Integrated Design Process in Problem-Based Learning

Integrated Design Process in PBL

Knudstrup, Mary-Ann

Published in:
The Aalborg PBL Model : Progress, Diversity and Challenges

Publication date:
2004

Document Version
Publisher's PDF, also known as Version of record

"Integrated Design Process in PBL" by Knudstrup, Mary-Ann. article in The Aalborg PBL Model, red. Annette Kolmoes, Flemming K. Fink, and Lone Krogh. Aalborg University Press 2004. Denmark.

Integrated Design Process in PBL
- INTEGRATED DESIGN PROCESS IN PROBLEM-BASED LEARNING

Mary-Ann Knudstrup

Associate Professor, Architect maa[1] Department of Architecture & Design, Aalborg University

Abstract:
This article reports and reflects on the learning achievements and the educational experiences in connection with the first years of the curriculum in Architecture at Aalborg University's Civil Engineer Education in Architecture & Design. In the article I will focus on the learning activity and the method that are developed during the semester when working with an Integrated Design Process combining architecture, design, functional aspects, energy consumption, indoor environment, technology, and construction. I will emphasize the importance of working with different tools in the design process, e.g. the computer as a tool for designing and optimising the building. I will also consider the dilemma of the Integrated Design Process in Problem Based Learning that emerges when the number of courses in the learning model, as is often the case, clashes with the demand for time and scope for reflection which the students need in order to concentrate, mobilize creativity and find the personal design language which is a precondition for making good architecture.

1. THE NEW PROFILE IN ARCHITECTURE

Our intention with the curriculum in Architecture was to focus upon the ability to integrate knowledge from engineering and architecture in order to solve the often very complicated problems connected to the design of buildings. According to the provisions for the Architecture curriculum at Architecture & Design at Aalborg University, the main objective is:
"To educate graduates who are able to work independently and professionally at the highest level with the architectural and technical design of buildings, and who have a thorough knowledge of project planning and project management in connecting with building projects". [Kiib]
As can be seen from this quotation of the objective, the graduates must through the learning process achieve competencies in design, functionality and aesthetics as well as competencies in technical solutions. This implies – besides a critical, analytical, theoretical, functional and technical approach to the subject – that the students must perform a practical synthesis, i.e. a concrete presentation of a real sketch plan for a building e.g. an office building, residential buildings or institutions. The process is conducted as an integrated process of creation and design, in which a building with a number of qualities find their form. By using the Integrated Design Process the professional knowledge of architecture and engineering is integrated and optimised. The engineering programs at Aalborg University are based on PBL which is the basic educational model of Aalborg University. But in order to create the professional profile/scope which we expect of our graduates, to enable them to cope with technical and aesthetical problems, focus on the creative element, see new opportunities, make innovative solutions – a product or a building – new elements have to be added to the PBL model. Artistic learning, the creation of ideas, and an ability to see new possibilities and be creative become just as important parameters as the ability to identify problems and suggest a rational solution.

[1] Member of the Academic Architect Association

Therefore, the curriculum has to be deliberately organized in such a way that the pedagogical and learning objectives are achieved within the core subjects of the curriculum.

During one of the semesters at the master level of the Architecture curriculum's the students produce an energy and climate optimised building as their main project. The objective is described in the study guide for the semester [Knudstrup].

"At the end of the semester the student shall be able to:

- *analyse the aesthetic, technical and functional problems of the building and through various proposals (synthesis) prepare a building plan with high aesthetic, technical and functional qualities.*
- *use general theories and principles concerning the design of the building and integrate these in the proposed solution, including solutions based on technologies concerning ecology, energy and indoor environment in the design and construction of the building.*
- *produce and present the project graphically, in writing and orally – as importance is attached to both the project report and the presentation in drawings and model.*
- *make a presentation of the office building using a CAD tool."*

In order to achieve the objective, the project programme is arranged so as to give the students an understanding of the problems connected to an integrated development of the design, the aesthetics, the technical and environmental aspects of the building, and to further develop the student's ability to integrate architectural and technical design in the building. It is therefore very important that the two professional subject areas, engineering and architecture, are both introduced at the beginning of the semester, so that the students conceive them as equal parameters in the Integrated Design Process that follows.

