Integrated Energy Design - Education and Training in Cross-disciplinary Teams Implementing Energy Performance of Buildings Directive (EPBD)

Corresponding Author: Camilla Brunsgaard, Department of Architecture, Design and Media Technology, Aalborg University, Denmark. Gammel Torv 6, 9000 Aalborg. Email: cbru@create.aau.dk

Pavla Dvořáková, Department of Microenvironmental and Building Services Engineering, Czech Technical University in Prague, Czech Republic. Thakurova 7, 166 29 Praha 6. Email: pavla.dvorakova@fsv.cvut.cz. Telephone +45 9940 7899, Fax +45 9813 6107

Annemie Wyckmans, Department of Architectural Design, History and Technology, Norwegian University of Science and Technology, Norway. Sentralbygg I, 768 Alfred Getz vei 3, 7491 Trondheim . Email: annemie.wyckmans@ntnu.no

Werner Stutterecker, Forschung Burgenland GmbH, Austria, Steinamangerstrasse 21, A-7423 Pinkafeld. Email: werner.stutterecker@forschung-burgenland.at

Marina Laskari, Physics Dept., University of Athens, Greece, University Campus-Build-Phys-5, 157 84 Athens. Email: mlaskari@phys.uoa.gr

Manuela Almeida, Civil Engineering Department, University of Minho, Portugal, Azurém 4800-058 Guimarães. Email: malmeida@civil.uminho.pt

Karel Kabele, Department of Microenvironmental and Building Services Engineering, Czech Technical University in Prague, Czech Republic. Thakurova 7, 166 29 Praha 6. Email: kabele@epsilon.fsv.cvut.cz

Zoltan Magyar, HVAC Department, University of Pecs, Hungary. Boszorkany u. 2. HU-7624 Pecs. Email: zmagyar@invitel.hu

Piotr Bartkiewicz, Faculty of Environmental Engineering, Warsaw University of Technology, Poland. 00-653 Warszawa. Email: Piotr.Bartkiewicz@is.pw.edu.pl

Peter Op 't Veld, Cauberg-Huygen Raadgevende Ingenieurs BV. the Netherlands, Parkweg 22A, 6212 XN, PO Box 480, 6200 AL, Maastricht. Email: P.OpTVeld@chri.nl

Keywords: Education, cross-disciplinary, integrated design, energy-efficient building design, architecture, engineering

Abstract: In Europe, energy and climate policies started to take shape from the 1990s onwards culminating with the ambitious 20-20-20 climate goals and the Low Carbon Europe roadmap 2050. The European Commission empower the importance of achieving the objective of the recast Directive on energy performance of buildings (EPBD) that new buildings built from 2021 onwards will have to be nearly zero-energy buildings. The general belief is that the energy performance optimization of buildings requires an integrated design approach and cross-disciplinary teamwork to optimise the building's energy use and quality of indoor environment while satisfying the occupants' needs.

In this context, there is a substantial need for professionals such as architects and engineers specifically trained and educated in integrated design approach and trained to work in cross-disciplinary teams. To be able to push forward the development, it is essential that educational institutions foster professionals with such knowledge, skills and competences. An initiative towards this direction is the EU project of IDES EDU: "Master and Post Graduate education and training in multi-disciplinary teams".

The paper describe the necessity of more integrated and cross-disciplinary approaches to building design through state-of-the-art of the building sector and educational initiatives in the participating countries in the project, and through theory of design processes. The paper also communicates the results of newly developed cross-disciplinary education established by fifteen different educational institutions in Europe. Finally, the paper explains and discusses the challenges encountered during development and implementation of the education across different professions and countries.

1. Introduction

1.1 Motivation

Energy is at the heart of most critical economic, environmental and developmental issues faced by the world today [1]. In Europe, energy and climate policies started to take shape from the 1990s onwards culminating with the ambitious 20-20-20 climate goals aiming to be met by 2020 and the Low Carbon Europe roadmap 2050 with the ambition of converting EU into a competitive low carbon economy by 2050 [2]. According to the European Commission, greenhouse gas emissions in the built environment could be reduced by 90% by 2050 [2], empowering the importance of achieving the objective of the recast Directive on energy performance of buildings (EPBD) that new buildings built from 2021 onwards will have to be nearly zero-energy buildings [3]. The IEA World Energy Outlook even requires zero emission standards for new buildings from 2015, and increased energy efficiency for all building stock, with CO_2 emissions to be reduced by 30% by 2020 compared to 1990 level [4].

The development and operation of energy-efficient buildings are complex tasks that fully require the combined effort of designers in the development of the projects, qualified architects and engineers with different skills and installers and builders to deliver the building as designed and commissioned as well as building operators capable of maintaining the building in its full energy performance. EPBD and the EU Energy Efficiency Plan 2011 both underline the importance of the continuous training of such professional experts for their successful implementation [3] [5]. Even though, energy and resource use primarily is in focus, it is also important to pay attention to the indoor environmental quality of future building, which sometime is neglected on the expense of minimising energy use. Aiming for satisfactory indoor environment also increases the complexity of designing future built environment.

