a design tool all interpreted functions (step 1, Figure 3) and all generated (sub) solutions (step 2, Figure 3), represented by 'chunks' of object design knowledge, can be structured. During following activity (step 3/3', Figure 3), it is important to understand that integration of initially presented discipline based design object knowledge is something different than plain combination of (sub) results from various abstraction levels. Combination can only lead to redesign (RE), while in literature much referred designer's 'creative leap' is needed for integral concepts (ID). This is the major step in understanding how to work with morphological overviews, and needs 'designerly' [5] attitude. Because concept integration involves *transformation* of design knowledge (C-K theory), it requires design thinking / creativity. Contrary to redesign, the connections design team (members) make between presented (sub) solutions / design aspects in order to produce ID-concepts are subjective, design task and context dependent. Therefore, they cannot be objectified and/or rationalized. This is the reason why 'ID-methodology' can't be automated, even though the structure of morphological overviews makes it very tempting to try (Figure 4).

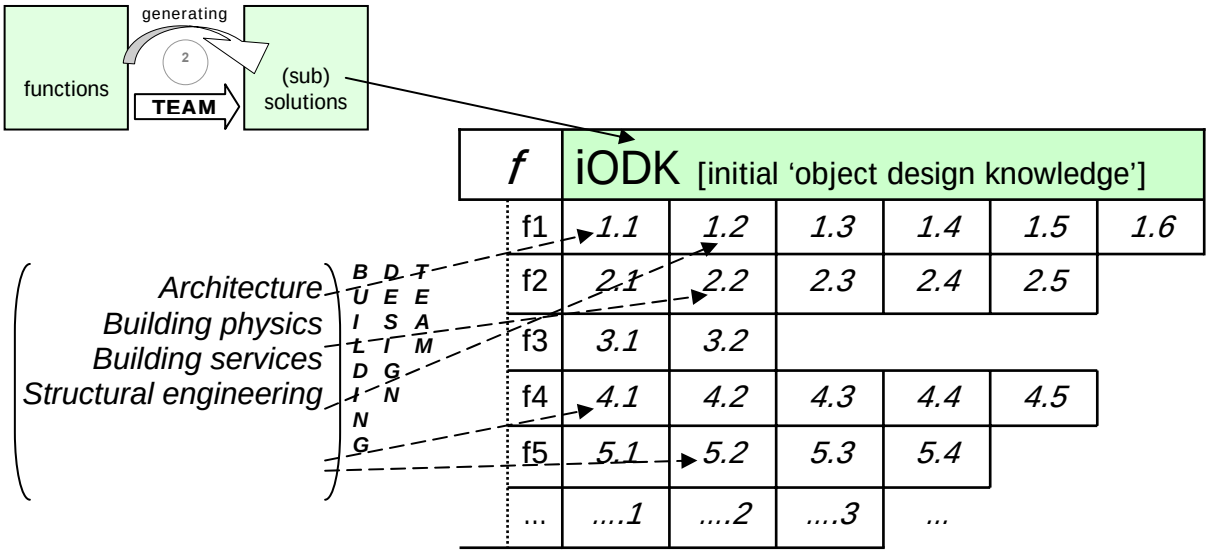

Figure 4. Morphological overviews show the initially available object design knowledge

The essence of 'ID-methodology' is strict separation between synthesising design proposals, being it RE or ID concepts, and selecting suitable ones. This selection step, which once again emphasises importance of interaction between design team and client, represents extension of methodical design model [35] as introduced by Zeiler [38]. A suitable method for joint evaluation is Kesselring diagram [20], which raises both process transparency and product understanding. Each selection iteration cycle leads towards more detailed design and can also be seen as shaping stage on a given abstraction level.

5 BNA-ONRI-KCBS WORKSHOPS 'INTEGRAL DESIGN'

5.1 Overview

Suitability of workshops for integration of design team activities and a need for structuring knowledge of design team members (Figure 4) formed basis for development (through implementation) of workshops, mainly done within Savanović's PhD project 'Integral design methodology in the context of sustainable comfort systems' (2004-2008). This project was initiated within Knowledge Centre Building and Systems (KCBS), cooperation between Technische Universiteit Eindhoven (TU/e) and the Netherlands Organization for Applied Scientific Research, core area Built Environment and Geosciences (TNO Bouw en Ondergrond). The workshops, in which gradually structural engineers and building physics consultants were introduced into design teams, were/are organized together with the Royal Institute of Dutch Architects (BNA) and the Dutch Association of Consulting Engineers (ONRI). All workshop participants are members of either BNA or ONRI; they are experienced professionals who voluntary apply for learning-by-doing 'Integral design' workshop course.