2. THE CURRICULUM IN ARCHITECTURE

As mentioned above, the project programme focus on the design of a new office building. The geographical site is chosen in an area, which is currently going to be rehabilitated or developed in order to make the project as realistic as possible and to achieve momentum in the work process. The project must be adapted to the architectural context of the area, and relate to the future wishes for development of the area according to the urban development plan. The architecture of the building and its' position on the site may also substantially influence the solutions and choices with regard to resource consumption, outdoor environment, energy consumption and indoor environment. Besides, in this project special attention is attached to the integration of passive energy technology systems.
The internal functionality and the architectural volumes must be consistent, so that all of the future resident's demands for functionality and logistics of the building are considered in the best way possible. The construction of the building must be clarified.

2.1. The Integrated Design Process as a method in the PBL process

The project is conducted as group work. The students work their way through the phases of the project, which are at first described in short terms and later in more details. During the various phases of the

project the students are taught by architects[1] and by engineers[2], so that the professional approach of both architects and engineers is ensured. An open-minded commitment from both groups is very important in order to achieve a successful integration of the two professions, or else it will give no meaning to bring the two professions together. For this semester I developed the model described below. In this model the traditional architecture and engineering disciplines are split into different components, and some of the components from engineering are combined with the architecture components into a new method. This is what I call the Integrated Design Process. The Integrated Design Process is a synthesis of the pedagogical method (PBL), the students' personal learning efforts, and the professional learning components from architecture and selected components from engineering.

The **I**ntegrated **D**esign **P**rocess intertwined in the PBL process.

Problem formulation / project idea

↓

Analysis Phase
Analysis of site, urban development plans, company profile, chart of functions, principles of energy consumption, indoor environment and construction.
Aim and programme.

↓

Sketching Phase
Through the sketching process architectural ideas are linked to principles of construction, energy consumption and indoor environment as well as the functional demands to the new building

↓

Synthesis Phase
Architectural and functional qualities, the construction and demands for energy consumption and indoor environment flow together, and more qualities may be added.
A new building has been created

↓

Presentation Phase
The final project is presented in a report, drawings, a cardboard model and IT-visualisation.

[1] Teaching staff from the Department of Architecture & Design,
[2] Teaching staff from the Department of Building Technology and Structural Engineering.

2.2. Project phases in the **I**ntegrated **D**esign **P**rocess

In the following the various project phases will be described in details to give you an insight into these phases and into the Integrated Design Process. Fig. 1 shows the design process map. The process is, in fact, a much more complex mental process, so this map is a simplification of the design process. However it illustrates the various phases and the main loops connected to the process.

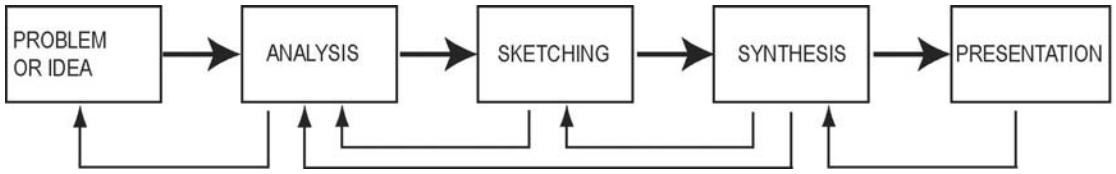

Fig. 1. The design process map.

Problem formulation or project idea The first step of the project work is description of the problem or the project idea. The purpose of the project here is to establish energy and climate optimised office building at proximately 3000 m^2 with a number of specific properties.

The Analysis Phase encompass an analysis of all the information that has to be procured before the group is ready to begin the sketching process, e.g. information about the site, the architecture of the neighbourhood, topography, vegetation, sun, light and shadow, predominant wind direction, access to and size of the area and neighbouring buildings. The group should also consider demands coming from regional plans, municipality plans and local plans which state a number of exact demands and limits for the area such as building restrictions and give information about the site's location in the city and relation to the general urban plan, e.g. connections to the road and path system of the area, and the future development plans for the area. Furthermore, it is important to be aware of special qualities of the area.

In the analysis phase detailed information is procured about the client's demands for space, functionality, logistics etc. It is up to the project group to decide who the building owner is and to make a user profile. It may be a fictive company or a real company to which the group take contact or a company profile described on the Internet. The company can be used for instance as a sparring partner for the elaboration of a room program and logistic needs, a chart of functions and a company concept which can lend inspiration to the design of the building. This is combined with new concept as for instance New Ways of Working. It is also decided if the company may want the building to be an icon for the company in the urban landscape.