The general belief is that the energy performance optimization of a building requires an integrated design approach to minimize the building's energy use while satisfying the occupants' needs [6]. Design strategies such as building orientation and architectural features to minimize solar gains in summer and maximize the availability of usable daylight combined with building construction, clever design and accurate control of the heating, ventilating, air-conditioning and lighting systems are examples of an integrated design approach to optimize the building's energy performance. Integrated design considers and optimises the building as an entire system including its technical equipment, the surroundings and for the whole lifespan [6]. This means that architects and specialists like mechanical, civil, and HVAC engineers, energy experts and installers should work together in cross-disciplinary teams from the very beginning of the design phase, requiring an extra effort of the parties involved [7]. However, this integrated approach is not common for architects and engineers in most European countries. The design process is usually a fragmented process where engineers and experts are involved in a stage of the process where some of the most influential design decisions have already been made [8], leading in many cases to inefficient solutions, non-optimized buildings and higher costs due to untimely and non-integrated addition of energy efficiency measures and renewable energy systems [6] [7].

In this context, there is a substantial need for professionals such as architects and engineers specifically trained and educated in integrated sustainable design approach and able to work in integrated cross-disciplinary teams [8], addressing the need to optimize the energy use in new and existing buildings and the built environment [9], not only to produce buildings meeting current EPBD standards, but especially for buildings within the nearly zero-energy concept meeting the future EPBD. To be able to push forward the development in this field, it is essential that educational institutions foster professionals for whom cross-disciplinary work will be the basis of the design process. An initiative towards this direction is the project of IDES EDU: “Master and Post Graduate education and training in multi-disciplinary teams” (Grant agreement no.IEE/09/631/SI2.558225, Period: 01-07-2010 to 30-06-2013, duration: 36 months).

1.2 Objectives

The objectives of this paper are to:

- describe the necessity of more inter- and cross-disciplinary approaches to building design
- communicate the result of newly developed cross-disciplinary education in the project IDES-EDU established by 15 different educational institutions in Europe (Figure 1)
- explain and discuss the challenges in developing cross-disciplinary education across different professions and countries

The paper begins with a state-of-the-art of the building sector and educational initiatives regarding energy optimisation in the built environment in a selection of the participating countries in the IDES-EDU project (Chapter 2). Chapter 3 reviews different design process models, while Chapters 4 and 5 describe and discuss the educational packages produced by IDES-EDU and the challenges and experiences encountered during their development and implementation.

1.3 Enery.efficient building design – state-of-the-art in education and the building sector in seven EU countries

The overall pressure to reduce energy needs for buildings urged by the EPBD, has given rise to an increasing number of low energy (passive, zero-energy) building projects in the European building sector. The building projects have demonstrated that this type of design is a complex task and in fact requires successful coordination of architectural, constructive, HVAC and lighting concepts in the early design stage [10] [11]. The European Commission recognizes the lack of appropriately trained specialists in this field and intends to work with the Member States to adapt their professional and university training curricula to reflect the requirements for new skills, education and training in the construction sector [5]. In the following, a selection of the fifteen universities in the IDES-EDU project present in brief the state-of-the-art in education and the building sector in their respective countries.

Figure 1: All fifteen participants: Norway, Norwegian University of Science and technology (NTNU). Sweden, Lund University (ULUND). Denmark, Aalborg University (AAU). Lithuania,Vilnius Gediminas Technical University (VGTU). Poland, Warsaw University of Technology (WUT). The Netherlands, Cauberg-Huygen (CHRI) and Hogeschool Zuyd Heerlen (HSZ). Czech Republic, Czech Technical University Prague (CTU-FCE). France, University of LaRochelle (UNIV-LR). Austria, Fachhochschulestudiengänge Burgenland (FHS-B). Croatia, University of Zagreb (UNI-ZG). Slovenia, University of Ljubljana (UNI-LJ). Hungary, Pecs Technical University (PTE). Italy, Politecnico di Torino (POLITO). Greece, National and Kapodistrian University of Athens (NKUA). Portugal, University of Minho (UMINHO).

1.3.1 Norway

In Norway, a growing body of quality and functional requirements present financial and technological challenges to the construction industry. The Norwegian Ministry of Oil and Energy has recently issued updated ambitions for the design, construction and operation of energy-efficient buildings, as energy consumption for the operation of buildings currently accounts for 37 percent of energy use in Norway. By 2040, the Government is asking for buildings where materials, use of energy and water, indoor environment, pollution, transport and waste are watched in a holistic context in a life cycle perspective. In addition, energy-efficient buildings should be attractive and inspiring to all users, and universally designed; have a good indoor environment and moisture balance; and have low energy use and greenhouse gas emissions in a life cycle perspective [5].

Appropriate policy instruments will contribute to achieving this goal, amongst others including more energy-efficient equipment, fees, regulations and funding schemes. Technical requirements were intensified in 2007 and 2010, and will demand passive house level standards by 2015 and near zero energy levels by 2020.

This ambition requires a cross-disciplinary and cross-institutional approach, in education, industry, governance and research [5]. Holistic integration of design procedures and innovative technologies can reduce energy use as well as greenhouse gas emissions in Norwegian buildings. Building owners' competency in specifying requirements needs to be improved, and the effectiveness of energy-efficient measures and policies need to be documented and validated. In addition, improved knowledge on user behaviour and interaction with energy technologies may support the effectiveness of implemented measures. In order to achieve this, a cross-disciplinary approach combining social sciences, engineering, architecture and economy is needed – not only in construction practice but from the early stages of building education [14] [15]. In addition, architecture and engineering education need to a larger degree to take into account the renovation of existing and historic buildings. The new construction rate in Norway is currently only 2,1 per cent per year [5]. In order to integrate these aspects fully in Norwegian architecture and engineering practice, the following measures are needed in education [5]:

- Revision of curricula and development of new subject areas for energy efficient engineering, rehabilitation and management on BSc and MSc level;
- Introduction of programmes for continuing education of teachers at colleges and universities;
- Increase of training capacity through establishment of new programmes with focus on energy efficiency;
- Special training initiatives aimed at property developers, managers and technical operations personnel.

