Education in Sustainable Architecture for the future – For a joint climate action!

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ABSTRACT:
The paper shortly presents a teaching method, the Integrated Design Process (IDP), used for the Architecture specialization at Architecture & Design in the problem based learning environment at Aalborg University (AAU). It also explains the difference between this approach and traditional design approaches to buildings. When using this IDP method designing sustainable buildings we can lower the energy use in the building with a considerable amount. The IDP focuses on combining the architectural approach with engineering parameters in order to achieve a more inter-disciplinary and holistic approach to environmental sustainable architecture. The goal is to reduce the use of energy for heating and cooling and thereby bringing down the emission of CO_2 *by reducing the amount of fossil fuel consumed by the built environment, addressing this issue already in the early stages of the design process. Since 2005 the Master of Science education in engineering with specialization in Architecture has been offered in English at AAU enabling foreign students to participate in the master program. The education has lecturers from architecture and design and civil engineering. Graduates from AAU are highly valued in industry, typically because their expertise in group work and their focus on problem-solving in context are well developed compared to graduates from traditional engineering and architecture programs. The students are trained in inter-disciplinary problem solving and how to build low energy buildings. The paper also includes a case of a housing proposal in Environmental Sustainable Architecture from the master program and discusses barriers and benefits from that approach.*

Keywords: new educations, sustainable architecture, inter-disciplinary design approach, comfort, low-energy buildings

1. INTRODUCTION

Architects and engineering consultants in the building and construction industry are today facing great challenges due to the fact that energy consumption has to be reduced to a considerable degree within the next few years in order to ensure that no further damage is done to the global environment from new buildings. The industry is thus facing major changes in terms of public regulation and in the way building and construction is carried out in practice, whereby “bad habits” seen in relation to an energy optimization of the building will have to give way to new and better methods. But not only is the global environment in danger. There is also an increasing need for energy in the coming years not only in Europe but also in the fast growing economies in Asia [1]. And we are clearly living in an energy crisis where the fuel deliveries are unstable and the producers of fossil fuels such as oil, gas and coal demand their price!

New educations are needed facing these problems and bringing down the use of energy in the built environment. The build environment stands for up to 40% for all CO_2 emissions in EU. The Danish plans for energy use in new buildings in 2020 will require a reduction of minimum 75% [2]. The paper will present a teaching method developed and used for the Architecture specialization at the department Architecture & Design. A M.Sc. in Engineering with specialisations has been offered in English since 2005. The method is called the Integrated Design Process (IDP), a hybrid method of designing integrated architecture in an inter-disciplinary approach between architecture and engineering [3].

2. BACKGROUND

It has been a natural challenge for a relatively young university like Aalborg University to develop teaching methods that are tailored to deal with current societal/technological issues. In terms of both research and teaching, Aalborg University utilises an inter-disciplinary approach to a considerable extent.
The approach is characterised by working on practical problems, by a so-called problem-based learning approach, PBL, implemented in a project-organised learning environment. This approach means that knowledge can be acquired from the practical trade or profession in project work [4].
Aalborg University offers a full graduate programme in Architecture & Design (A&D) as an engineering education with specialization in Architecture as well as Industrial Design, Urban Design and Digital Design. The education started in 1997 and today there are about 40 teaching staff and 580 students.
Today, the Architecture & Design study programme at Aalborg University is based upon the Bologna model: with a three-year bachelor and two-year master programme. The title awarded to the graduate student is Master of Science in Engineering with specialization in one of the four fields of specialization [5].
In the 3-year bachelor programme, the students integrate technical and design-related aspects into a broad architectural and design-related context and specialize in, Industrial Design, Architecture, Urban Design or Digital Design during the last two semesters of the three-year programme. This is followed by a two-year master programme taught exclusively in English within the chosen A&D specialization.

The curriculum is organized so that engineering lecturers from the technical departments and lecturers of architecture and design from the new and more aesthetically oriented Department of Architecture & Design are teaching the core competencies of their professions in a well-balanced blend supported by lecturers from departments of technical science at the university.

Achieving a successful blend of the different professional attitudes and traditions has been a sometimes difficult process, but today some of the barriers between these fields have been broken down and replaced by mutual respect and cooperation. It has been a challenging process for the participating teachers and researchers who have had to be open minded and willing to share knowledge across professional borders.