The group also works with principles for natural ventilation in a new building, taking the outdoor environment, wishes for the climate shield, the purpose of the building and the demands for functionality into consideration. The group follows lectures, courses and workshops in architecture and engineering, and is conducting parallel studies in literature.
At the end of the analysis phase a statement of aims and a programme for the building is set up.

The Sketching Phase is the phase where the professional knowledge of architects and engineers is combined and provide mutual inspiration in the Integrated Design Process, so that the demands and wishes for the building are met. This also applies to the demands for architecture, design, working environment and visual impact, and the demands for functions, construction, energy consumption and indoor environmental conditions. During the sketching phase all demands are considered to find the best solutions as possible, which will meet the demands for the building, the demands for logistics and other demands, which are described in the room programme. New creative ideas and solutions are produced in this phase.
The students have to have capability to visualize their ideas from mind to hand to paper or models. As mentioned above, in this phase the professional knowledge of both architects and engineers are flowing together in the Integrated Design Process. The precondition for designing an energy saving building in an Integrated Design Process is as follows: In the sketching phase the group must repeatedly make an estimate of how their choices regarding the form of the building, the plans, the room programme, the orientation of the building, the construction and the climate shield 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 elements must meet the demands which have been set up for the architectural, functional and technical aspects of the building. The group works with sketches on manifold paper, with physical models, and with computer-designed models.[3] (Fig. 2.)

Fig. 2. Students' sketches, models and working with computer models.

[3] E.g. programmes like „ Auto Cad" or "Autodesk VIZ 4".

The consequences of the technical choices are calculated by means of rather simple calculation methods/models, which make it possible to compare and select solutions. For example the project group can see which influence a 25% or a 100% glass facade has on the total energy frame of the building. From these calculations the group gains an insight of the parameters that really matters to the energy optimising. In this way the group can sketch various well-founded solutions. At the same time they make an estimate of which of the sketches for the building meet the demands of the architectural expression, and which do not and with that in mind they make their choices.
In this phase the group make a lot of sketches (Fig. 3.) to solve the various problems in order to optimise the final and best solution that hopefully will appear in the next closely connected phase, the synthesis phase. Technical and architectural literature is also studied carefully in this phase.

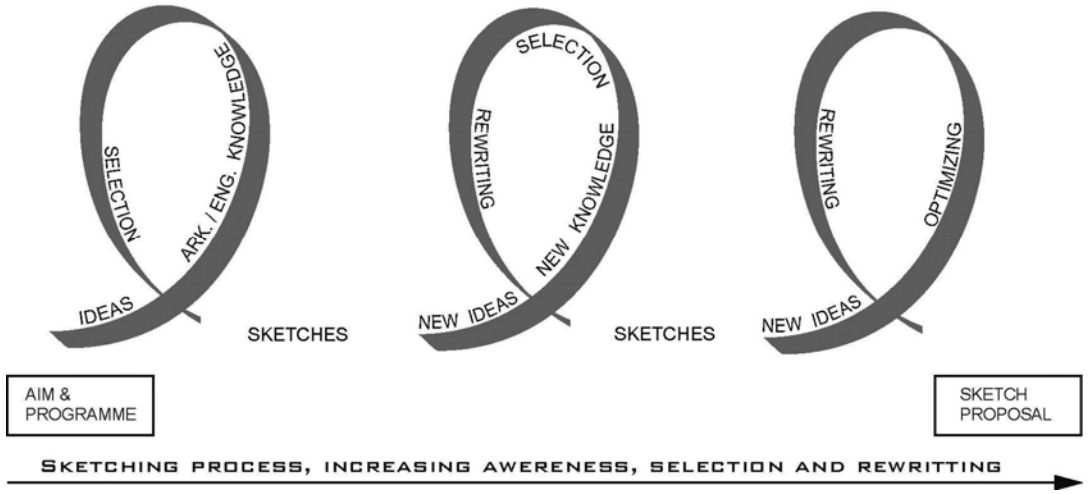

Fig. 3. The sketching process is repeated several times. S. Agger inspires to this illustration.

The Synthesis Phase is the phase where the new building finds its final form, and where the demands stated in aims and programme are met. Here you reach a point in the Integrated Design Process where all elements considered in the sketching phase flows together – and architecture, plans, the visual impact, functionality, company profile, aesthetics, the space design, working environment, room programme, principles of construction, energy consumption and indoor environment technology form a synthesis. In the synthesis phase the various parameters used in the project seen in Fig. 4, should be optimised, and technical calculation models should document the final calculations regarding the climate shield and the energy frame of the building, and the natural ventilation. In this way the project reaches a phase where every item, you may say "falls into place", and other possible qualities may even be added.
The project finds its final form and expression, and a new building with – hopefully good – architecture, architectural volumes, aesthetic, and visual impacts, functional and technical solutions and qualities have been created.