1.3.2 Denmark

The building regulations in Denmark as regards to energy use have been sharpened in the resent years and are continuing to do so (year 2006, 2010, 2015 and 2020), including sharper demand for the quality of the indoor environment in 2020 [16]. It has resulted in a growing interest in optimising the design process in the building sector – A design process that traditionally consists of actors who has specialised knowledge and competences and little knowledge about related businesses, which therefore complicate the process. At Aalborg University they have faced this challenged already in 1997 by bridge the gap between architecture and engineering in the master programme of Architecture at the Department of Architecture, Design and Media Technology, where the architectural students are introduced to aspects of engineering [17]. The candidates get an inter-disciplinary profile, which prepare them to fit into a design team with more traditional profiles and thereby facilitate and help the design team to work cross-disciplinary within an integrated approach. The candidates are highly requested. Nevertheless, there are still room for improvement and optimisation. The building industry still needs additional knowledge about the principals and technologies of energy-efficient design including optimisation of indoor environmental quality, and experience in working in cross-disciplinary teamwork. Especially, post-graduate programmes are needed and can benefit from the IDES-EDU project.

1.3.3 Czech Republic

Growing experience in designing passive or nearly zero energy buildings, shows that an integrated approach to the design is essential. Czech Republic (CR) is ready to comply with the requirement of EPBD as soon as the designers and building companies reach the proper knowledge [12].

Education of professionals within building design and their systems are in CR done at universities by faculties of architecture, civil engineering, mechanical engineering and electrical engineering. These study programs has a wide range of focus from the purely architectural and artistic approach with emphasis on the artistic concept (e.g. Academy of Arts, Architecture and Design) to purely technical approach (e.g. Faculty of Mechanical or Electrical Engineering). Faculties of civil engineering produce architects with deeper knowledge of technical aspects and engineers with wide range of focus. Specialist from all these faculties finally work in the design process together and their lack of knowledge in other fields may complicate the communication within the team.

Recently several changes in the educational field have been made to bridge large gaps between professions. Master programme “Buildings and Environment” at Faculty of Civil Engineering at Czech Technical University in Prague (CTU) running since 2007/2008 aims to integrate architectural, constructive and building services approach [19]. Nevertheless graduates from this program are more or less focused on building construction or HVAC design and usually do not come across the architectural design. Another MSc. program “Intelligent Buildings” has started in 2009/2010 to answer the market needs of more integrated design at CTU in Prague. Three faculties are participating in this program: Faculty of Civil Engineering, Faculty of Mechanical Engineering and Faculty of Electrical Engineering. The motivation for the development of this program was the lack of inter-disciplinary professionals that are able to create conceptual design of buildings; coordinate the group of different specialists during the design and building-up stage and operate the building in the most proper way. However the program Intelligent Buildings produces professionals focused more on technologies and building operation systems than the integration with the architecture. An educational program focused on integrated building design is still needed.

1.3.4 Austria

An Austrian study about the quantitative meaning of green jobs and their qualification requests that new alternative heating technologies imply an increasing complexity of the products [20]. Regarding green skills the future request will rise. Based on profound specialist knowledge, competences like e.g. consultation knowledge, a combined knowledge of the discipline and of the complexity, and cross-disciplinary networking and cooperation will become important.

At the University of Applied Sciences Fachhochschulstudiengänge Burgenland Ges.m.b.H. the two building sector related master courses “Building Technology / Building Management” and “Sustainable Energy Systems” are offered. Until now the cross-disciplinary idea was only partly implemented in the two mentioned courses e.g. in cross-disciplinary project works. However the idea of the integrated design (and the results of the IDES-EDU project respectively) will be implemented even more in the existing master courses stepwise in the very near future where applicable.

1.3.5 Hungary

The energy regulation in Hungary was introduced in 2006 and 2008 [21]. The number of low energy buildings is increasing (passive, low energy, zero energy) thanks for several financing support. Experiences show that the qualification needed is inter-disciplinary and cross-disciplinary approaches in the design process, industry and education. Additionally, innovative technologies can reduce energy use, greenhouse gas emissions and improve indoor environmental quality.

The education and training started concerning the energy certificating of buildings and continued with different MSc and postgraduate courses [22]. A new MSc (4 semesters) was introduced in Hungary for architects, civil engineers, mechanical engineers and electrical engineers. The main aim is to get a wide range of building design and operation. The specialization of the MSc course could be integrated design approach, building operation, general building engineering. The education will be started in University of Pecs within 2 years and used majority of the modules developed by IDES-EDU.

The need arises for people who are involved in the design, construction, commissioning and operation to get up-to-date information about the integrated building design. A new postgraduate course (2 semesters) was recently introduced in University of Pecs combining building services, architectural and construction topics. This course has direct link to the IDES-EDU project.

1.3.6 Greece

In recent years, the demand for energy efficient and sustainable buildings has increased in Greece [23]. This fact along with the adoption of more stringent building regulations has unavoidably led to an increase in the need for more specialized and skilled experts capable of delivering such buildings in Greece [24]. Although the specialization in individual fields is present in Greece, the design approach followed is still more traditional rather than integrated.