3. THE IDEA BEHIND THE IDP METHOD DEVELOPMENT

The idea behind the development of the Integrated Design Process IDP by Knudstrup from 2000–2002 [3, 6], was to focus on the ability to integrate knowledge from engineering and architecture in a hybrid design approach.
The approach was integrated in the study guide for the 6th semester and today the Integrated Design Process is applied on most semesters in the master program for the architecture specialization and on some semesters in the bachelor program. The education bridges the intermediate space between the architectural and building engineering educations in Denmark, with the aim of bridging the professional gap between the architecture and engineering professions. The IDP runs through five phases of the design process where it deals with different tasks relating to design projects in general as well as tasks relating to environmental building design [7].

What makes the IDP interesting is that it enables the designer to control the many parameters which must be considered and integrated in order to achieve better sustainable solutions when creating a more holistic approach to environmental sustainable architecture.

The method copes with technical as well as aesthetical problems that must be solved in an integrated building design, and it focuses on the creative element in the design process, in order to identify new opportunities and come up with innovative solutions in a new building design. Therefore, the architect's artistic approach to the creation of ideas as well as his or her ability to see new solutions and work strategically and inter-disciplinary in interaction with engineering parameters is very important. Using this ability without losing the creativity in the process is always very important when designing new architecture. [7]

5. ARCHITECTS AND ENGINEERS DIFFERENT APPROACHES

Danish architects are traditionally trained as generalists and to provide an overview of often complex projects. Therefore they use specific professional knowledge about architecture, design methods, space concepts, functionality, building structures as well as knowledge about the users and their needs and preferences for good living and working environments. Architects posses a basic architectural knowledge, but besides this basic knowledge, a different and complementary knowledge in the design process depending upon the purpose of the building and the needs of the users, is required. There are building types for different purposes e.g. offices, accommodation buildings, kindergartens, assisted living houses, schools, colleges, universities, airports, train and metro terminals, museums, hospitals, concert halls etc. It is part of the architects' professionalism to be able to accommodate the individual building to the specific function and set of users.

Up until the late 1990s the Danish schools of architecture and schools of design held a monopoly in terms of architectural designs education. This might be the reason why no major changes were seen in the area of design education before Aalborg University (AAU) set up this new initiative in 1997 - an initiative that broke with the long tradition of Danish architects graduating from beaux-art schools. The lack of technical skills in the existing architectural degree courses has been the subject of continued criticism. Thus, for many years, the technical scientific aspect has been practically non-existent in such courses [8, 9].

On the other hand building engineers in Denmark are traditionally educated as specialists within more or less comprehensive areas such as construction, mechanical ventilation, natural and hybrid ventilation, light, heating e.g. The technical scientific aspect of design has been taught only in courses of engineering, which have in turn all but ignored the aesthetic dimension during the 20th century [4].

The conventional way of building in Denmark is that the architect shares or hands the project over to the engineer when he or she has pretty much finished the schematic design of the building. This leads the engineer to take a reactive role in the design process in stead the proactive role which is required in an inter-disciplinary approach to design. [10]

6. ARCHITECTS AND ENGINEERS WAY OF PROBLEM SOLVING

In a PhD thesis from 2007 Hansen investigated how the professional differences were influencing the success of the inter-disciplinary process. Professor Donald Schön's study of problem solving situations in the architectural and the science-based engineering design professions showed that their approaches to problem-setting and solving is different [11, 12].

"Based on Schön's studies of respectively the architecture and the engineering design cases, it is possible to conclude that the differences in the approaches to problem and experimentation relate to different criterions of truth. The approach taken in the engineering design case would most likely apply the consistency and correspondence criteria of truth while the approach taken in the architecture case would most likely rely on criterions of consensus and coherence, because it is not possible to apply the consistency and correspondence criteria of truth for the type of experiment conducted in the case of architecture. This can obviously cause difficulties of communication during the process when engineers and architects have to agree on the different decisions involved in the creation of architecture. This might not be a problem if these differences are addressed in the beginning of the project when the inter-disciplinary design team is formed." (Hansen 2007)

Table 1: Comparison of problem-solving and setting in respectively engineering design and architecture professions [13].

Engineering design	Architecture
The problem is constant and a hypothesis for how to solve the problem changes as a result of hypothesis-testing experiments.	The problem is revised and specified in relation to the results of move-testing experiments (i.e. what happens if I do this? Or that?).
The solution is dependent on the problem and the investigated hypotheses, and the problem defines the solution.	The problem and the solution are interdependent, and the solution is the result of iterations between solution and problem.
Both: The solution is more important than the problem.	