Because most of the disciplines involved have 'hard' engineering, rather then 'designerly' attitude, in order to present in familiar way that integral design (as we have defined it) is worthwhile, we have ultimately chosen to use (as far as possible in our approach) standard (reductive) scientific methods in form of experiments. The general notion of integration (between considered subjective and objective matters) has indeed also played a role in choice of research methodology as well.

Two exploratory ½-day workshops with elements of methodical design model were first conducted, in order to further determine which aspects in our approach are most crucial and/or need to be improved before defining experimental setting in which the effects of 'ID-methodology' can be tested. The ultimate goal of 'ID-methodology' is integration of sustainable energy within building (designs). On product level this means creation of new concepts for sustainable comfort systems. The primary research interests concerning building design teams are: how is communication between different design disciplines influenced by the used design process model (Figure 3); does use of morphological overviews (Figure 4), as one of methodical design tools, enhances generation/creation of integral design concepts / new object design knowledge within design team setting; how are these two questions related to each other?

The choice for workshop development in the direction of experiments formed the basis on which evaluation of two explorative and subsequently developed workshop series types was done.
Initial exploratory workshops, organized in year 2004, showed that ½-day setting (as used in 'Integral design'-project) [24] isn't sufficient for understanding and use of 'ID-methodology' / 'morphological overviews', even if information about them is in advance sent to participants. Design teams tend to revert to traditional design process pattern, especially as time pressure increases. General conclusion was that a training-like setting is needed. At the same time all participants confirmed the need for continuous education for professionals regarding 'Integral design'. An important insight concerning design team configuration was gained: share of action / knowledge contribution within design teams can be considered as discipline, instead as participant related. This means that more participants from the same discipline can be seen as one single unit within multidisciplinary design team setting.
Based on results from two ½-day workshops, a training-like setting in form of three-½-day workshop series was defined. The first ½-day was meant as the training part, with emphasis on utilization of morphological overviews for generation of solutions / structuring of object design knowledge. During second and third day, a selection of design steps from 'ID-methodology', considered as not needed to be forced upon design teams (Figure 5), were performed during four different design sessions. The results of two workshop series, organized in year 2005 according to this scheme, are extensively discussed in [28]. The main conclusion was that instead of theoretical interpretation–generation–combination–transformation activities, generation–combination-presentation was observed (Figure 5). Feedback with the client was preferred by designers at the end of design process.