Greek universities still consist of the more traditional building design and engineering schools and therefore provide more conventional under-graduate degrees. Nonetheless, efforts of updating courses with modern technologies and approaches are being made at module level, either through the introduction of new modules or throught the update of existing ones. On the other hand, many intercollegiate graduate courses are available allowing for students from different backgrounds to specialize in a common subject. The IDES-EDU project will contribute to strengthen this development.

1.3.7 Portugal

The concerns for energy use in buildings, as well as energy regulations, are relatively new in Portugal. Due to an apparent mild climate, cultural traditions and poor comfort conditions inside Portuguese homes, the energy consumption in buildings has been low. However, the national panorama in what concerns energy issues is changing. The increase in the quality of life, together with the younger generations' actions, more demanding in what concerns comfort conditions, are causing a change in the national energy profile. At the same time the energy consumption in the building sector has grown in an unsustainable way in recent years. Moreover, the concern for sustainability in buildings are becoming more important every day and the new legislation, due to the implementation of EPBD, is very demanding and technicians are generally not prepared for this new challenge. At the moment, at national level, there is a deep lack of knowledge on how to design energy efficient buildings in accordance with the new rules [25] [26].

Within this context and with the increasing complexity of the building projects, the market starts looking for professionals with more comprehensive project skills and capable of integrating different knowledge and concerns in building design. However, the educational provision in this area in Portugal is very scarce. Mostly, universities offer courses in very traditional areas of activity and the dialogue between the actors involved is very difficult since they have different visions and approaches to the related problems. Recognizing this problem, the Civil Engineering Department of University of Minho launched in 2008 the Master Course in Sustainable Construction and Rehabilitation putting together engineers and architects discussing sustainability in building construction where energy issues are deeply discussed and analysed and where an integrated approach is the main objective.

1.3.8 A common challenge to approach energy-efficient buildings

All the countries mentioned here face similar challenges within the building sector, but the situation in the educational system across Europe varies. Overall, universities are moving towards a more holistic understanding of integrated design, construction and operation processes in energy-efficient buildings, though at their own pace.

The IDES-EDU project was created with the goal to centralize these efforts, with funding from Intelligent Energy Europe (IEE) (Grant agreement no.IEE/09/631/SI2.558225, Period: 01-07-2010 to 30-06-2013, duration: 36 months). The overall intent is to educate, train and deliver specialists, both students and professionals, with a cross-disciplinary profile and competency in integrated design approaches that support energy-efficient design. These efforts are described and discussed in Chapters 4 and 5.

But what is integrated design? We often use the term and claim it is the approach to use when designing energy-efficient (or nearly-zero energy) buildings. Throughout the IDES-EDU project, partners have discussed different, sometimes conflicting perspectives and practices of integrated design, aiming to align best practices across participating institutions and learning from each other to overcome challenges. The following chapter will outline and clarify this aspect.

2. Theory and Method – Integrated Design

"As well as letting in daylight and sunlight and allowing for natural ventilation, the window is also usually required to provide a view while retraining privacy. As an interruption in the external wall the window poses problems of structural stability, heat loss and noise transmission, and is thus arguable one of the most complex of building elements." [27]

The quote illustrates the complexity of design in general, but as requirements to energy use and indoor environment are tightened the complexity of design is increasing even further [28]. And with the adoption of the EPBD EU Member States face new tough challenges moving towards new and retrofitted nearly-zero energy buildings by 2020. The goals cannot be reached by using technology alone because the strategies to fulfil low energy goals are also highly related to the architectural design of the building and to user behaviour. The general perception is that the “traditional design process” (TDP) cannot facilitate this complex task. On the other hand, a more integrated design approach can deal with the higher levels of complexity [6][33][34]. But what is the difference between the two approaches?

2.1 The Integrated Design Process (IDP) vs. the Traditional Design Process (TDP)

If generalized, the TDP often proceed like this: The architect and the client agree on the design concept consisting of the form concept, orientation, fenestration and the exterior appearance like characteristics and materials. Then, the engineers and consultants are asked to implement or design technical systems for the building. This procedure seems simplistic mainly because the “active” actors in the process are limited and they are implemented linearly [6], see Figure 2. In a linear process it is often difficult or even impossible to optimise the design according to e.g. energy and indoor environmental issues, because the expertise comes in late in the process and the architectural concept is fixed. Nevertheless, this approach is mostly used, however the reasons for doing so is not clear. On one hand, the barrier of integrating IDP in praxis could be because the architects protect their professional domain and the engineers do not want to intrude on the architectural domain and vice versa [29]. Another barrier could be that the professions are not trained to work in an integrated way and simply stick to the what thay know. The complex design process has become even more evident when designing energy-efficient (or nearly-zero energy) architecture because more parameters come into play and the solutions are much more interdependent than in standard building design fulfilling the conventional level of performance [30].