These differences can explain why engineers and architects sometimes have difficulties agreeing about how to approach projects, and why engineers sometimes find it difficult to take a proactive approach to design strategy development – their educational background leads them to take a reactive approach to problems [11, 13, 14].

6.1 Language

Multi-professional staff members often work hard to learn each others language. This is our experience from the process of building up the new education in Architecture & Design. It corresponds with Schön’s identification of a ‘language of designing’ [13]. Therefore learning from both professional professions is a must for our students at the education in Architecture.

7. THE INTER – DISCIPLINARY APPROACH IN THE INTEGRATED DESIGN PROCESS

The Integrated Design Process in the new A&D education takes an inter-disciplinary approach to designing a building instead of the conventional based on the discipline-oriented approach [3]. By bringing the knowledge from different disciplines together from the first step in the process, creative solutions for a sustainable built environment can be developed.

As an outcome of this process the students learn the architects’ language as well as the engineers’ language as they are supervised by both the architectural professors from the Department of Architecture & Design and the engineering professors from the Department of Civil engineering.

The IDP includes work with the architecture, the design, spaces, proportions, and the light in the rooms, functional aspects, energy consumption, (cooling, ventilation), technology, and construction. The IDP hence supports the students’ effort to create a built environment that people feel comfortable to live and work in. In the following section, the various phases of a design project are described to give an insight to the different phases of the IDP.

The Integrated Design Process taught at A&D consists of the following main phases:

1. Problem formulation / project idea, 2. Analysis Phase, 3. Sketching Phase, 4. Synthesis Phase and 5. Presentation Phase. The process is described as a linear process, but it is very important to be aware that it is an iterative process. [3]

7.1. Problem Formulation or Project Idea

The first step of the building project is the description of the problem or the project idea for an environmental, sustainable building or zero emission building.

7.2. The Analysis Phase

The Analysis Phase encompasses an analysis of all the information that has to be procured before designing the building. Information about the municipality plan, the site, the architecture of the neighbourhood, topography, vegetation, sun, light and shadow, predominant wind direction, and access to and size of the area and the clients’ demands. It is also very important, in this phase, to decide the targets for energy use (heating, cooling, ventilation, lighting) and indoor environmental quality (thermal, comfort, air quality, acoustics, lighting quality) of the new building as well as criteria for application of passive technologies. Other criteria or wishes from the client such as life cycle assessments on materials, solar cells e.g. can be integrated at this stage. The tools applied can be: Hand sketches, Pre-designed spreadsheets regarding: Energy consumption, internal heat gains, CO_2 and sensory pollution, 24 hour average, max and min temperature, the daylight factor.

At the end of the analysis phase, room program and architectural and technical design parameters as well as the goal for the building are put into an architectural programme.

7.3. The Sketching Phase

The Sketching Phase is the phase where the professional knowledge of architects and engineers is combined through the design process and tools to provide mutual inspiration. This also implies the demands for the architecture and living environment and visual impact, as well as the demands for functions, construction, energy consumption, indoor environmental conditions and other quality criteria to be met like architectural quality, thermal comfort, view to the outside, lighting quality, etc.. During the sketching phase all defined criteria and target values are considered in the development and evaluation of design solutions.

In this phase the professional parameters from architecture and engineering are merging in the IDP interacting with each other. The precondition for designing an low energy or sustainable building in an IDP is as follows: In the sketching phase the designer must repeatedly make an estimate of how his or her choices regarding the form of the building, the plans, the architectural programme, the orientation of the building, the construction, and the building envelope influence the energy consumption of the building in terms of heating, cooling, ventilation and daylight – and how these choices inspire each other. The mutual influence and inspiration of all the above parameters must meet the specifications which have been set up for the architectural, functional and technical aspects of the building.

Typically, the different solutions have different strengths and weaknesses when the fulfilment of the different design criteria and target values is evaluated.
The tools applied are: Hand sketches, foam or cardboard models, digital sketches in Sketch Up, 3D MAX, Rhino, pre-designed spreadsheet calculations regarding: Natural ventilation, Build desk or PPHP or Be06 and BSim, Dial Europe or Dialux, EcoTect and Radiance.