"Integrated Design Process in PBL" by Knudstrup, Mary-Ann. article in The Aalborg PBL Model, red. Annette Kolmoes, Flemming K. Fink, and Lone Krogh. Aalborg University Press 2004. Denmark.

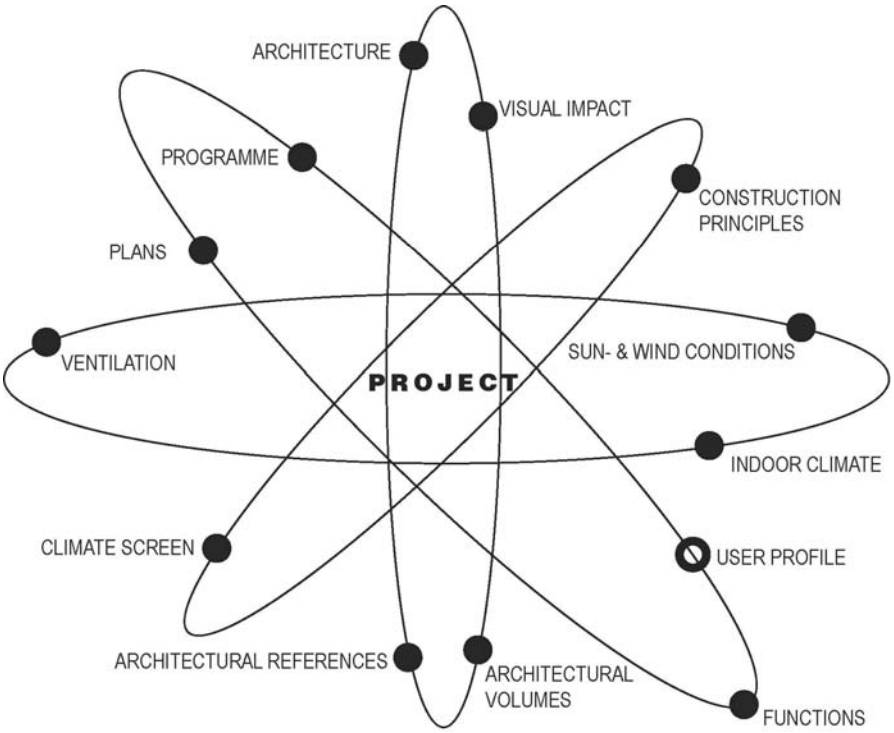

Fig. 4. Illustrate the various parameters that are integrated in the Integrated Design Process

The Presentation Phase is the final presentation of the project. The project is presented in such a way that all qualities are shown to advantage, the outcome of the Integrated Design Process is specified, and it is clearly pointed out how the aims of the project have been fulfilled. The presentation includes a project report with documentation of all aspects of the previous phases, and a presentation and description of the finished project in text, diagram's, facades, plans, and architectural volumes, details and calculations, which prove the measurable qualities. The project report also includes a process evaluation, which relates to the plan for the organization and accomplishment of the work which makes the groups aware of their working process and of the learning they have accomplished during the semester. Furthermore, a computer presentation and animation is made together with physical models and posters with text and drawings. The project is also accompanied by a CD witch will be part of the student's portfolio.

3. THE PROVOCATION IN THE BORDERLAND BETWEEN THE VARIUS TOOLS AND METHODS

The tools of the sketching process are pencil drawings on manifold paper, building of models in cardboard, plastic or other materials, or 3D models on the computer.
Many different tools are used during the sketching process, at the same time as the students are making calculations on indoor environment optimising and the energy frame in order to solve the often very complex problems attached to office buildings. A tool like the pencil is the traditional tool for

architects. It is used in combination with models. These tools all contribute to circumscribe and develop the final form, function and technical structure of the building. The sketches help to maintain the thoughts and ideas, which arise during the process. In this way the sketches become the tool of the student's internal creative dialogue during the sketching process – a dialogue where many ideas on architecture, space design, functionality, room programme and plans are compared to concepts for New Ways of Working and technical demands for indoor environment technology and the cooling and heating.