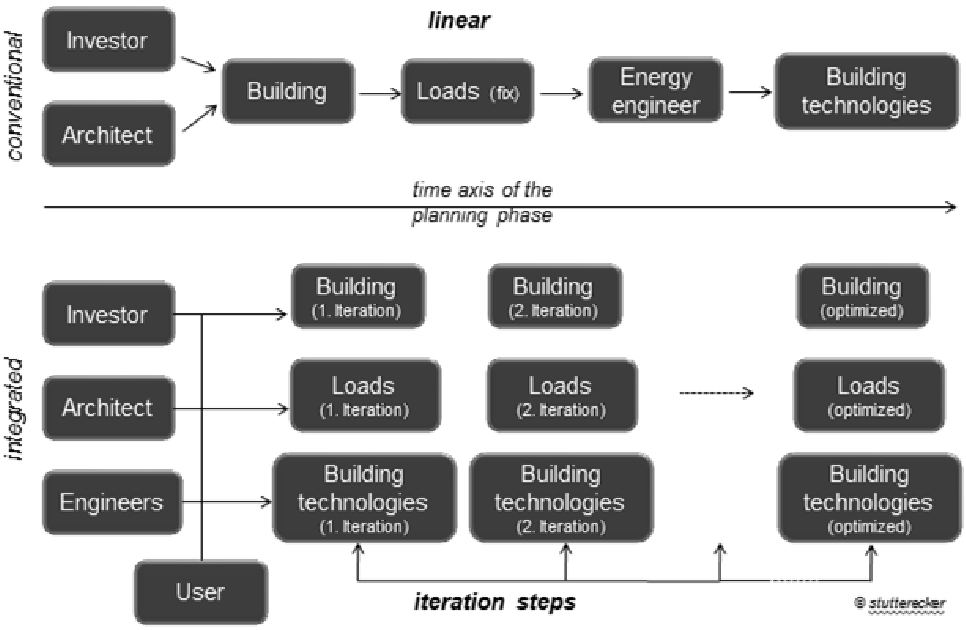

Figure 2: Top – The Traditional Design Process – a linear approach. Bottom – The Integrated Design Process – an iterative approach

In the TDP the design often results in [6]:

- unused potential of solar gains, resulting in higher heating demands
- exposure of glazing to summer sun, resulting in higher cooling demands
- unused potential of daylighting due to a lack of appropriately located/dimensioned glazing, or lack of features to channel daylight further into the interior of the building
- exposure of occupants to discomfort, due to local overheating or glare in areas lacking adequate shading
- non-efficient use of area due to lack of integration of equipment in the building
- higher investment and life cycle costs due to add-on of equipment during advanced design and even operation stages
- lower architectural and use value due to lack of alignment with technical equipment
- less efficient or unnecessary HVAC systems

In recent years a number of different approaches to IDP have been developed including some with slightly different names like: Integrated Design Process – A Guide for Sustainable and solar-optimised Building Design by International Energy Agency (IEA), Solar Heating and Cooling Programme, Task 23 [6]; Integrative Design Guide to Green Building by Bill Reed et al. [32]; Integrated Energy Design by the project INTEND by Intelligent Energy Europe (IEE) [33]; Integrated Design Process developed and used at Aalborg University in the Civil Engineering programme Architecture & Design [34] [35] and Integrated Energy Design at the Norwegian University of Science and Technology [36]. Generally, most of the methodologies wish to reach the same goal. They tend to focus on the importance of integrating both engineering and architectural design aspects in a holistic synthesis. The most acknowledged approaches to IDP include an iterative process, where all design issues are discussed by all actors in a team; see Figure 2 – e.g. like the method from International Energy Agency (IEA), Task 23 [6].

An IDP is often identified by the following parameters [6]:

- an iterative process
- considers and optimizes the building as an entire system including its aesthetic and functional aspects, technical equipment and surroundings
- all actors of the project cooperate across disciplines and agree on far-reaching and crucial decisions jointly from the beginning
- the design concept is subject to iterations early in the process, which is done by a coordinated team of specialists

2.2 Impact on building design and the challenges of different work methods

By approaching the design process in a more integrated way the whole design concept will be more holistic. It means the climate, strategies to optimise the indoor environment and energy use are thought together into a common concept avoiding fragmentation, incoherency and/or technologies that are “add-on´s”. The quality of the concept and final building design is highly dependent on the competences and communication in the design team and the view on design processes in general [39]. Even though a design process holds other actors than architects and engineers like; clients, contractors and users, the first two will be used to explain the different approaches to design.

Table 1. Examples of quantitative and qualitative issues relevant in an architectural design process.

Quantitative issues	**Qualitative issues**
Statics Energy consumption Indoor environment Economics Etc.	Aesthetics: spatiality, texture and materiality, light and shadow Functionality as regards to context, users etc. Users, everyday life, activities Atmosphere Physiological requirements Cultural expectations Etc.

Traditionally, architects acted alone on the design of the building and such a design process usually is a cognitive process where the architect conjectures an approximate solution to structure the understanding of the problem and test its resistance [40]. Architectural design problems have a large number of solutions open, mainly because the field of architecture takes qualitative and quantitative issues into account at the same time and they inform each other, which means they cannot be solved individually, see examples in Table 1. At the same time, every assignment is unique because relevant issues such as functional programme, local climate and site etc. vary in each case [27]. Today, especially the competences of engineers have to come into play in the architectural concept because form concept, orientation, fenestration etc. influence performance of the building [37] Trebilcock, M. Integrated Design Process: From analysis/synthesis to conjecture/analysis. PLEA2009 - 26th Conference on Passive and Low Energy Architecture, Quebec City, Canada, June 2009

[38][39]. Therefore the approach to the design processes is challenged. Engineers often have focus on the solutions having an analysis/synthesis(A/S) approach where the architects have focus on the problem having a conjecture/analysis(C/A) approach [trible4] [40]. In an A/S approach the problem is firstly broken down and analysed in sub-problems and individual problems. The individual solutions and sub-solutions are then synthesized until achieving the overall solution. In a C/A approach one proposes an idea that is holistic in nature before attempting to conduct any analysis. The two (competing) approaches or paradigms can result in conflicts when combining them in an IDP. Maureen Trebilcock concludes that when designing sustainable architecture it requires that architect and engineer overlap their knowledge and skills and share the character of a designer, it stresses the necessity for each discipline to cover basic and essential knowledge and skills of the other, resulting in architects and engineers with a new character, different from the traditional one [8] Heiselberg, P. Integrated Building Design - DCE Lecture Notes No. 017, Aalborg University, Department of Civil Engineering, Indoor Environmental Engineering; 2007.