7.4. The Synthesis Phase

The Synthesis Phase is the phase where the new building finds its final form, and where the demands in the programme are met. The designer reaches a point in the design process where all parameters considered in the sketching phase interact – architecture, plans, the visual impact, functionality, clients goal, aesthetics, the space design, working environment, room programme, principles of construction, energy solutions and targets and indoor environment form a synthesis. In the synthesis phase the various elements used in the project should be optimised, and the building performance is documented by detailed calculation models.
The tools there can be used are: Hand sketches, cardboard models, digital sketching in Sketch Up (more detailed), Dail Europe or Dialux, BSim, ADT, 3D MAX, Rhino.

This way the project reaches a phase where each item, one might say “falls into place”, and other possible qualities may even be added. The project finds its final form and expression and the project fulfils the architectural programme.

7.5. The Presentation Phase

The Presentation Phase is the final phase that includes the presentation of the project. The project is presented in such a way that all qualities are shown and it is clearly pointed out how the aims, design criteria, and target values of the project have been fulfilled for the client.

The integrated design approach in the IDP method has been tested in many projects with success. The following case shows a housing proposal from the 8th semester.

8. THE CASE PROPOSAL

The case describes an environmental sustainable building complex with very low energy consumption and a comfortable indoor climate. The building also represents high architectural qualities in terms of expression, functionality and spatial expression and god living conditions for the inhabitants. The building fulfils low-energy class 1: 35kWh/m^2 + 1100/A which will bee implemented in Denmark in 2015 according to the Danish Building regulation. [15]
This project called “THE LINK” describes a new building complex (see fig. 1) in the western part of Aalborg on the edge of the dense city [16]. The complex contains dwellings for both families with children and dwellings for singles or couples.

Fig. 1 The new building complex called THE LINK

The goal is to use the advantages of the multi-story apartment house and integrate the qualities of the single-family house by giving access to terraces from every apartment and an access to at space between the houses with leisure areas, sport , playground etc.

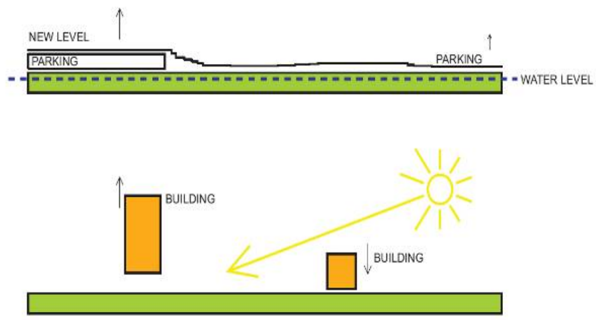

Fig. 2 The concepts

The projects main concept (se fig. 2) is to lift the terrain and then protect the complex against the rising water level that is becoming more and more common in this area. Another concept is to lift the complex up in different heights. By lowering the buildings to the south the passive solar heat is allowed into the buildings at the north and very good daylight conditions are also let into the courtyard.

Fig. 3 The site plan of the complex

The high multi-storey building to the north contains apartments and the lower buildings to the south are two and three storey row houses. A common area is programmed between the buildings with spaces for several activities such as a barbeque area, water pond, sports areas and a terraced “hillside” for playing and relaxing as illustrated in the site plan (see fig. 3).

The northern building is raised three meters and the area underneath is used for storage, bicycles and car parking. This area is entered from the east, which leaves the courtyard completely free of cars and it is therefore a safe environment for children to be in.

The row houses have a private garden and parking to the south and access to the common area to the north.

The expression of the facade varies in depth as well as in colour contrasts. The depths are used to cast shadows on to the facade as well as providing a varied expression. The contrast in black and white materials highlights this variation and makes the building seam less compact.

Fig. 4 Part of west façade of the multi-story building

The intention of the white parts of the facade is to reflect light into the apartment and brighten up the balcony (see fig. 4). Sliding wood lamellas are chosen to soften the brightness from the white colour into a pleasant natural light when being on the balcony or inside.

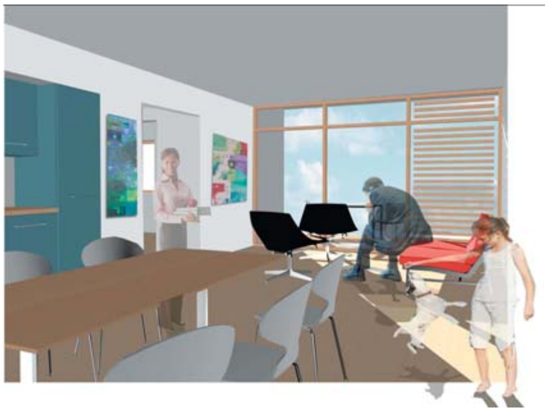

Fig. 5 3D visualization of the living room

The lamellas as well as the depth in the facade have a positive influence on the indoor climate in terms of preventing overheating during the summertime (see fig. 5).