There are, as it was, various degrees of "resistance" in the sketching tools when the creative thought, the associations and the ideas are tested and formed by means of the pencil, the model and the computer. The resistance provokes the person in charge to consider and test new possibilities, new combinations and solutions to the problems. The synthesis arises in the borderland between the provocations given by the various media, and a synergy effect arises between the various professional worlds when the process is successful.

It is my experience that when the computer is used, other forms are some times generated than the classic geometric forms, and the computer gives another kind of "provocation" to the students than does the physical model and the calculations. In this way the students manage to build a new imagery and think in new ways. In my opinion the computer will be a very important tool for sketching in the future – not only in the presentation phase, but also – and maybe more important – during the Integrated Design Process. As I se it, it offers new professional opportunities and contributes to finding new solutions to the projects. Also, the computer will become a very important tool for handling the increasingly complex problems attached to optimising many different elements at the same time, as suitable programmes are developed for this purpose.

4. THE SEMESTER AND ITS ORGANISATION

The semester is planned and organized by an associated professor – called the semester coordinator - who is responsible for the study guide, the timetable and the course of the whole semester. When planning the semester the coordinator meets with a group of students from the previous and the coming semester functioning as a sparring partner. The semester contains a main project and a mini project, and the semester will typically comprise the below elements.

The students do the mini project, which takes about 2-3 weeks, individually. The purpose of the mini projects is to strengthen the students' individual originality and design language, their ability to set forward proposals and their awareness of methods. These are all basic elements, which are important to their professional competencies.

4-5 students groups do the main project, which occupies the rest of the semester. To each group a main supervisor with architect qualifications and a subsidiary supervisor with engineering qualifications are attached. Very targeted project related courses support the project, which is very important for the professional level of the projects. About 50% of the time is used for courses (courses related to the project and courses related to the curriculum), and 50% of the time is used for project work and preparation for examinations. We also have conducted some courses with architects or engineers from the professional practice, which ends up in workshops – successful, but also very time-consuming. But we find that the workshops are important to strengthen the student's theoretical and professional level.

Halfway through the semester we have a seminar with an external guest reviewer, the supervisors and all the students of the semester. The project groups get their work and project sketches evaluated. The evaluation is pointing forward, and all students have the possibility to learn from each others reviews.

The students work in transparent learning environments in a drawing hall with students from different semesters. In this way the students get an opportunity to be inspired by the other semesters and an idea of how it will be to work in a drawing hall in their future professional life. The drawing halls also improve the development of social contacts between the semesters and the synergy effect that will arise from this both professionally and socially. The supervision takes place here at the group's working place and is based on sketches, models, CAD models or text. Both supervisors and students communicate orally, through sketches, models or drawings and calculations. References may be made to existing projects, theory or literature.

The evaluation of the projects is based on the material handed in, the oral presentation on the day of the examination and the following evaluation. We give individual marks after the 13-scale. And the evaluation of the students is based on the aims to be achieved at the end of the semester, which can be seen in the study guide, and the group's aims and programme for its project.

In the end of the semester we also arrange national as well as international study tours to give the students inspiration.

5. IS THE INTEGRATED DESIGN PROCES A SUCCESS?

Based on my three years' experience and the evaluations of the semesters it is my assessment that the semester has been successful, and I find that we have managed to fulfil most of the initial aims. The method, the Integrated Design Process in PBL, is so far a success. The students' project shows that it is possible to integrate the engineer skills with the architect skills in the projects, and that the students are learning a method, which enable them to combine other components than the traditional architect components in the process.
The students are, in fact, creating very interesting office buildings with high qualities, where the architecture language is integrated with and inspired by engineering parameters, so that the architectural and technical solutions are optimised. The point is that the students have to integrate the engineer parameters from the very beginning, already in the analysis phase, and further in the process when the sketching of the building is taking place, so that they can make a synthesis of the architectural and engineering parameters.

Seen in relation to the objectives[4] of the semester we have managed to:

- Exploit the professional knowledge of engineers already in the sketching process by developing methods/models that in an easy and transparent way presents the indoor environment and the energy frame of the building. This knowledge can be used for the choices made in the sketching process. Normally these calculations have been conducted ex post.
- Conduct group works in a drawing hall instead of in the ordinary group rooms. In the drawing hall students from different semesters are working in the same creative working space (Fig. 5.).

[4] cf. page 2 of this article

- To include the computer as a learning tool in the sketching or modelling process – and not only as a tool for presentations.

Fig. 5. Student group working in the drawing hall.