]. To design energy efficient architectures is not just a matter of timing, like bringing all participating together from the beginning, or the use of common language. It is also about the approach to designing a building in itself that needs to be addressed – and especially in education.

Therefore, the project of IDES-EDU put an effort in educating in integrated design approaches, alongside improving the common knowledge and skills about energy efficient architecture. The candidates will hopefully influence design approaches in practise and thereby the industry will hopefully overcome the barriers of implementing IDP. In the following the project of IDES-EDU will be further explained.

3. Results – IDES-EDU Project Aims, Structure and Implementation

The IDES-EDU project approaches the challenges outlined in Chapter 3 by creating Master and Post Graduate education and training in multi-disciplinary teams. The aims, structure and implementation of the educational packages developed by IDES-EDU are explained in the following, along with challenges encountered during development and implementation of the project.

3.1 IDES-EDU project

IDES-EDU is a project co-funded by the Intelligent Energy Europe programme (Grant agreement no.IEE/09/631/SI2.558225, Period: 01-07-2010 to 30-06-2013, duration: 36 months) [42]. In IDES-EDU fifteen European educational institutions work together to develop curricula and training programmes for MSc students and professionals (Post Graduate courses, PGr) that will meet the building sector's modern needs for experts capable of applying the integrated design approach and performing well in a cross-disciplinary and interdependent problem-solving framework. The participating institutions can be seen in Figure 1.

3.1.1 Aims

The main aim of the project is to promote and implement the integrated design approach for buildings and energy systems and as a result to contribute to the optimisation of the market orientated implementation of the EU directives on EPBD and renewables. The project also aims to facilitate the process to reach long-term targets for a resource-efficient, low-carbon Europe by 2050.

The main objectives of the IDES-EDU project are to:

- Create and implement curricula and training programmes (master and post-graduate courses, respectively) that will educate, train and deliver experts in Integrated Sustainable Energy Design taking into consideration the policies of the EU, while working in a multidisciplinary environment;
- Establish close collaboration with key actors and stakeholders of the building sector at national and at European level in order to better understand their needs for new skills, knowledge and competencies and incorporate them in the curricula and training programmes;
- Increase awareness, promote implementation and commitment on integrated multidisciplinary design through promotional campaigns in the building sector and exchange programmes with other European universities.

3.1.2 Outputs

The major outputs of the IDES-EDU project are:

- Design and development of a four semester master course and a post-graduate course on Integrated Energy-Efficient Building Design including an EPBD basic package, fundamental, theoretical, and practical educational packages integrating elements of architectural, civil, environmental and mechanical engineering. These courses are designed in such a way so as to be flexible and adaptable to a specific country's or educational institutions requirements while maintaining their European wide applicability;

- Implementation of the courses in at least fifteen European countries;
- Establishment of national consortia between participating educational institutions and accrediting bodies and relevant key actors and stakeholders from the building sector for collaboration in the framework of IDES-EDU;
- Internal students exchange program;
- External student exchange activities with other European universities and businesses of the building sector;
- A general framework for the training and education building objects to be used by students and post graduate participants as cases for implementation of Integrated Energy-efficient Building Design theory and methodology;
- Elaborated designs and terms of references for building objects by each educational institute and business plans for realization of the building objects by the participating educational institutes and the members of the collaborating national consortia;
- Realisation of training and education objects by Hogeschool Zuyd, Heerlen. i.e., 'The District of Tomorrow'[42][43], and by University of Ljubljana i.e. 'Self-sufficient living cell' [42][44];
- An intelligent dynamical and adaptive Multimedia Teaching Portal (MTP) to facilitate the learning and teaching process for students and teachers, respectively;
- Recommendations to relevant stakeholders and policy makers on the potential of integrated sustainable energy building design, capacity and potential of the trained experts.

3.2 Educational approach

3.2.1 Structure

The IDES-EDU project intends to educate, train and deliver specialists who will be able to follow the principles of the integrated design approach. Since the project address both students and professionals from various countries working in the building sector, the structure of the IDES-EDU course must be flexible but also coherent. Each institution has different teaching traditions and to support implementation the pedagogical approach in the project of IDES-EDU can be adapted to local approaches. The materials in the educational packages contain presentations in PowerPoint with notes and descriptions of example of exercises, workshops and seminars. The developed material should be seen as a toolkit which each institution can customize to fit into either an existing curriculum or to start up a full cross-disciplinary master.

The courses are classified into three educational packages Fundamental, Theoretical and Practical Educational Packages (Figure 3) which will be presented in the following paragraphs.