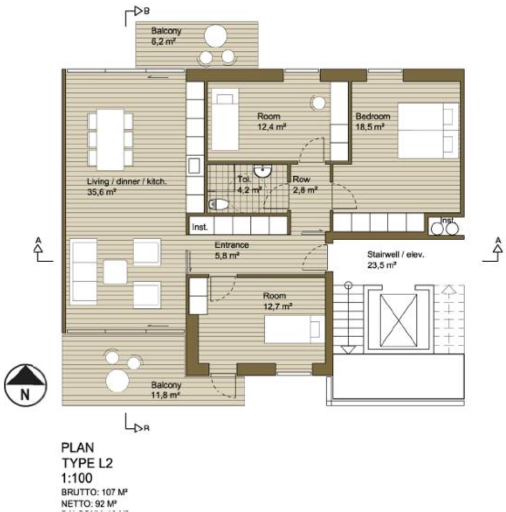

Fig. 6 The apartment suitable for a family with 2 children or for couples.

Fig. 7 A row house suitable for a family with children with direct access to a private outdoor space.

The complex contains six different types of dwellings. It creates an interesting expression of the buildings and the different needs for the target groups are fulfilled (see fig. 6 & 7).

Fig. 8 3D visualization of the 1 floor in the row house complex

The construction principle in this proposal is based on the curtain wall. The facades are light and the inner walls are load bearing and stabilizing. This results in thicker outer walls when putting in more insulation to minimize the heat loss.
By the compact shape, good U values, the use of hybrid ventilation including heat recovery and other passive approaches in the design, the building fulfils a Danish energy class 1 (35kWh/m^2 + 1100A (per year)). It should also be possible from the drawings and 3D visualizations to have an impression of the good qualities and living conditions this project gives to the families in their new living environment (see fig. 8).

However, it is very important to remember that simply adding together design parameters and calculations does not make the building itself. Architecture is not the result of making complex calculations, as some may be tempted to suppose. Such calculations can only be used as guidelines in the integrated design process and must be combined with other tools and creative ideas that are provided through the architectural design process. The test on students' projects illustrates that it is certainly possible to design buildings with architectural qualities where the technical approaches are well integrated into the function and expression of the building.

9. CONCLUSSION

The new education with specialization in Architecture with its inter-disciplinary approach, no doubt, is a challenge to the established educational system as well as the professions as it produces highly skilled graduates with an inter-disciplinary perspective and new professional culture. Today, the graduates from AAU are highly valued in industry, especially because their expertise in group work and their focus on problem-solving in context is well developed [17, 18]
There is no doubt that the traditional educations in architecture and engineering in Denmark support practice by well educated graduates who are trained and qualified to practical work in the conventional way. But as the need for a new kind of sustainable environment emerges the professions must accommodate with new methods and ways of working that in turn require new types of professional competencies with the graduates. Thus there is a need for an alternative approach to solve the problems we are facing in the built environment in the coming years. It is not enough to employ more or less tacit vocational knowledge and technical engineering skills to ensure the optimal design and sustainability of a new low energy building.

Working with IDP gives the student a new kind of knowledge developed in close collaboration between architects and engineers in the design process. In order to develop this new inter-disciplinary professionalism with the students we have to overcome the barriers created by the different ways in which the established professions solve problems. The IDP provides the students with a different understanding of the design process as it facilitates an integration of technical and architectural aspects of the process. Thus the graduates get an inter-disciplinary approach that also enables them to work as facilitators between engineering and architecture in practice. They are well equipped to ensure that the final product does not only fulfill the technical standards as measured out by the engineers, but also have the architectural qualities of good living or working environments for the inhabitants.

The lack of form finding tools! Different kinds of software for modeling and tools for calculations are used in the IDP program at Aalborg University. But one of the major obstacles is the lack of tools, which allow the designers to use their knowledge about how to reduce for example energy consumption in the early design phases, especially in larger complex projects. Present engineering tools are specialized and very detailed [19], making them difficult to use for designers because they give a numerical output and does not show where possible problems can occur or where improvements might be made. Furthermore these tools do rarely possess interoperability with traditional CAD tools used for modelling [20], making the integration and evaluation of the different parameters more difficult than necessary. Therefore new form-finding tools have to be developed to make the integration process easier. But also new calculation tools are needed to complex projects.