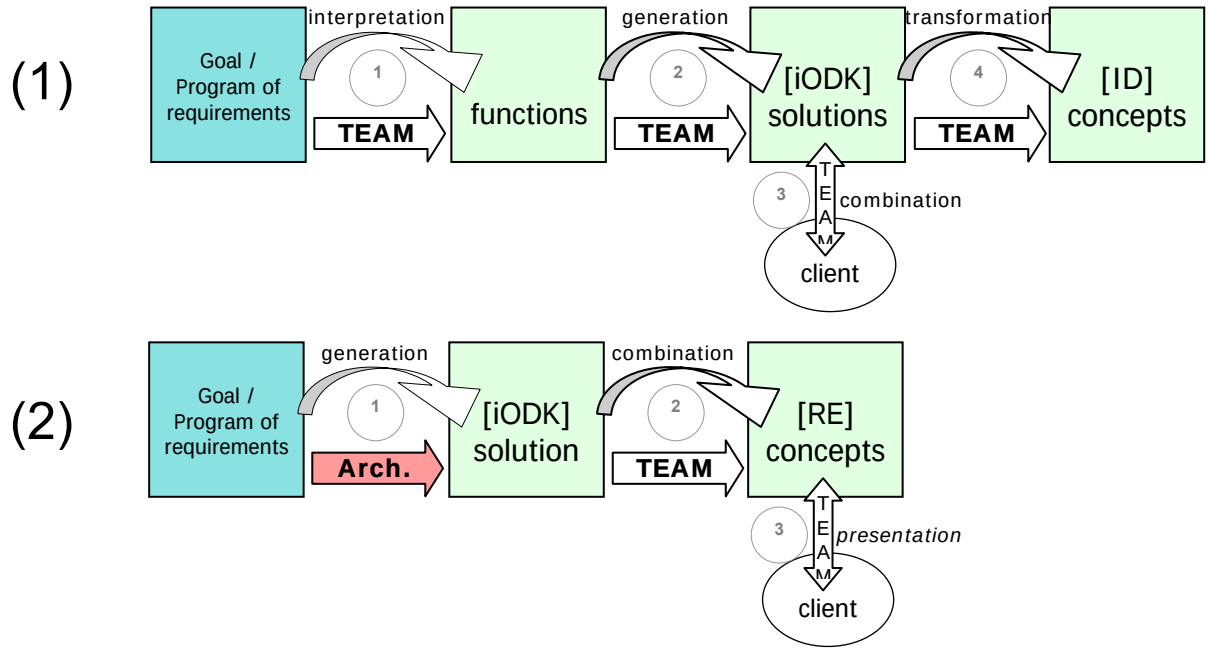

Figure 5. Tested (1) and observed (2) steps of 'ID-methodology' design model

The third workshop series, organized in year 2006, was meant as the first experimental setting for assessment of 'ID-methodology' effectiveness, with measurements being done in five different ways: through direct observations of design teams' activities, by videotaping them, by taking photographs of design team's work development, through analysis of produced concepts and by asking participants to fill in various questionnaires. The following hypotheses were to be tested:

1. simultaneous involvement of all design disciplines on a same design task results in more considered design functions/aspects;
2. additional application of morphological overviews transparently structures design functions/aspects, resulting in more (sub)solution proposals;
3. formation of multidisciplinary design teams at the very beginning of preliminary design phase results in creation of integral concepts.

However, the consequence was an experimental setting where morphological overviews couldn't be introduced at the start of workshop series, because it would exclude possibility of simulating traditional building design approach. This proved to be an insurmountable problem, since in

combination with the two main changes we propose (all disciplines starting working simultaneously within design team setting from the very beginning of conceptual design phase and use of methodical design model / morphological overviews), there was no place for the indispensable learning cycle within this specific three-½-day-approach. The lack of possibility to first learn/practice the new approach essentially meant that this 3rd workshop series didn't work out. However, it did lead to definition of the fourth hypothesis:

4. creation of ID concepts, as they are defined, will not happen (if at all) before last experiment.

This hypothesis is also meant to confirm the need of an *individual* learning cycle. In order to be able to *effectively* apply a new approach, one has to first understand it, make it his own [19]. Although we believe that this is also possible to achieve within design team setting, it requires more time than available during workshop series.

5.2 Final experimental setting

In order to test 'ID-methodology', a new workshop series is defined that consists out of four experiments, to be performed during two (full) days. Phased changes (Figure 6) to traditional design setting are introduced in order to be able to say if, and in which way, 'integral design methodology' as we perceive it, is *effective* (resulting in more integral design concepts). The first experiment is meant to provide reference values, the second will be used for testing of first hypothesis, the third for testing of second hypothesis and to provide one full learning cycle required for fourth experiment, which is meant for testing of hypotheses three and four.