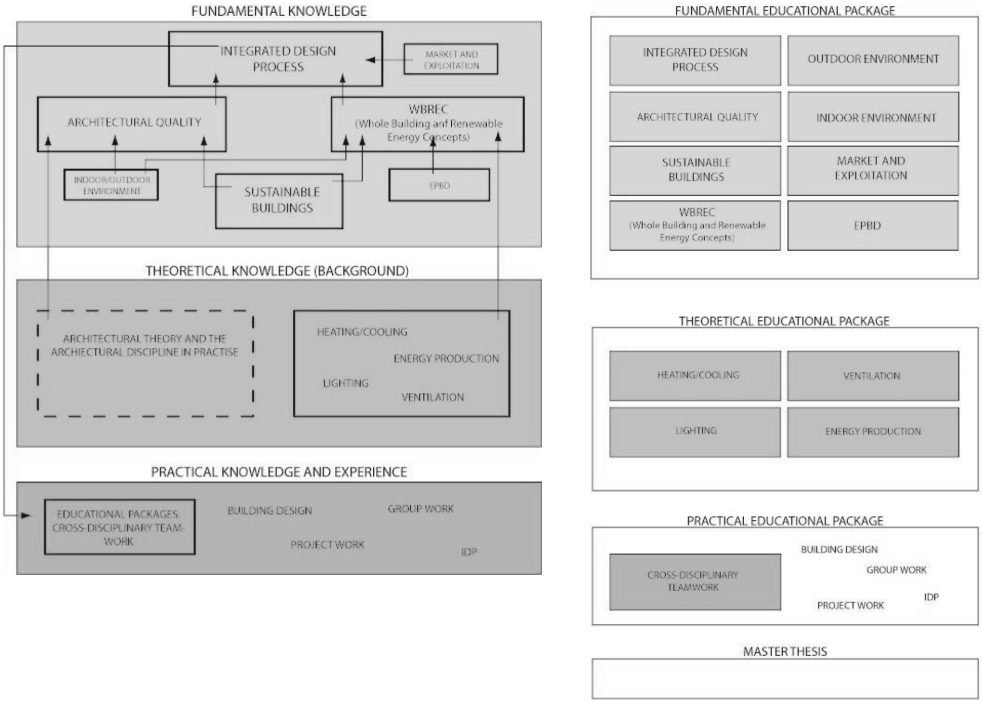

Figure 3: The illustration shows the content of the educational packages and the interrelations between its modules. Left: The interrelations between the different modules, the dashed box are not a direct part of the educational packages, but it is an essential part of the integrated approach. Right: The modules in each packages to which there are listed learning outcome and developed teaching material.

3.2.2 Fundamental packages

The fundamental educational package contains several modules on diverse topics which create the basis for working more advanced with designing energy-efficient (nearly zero energy) architecture, also taking into account quality of indoor environment.

The cornerstone is the module of Integrated Design Approach. The module introduce the students to the theoretical understanding of design processes and how designers think, which cover both the TDP and the IDP to illustrate the difference and importance of new approaches. The lectures also contain presentations of building examples from practice when working with the IDP. However, more general integrated concepts are also presented to illustrate the possibilities by working integrated. Additionally, workshops are suggested to be carried out in groups, which train the student in understanding the principals and outcome of integrated design.

Additional modules within this fundamental package are dedicated to Whole Building and Renewable Energy Concepts (WBREC), sustainable buildings, architectural quality, indoor environment, market and exploitation and EPBD. The integrated aspect within this educational package is obvious if the interrelations between the individual modules are considered (Figure 3, left). Architectural quality as well as the resulting module of WBREC are interrelating with the cornerstone of IDP. In addition the IDP must ensure that the quality requirement of the indoor environment (hydrothermal, air quality, acoustic, lighting, user behaviour and more) is met. In order to ensure a coherent structure for individual master and postgraduate courses the fundamental package is considered to be mandatory.

3.2.3 Theoretical packages

The second main part of the IDES-EDU teaching material is the theoretical educational package. The main topics of building technologies like heating/cooling, ventilation, lighting and energy production are the content of this package. The content of the two example modules, energy production and heating/cooling, can be seen in Table 2.

Table 2. Content of the module energy production (left) and heating/cooling (right)

Energy Production	**Heating/Cooling**
Energy carriers Heat generators – fossil fuels and biomass Heat Pump Solar collectors Earth heat exchangers for air pre-heating and pre-cooling Cooling compressor Evaporative cooling Solar Cooling PV electricity generation Small scale cogeneration (gas-pistio engine, gas-turbine. Biomass-Stirling engine) District heating, DWH and cooling systems, Large scale cogeneration	Fundamentals Passive heating and cooling Active Space Heating and Cooling Heating distribution network Heating and cooling systems control and operation Design and Analysis, H/C needs and loads optimisation Space heating and cooling concepts and emitters design Hydraulic system design

Since the theoretical educational package covers more specialized topics from the building technologies, compared to the fundamental package, all the materials are not considered to be mandatory. Therefore the contents of the theoretical package can be chosen depending on the background of the master course and postgraduate course students, allowing a high grade of flexibility. This flexibility allows each individual institution to implement the topics according to their educational background as well as to their implementation possibilities in terms of national accreditation requirements.