Seen from the perspective of an architect, it can be a huge challenge and time consuming to work together with building engineers and vice versa. You have to bend your professional profile and open your mind to what can be learned from the other professions. Then you have to implement this new knowledge on the design and construction of buildings in order to improve the integration of technical, architectural, and environmental elements in sustainable solutions. In order to reach this goal there are a number of theoretical and practical issues to take in to consideration in the preparatory as well as in the later phases of a building project. Good compromises have to be made so that the architectural demands and qualities of the project will co-exist with the technical demands and qualities. It is also our experience that you have to take good care of the "soft" qualities of the architecture, as they are often under pressure from the "hard facts" of the engineering.

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REFERENCES

[1]Meredith, R. "The elephant and the dragon: rise of India and China and what it means for all of us. 1st. Ed. W.W. Northon & Company Ltd. NY. USA.

[2]Energipolitisk aftale 21.01.2008. www.kemin.dk April 2008.

[3]Knudstrup, M.-A. 2004: "Integrated Design Process in PBL". The Aalborg PBL model – Progress, Diversity and Challenges'. Aalborg University Press, Aalborg University, Denmark. 2004.

[4]Eriksen, K: Knudstrup, M.-A. 2008."THE DANISH REVOLUTION IN DESIGN EDUCATION". I: Proceedings of the 10th engineering and product design education international conference, Universitat Politecnica, Barcelona, Spain 4-5 September 2008. Barcelona, Spain.

[5]Curriculum www.aod.aau.dk [April 2008]

[6]Knudstrup, M.-A., Studievejledning for 6. semester, Arkitektur og Økologi – Energi og klimatilpasset byggeri. Institut for Arkitektur, Arkitektur & Design, Aalborg Universitet, Danmark januar 2000 & 2002. [Knudstrup M. Curriculum for 6th semester, Architecture. Architecture and Ecology – Energy and environment in Architecture. Department of Architecture & Design, Aalborg University. Denmark, January 2000 & 2002]

[7]Knudstrup, M.-A. 2006: 'Barriers and Challenges in the Integrated Design Process Approach'. The International Conference on Asia – European Sustainable Urban Development, Chongqing, China April 4-6 2006.

[8]Periodical: Danske Ark Byg no. 8, 2007.

[9]Periodical: Design Danmark, The Danish Government, April 2007. ISBN 978-87-78622-48-8

[10]Hansen, H. T. R., Knudstrup, M-A. "The Development of a Tool for Sustainable Building Design: Facilitates Investigation of the Creative Space. PLEA 2009 - 26th Conference on Passive and Low Energy Architecture, Quebec City, Canada, 22-24 June 2009.

[11]Hansen, H. T. R. 2007: 'SENSITIVITY ANALYSIS as a Methodical Approach to the Development of Design Strategies for environmentally sustainable buildings'. PhD thesis, Aalborg University Denmark.

[12]Hansen, H. T. R., Knudstrup, M.-A. "Parametric analysis as a methodical approach that facilitates the exploration of the creative space in low-energy and zero energy design projects". PLEA 2008 – 25th Conference on Passive and Low Energy Architecture, Dublin, 22nd to 24th October 2008.

[13]Schön D. (1983). "The reflective practitioner – how professionals think in action" p. 76-105, 168-204.

[14]Lawson B. (2006). "How Designers Think – the design process demystified" p. 41-44. Architectural Press 2006 UK.

[15]www.ebst.dk/bygningsreglementer/0/91/0 [April 2008].

[16]Jensen L. G., Hartvig, J. M., Møller, K, Nielsen, D, Pham C.-L.. "THE LINK" 8th semester. Architecture & Design, Aalborg Univeristy 2007.

[17]Periodical: Ingeniøren, 30. Årgang nr. 13, 26.03.2004

[18]Assessment of candidates from Architecture & Design 2006, Study Board of Architecture & Design, Aalborg University.

[19]Malkawi, A. M. "Performance simulation: Research and tools". I: Performative Architecture – Beyond Instrumentality Kolarevic Branko: Malkawi Ali M. (Eds). Spoon Press, New York. 2005. ISBN 0-415-70083-3

[20]Edwards, B., "Green Architecture – An international Comparison". John Wiley & Sons. 2001.