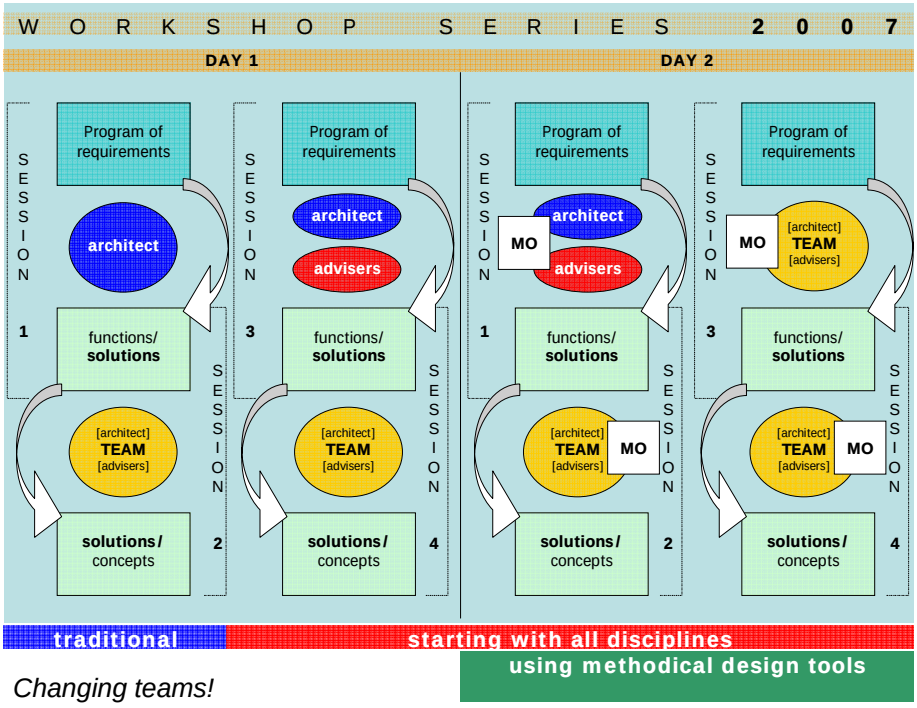

Figure 6. Final experimental workshop setting

Design team arrangement is the crucial element of our experimental setting. To compare different types of design processes, the usual solution would be to use 'matched design teams' [16,36], something that we fundamentally oppose; not only because of no resemblance with practice, but also because of need for large number of experiments in order to, in any way, be able to generalize the results. The solution we came up with was not to observe the same design teams during the whole course of workshop series, but to compare average results of each workshop day *while changing design team's arrangements*. This results in different teams each day, but at the same time consisting out of the same group of participating designers. The only rule is that *two designers could be in same team only once*. During previous workshop series we've also compared average results of different workshop days, but then we were only interested in *different activities* within *same type of design processes*. This time focus is on comparison of *same activities* within *different types of design*

processes. It is important to understand that experiments must be considered in relation to each other. The sequence of their performance is of utmost importance, reverse or mixed order is not possible.

5.3 Conclusions and discussion

'Integral design (ID) methodology', based on a reductive (positivism) framework [18,23,32,35] for design teams, in which concepts and knowledge (C-K) [14] constructs (phenomenology) [30] of individual designers are structured, provides suitable ground for creation of conceptual integral building designs. Subsequently, these integral concepts provide potential for creation of new (object design) knowledge. We have tried to build up this chain of reasoning as much as possible on our own observations of design teams during series of workshops with professionals. The development of workshop setting mirrors developments of 'ID-methodology'. Because we don't want this methodology to be yet another set of rigid prescription methods, but a flexible framework that most designers could fit to their own needs and ways of working, we have tried to modify and reduce it to a complexity level that would satisfactorily meet these needs. Taking into account that a fairly large number of new elements were introduced: workshop setting, design team configuration, methodical design, pressurised timeframe, forced client feedback, sustainable comfort systems, new design tasks and above all abstract thinking, a statement from W. Ernst Eder [18], made during one of design conferences, warns: "'If you have to use a new method, under time pressure, on a new problem – you will guaranteed fail!". Bearing this in mind, our framework was largely simplified (instead extended, as was initially expected). The only remaining tool, morphological overviews, however proved to be sufficiently suitable for 'learning-by-doing' explanation of integral approach involving 'ID-methodology'. They do require abstract thinking, for which an adaptation phase and a certain amount of training is needed, but they do provide framework for self-organization of design teams.

Although not yet tested, we believe that after two years we have found a suitable workshop formula to scientifically sound assess effectiveness of 'ID-methodology', as described in relation to knowledge creation. Besides developing and testing, BNA-ONRI-KCBS workshops are also meant to transfer this 'ID-methodology' to four main building design disciplines (architecture, building physics, building services and structural engineering), in a 'learning-by-doing' way. The 'Integral design' workshops are one of the catalysts in realisation of culture change in (Dutch) building design practice.

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