6. WHAT HAS TO BE FURTHER DEVELOPED?

As mentioned above the semester has, so far, been fairly successful, but there are still improvements to be done in the following areas:

- The time pressure should be reduced as the courses compete with the time the students have to spend to achieve the necessary sketching competencies and find their personal architectural expression.
- The students' ability to catch ideas and associations, to visualize and to let ideas flow easy from mind to hand to paper.

- The digital tools need to be elaborated to match the professional architectural and engineering demands.
- The technical tools, especially within construction, need further development.
- The interdisciplinary supervisor teams – which have worked well so far – must develop their teamwork and find a more precise definition of what can be learned from each other.
- Interdisciplinary research between architecture and engineering should be encouraged.

Especially the time pressure and the fact that all courses are placed in the first two of the three periods of the semester create problems. It is difficult to begin the sketching process in due time since only a few days are left for project work during the first two periods. The problem is whether the students in the time available are able to achieve sufficient sketching qualifications.
The students are stuffed with courses and lectures, and may loose the initiative to search for knowledge by themselves. The teachers know how to do problem-based work, but my concern is, are the students learning it, when so much time is devoted for instruction ex catedra?

7. THE INTEGRATED DESIGN PROCESS AND THE FUTURE CHALLANGES

It has been exciting and challenging to work with the Integrated Design Process in the Architecture programme with it's' combination of elements from architecture and engineering. It is obvious that it leads to other solutions – other types of buildings and new designs – when the technical disciplines are included in the design process. On the sketching level the projects become better defined than they use to be in the more "artistic" architectural setting. The indoor environmental conditions and the energy frame of the building become clarified. In this way you avoid frustrating problems when e.g. ventilation does not fit into the design of the building.
This is also important for the comfort, and for a good working environment for the coming users. From an economic point of view, the operating costs can be kept at a low level when the climate shield of the building is optimised saving energy for cooling and heating, and the passive ventilation principles are employed, which also reduces energy expenses.

Further development of the computer as a sketching tool is also an exciting challenge. When better sketching programmes are created this tool will be even more useful. Students who use the computer as a modelling tool have a good chance to obtain a good spaceial understanding. Working with the computer also animates you to produce new architectural designs. By using computer simulations of warm and cold airflows you can map in advance the position of cold and warm zones in a building.

It is a huge challenge for the future to develop programmes which can be used for co-optimising a wide number of parameters at the sketching level - both architectural parameters (design, climate shield, facades, plans arrangements, functions, logistics, materials) and engineering parameters (natural ventilation, climate shield, needs for heating and cooling, and construction). One could wish to be 3 – 6 years ahead in time when the immense calculation power of the computer, and its unlimited ability to store large amounts of information such as large collections of indoor environment principles and solutions, principles of construction, and available materials, have been submerged in a combined, computerised design process for the buildings of the future[5].

[5] These tendencies can be seen e.g. in the exhibition "Futures2come" in Dansk Arkitektur Center, Gl. Dok, in Copenhagen 12. March – 9. June 2003.

REFERENCES

Steen Agger. Kompendium til kursus i programmerings- og skitseringsmetodik. Arkitektskolen i Aarhus, 1983. [Steen Agger (1983). Compendium for course in programming and sketching methods, School of Architecture in Aarhus.]

Hans Kiib. Studieordning for Civilingeniøruddannelsen i Arkitektur & Design. 6. – 10 semester september 2001. Aalborg Universitet. [Hans Kiib (2001). Curriculum for MSc Engineering with special curriculum in Architecture & Design, 6th to 10th semester, Aalborg University.]

Mary-Ann Knudstrup. Studievejledning for 6. semester, Arkitektur og Økologi – Energi og klimatilpasset byggeri. Arkitektur, Arkitektur & Design, Aalborg Universitet, januar 2000. [Mary-Ann Knudstrup (January 2000). Study guide for 6th semester, Architecture. Architecture and Ecology – Energy and environment in Architecture. Architecture & Design, Aalborg University.]

Mary-Ann Knudstrup. Studievejledning for 6. semester, Arkitektur og Økologi – Energi og klimatilpasset byggeri. Arkitektur, Arkitektur & Design, Aalborg Universitet, januar 2002. [Mary-Ann Knudstrup (January 2002). Study guide for 6th semester, Architecture. Architecture and Ecology – Energy and environment in Architecture. Architecture & Design, Aalborg University.]

Bryan Lawson (2000). How Designers Think. The design process demystified, Architectural Press 2000.