3.2.4 Practical packages

The third main part of the IDES-EDU teaching material is the practical educational package. The practical educational package comprises practical methods such as design projects, project work (Problem-Based Learning (PBL) and group work and therefore can be considered the other cornerstone in educationg cross-disciplinary candidates. The package aims to transfer the idea of IDP to the IDES-EDU students through practise. Only if the students can experience the integrated design idea through cross-disciplinary teamwork, with learning-by-doing (or PBL), they will understand the impact of integrated design. Therefore the practical educational package is considered to be mandatory.

In the project work (group work) ideally the team members has different professional background to be able to experience the cross-disciplinary approach. Project work encourage the students to engage in self-directed endeavours of exploration. It involves a process of transformation, one filled with challenges and unknown problems [45][46]. The problem in the MSc within IDES-EDU is to develop at building design which is optimised in terms of energy efficiency, integration of renewables, thermal comfort and health, and costs effectiveness. The project work is also a dynamic, stimulating and socially challenging process where the students, working collaboratively, have to organize work, make decisions and evaluate their results. The project work involves negotiations, dialogues and inquiries relevant to the theme of the building design, and the student draw on lectures, courses and various resources that are available in the course of the semester [45][46].

The practical educational package includes a module about cross-disciplinary teamwork, where the student are introduced to knowledge of methods and tools in order to perform teamwork across different disciplines, e.g. between an architect and a mechanical engineer. The module improves the students' ability to perform cross-disciplinary teamwork within an IDP in practise. The term cross-disciplinary means that a team member is an expert in one field and has basic knowledge in the other fields [41] (Figure 4). Different disciplines also mean different languages. For example the meaning of the word "design" may be understood differently by an architect and by an engineer. The architect may associate definition of space with e.g. walls, windows, daylight and atmosphere, whereas the engineer may associate proper dimensioning of a heating appliance. This simple language example shows that the architect is more dedicated to the whole building, where as the engineer is more focused on a detail. The module cross-disciplinary teamwork aims to give the student knowledge, skills and competences to be able to carry out a project in cooperation with other profession and close the gap between different profession – then the condition for carrying out integrated design is realized.

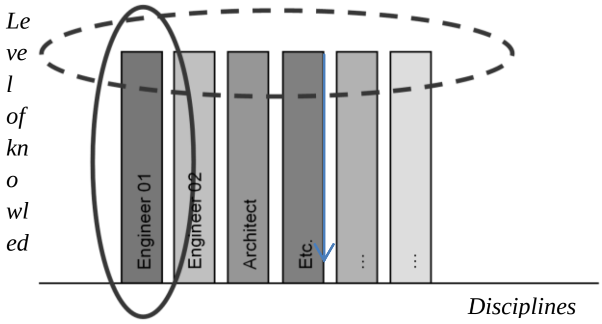

Figure 4: The overall conceptual idea of the cross-disciplinary profile. Each column represents an expert within a professional field, the IDES-EDU students should have expert knowledge within at least one field (red line) and be informed by other fields (dashed red line)

In order to emphasize the importance of the practical educational package the interrelations of cross-disciplinary topics are demonstrated in Figure 5 for the example of solar heating & cooling. The arrows in this figure show the interrelations between the topics. A topic like this can be used for simulation studies with the students. With the help of proper simulation tools (with different grades of detail) the students can experience in a safe environment the effects of different parameter changes and can evaluate how strong the examined interrelation is. Based on these self-studies the students develop step by step the meaning and power of integrated design from a technical (e.g. calculated performance figures) and architectural (e.g. opaque vs. non opaque areas) point of view.

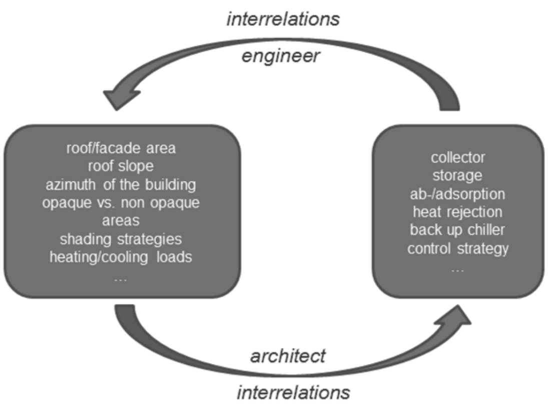

Figure 5: Interrelations of cross-disciplinary topics for the example solar heating & cooling emphasizing the connection of architectural and technical aspects within the integrated design approach

During the project work the students work with a building design where they for example use a building and building technologies simulation software like TRNSYS [45] Kolmos A, red. PBL at Aalborg university: contributions to the International PBL Conference in Lima July 17-24. Aalborg: Technology, Environment and Society, Department of Development and Planning, Aalborg University. 2006.

[46] Kolmos, A., & Graaff, E. D. (2003). Characteristics of Problem-Based Learning. International Journal Of Engineering Education, International Journal Of Engineering Education, 2003(19), 657-662.

[47]. It can be used in order to test the integrated design ideas. An example in TRNSYS could be to simulate a 2-story office building, where the students can do parametric studies very easily changing e.g. the area of the windows, the set-temperatures, the internal gains, the ventilation schedules, the heating power etc. The students can then analyse and discuss the effect of the different parameters changes both on the resulting energy use and architectural expression.

As a result of the project IDES-EDU, fundamental, theoretical and practical educational packages were developed. Together with a master thesis a full master course in integrated energy-efficient building design with a focus on cross-disciplinary teamwork can be planned. Additionally this structure can be used for the implementation of a post graduate course for the training of specialists from the building sector. All the developed modules are planned to be used as teaching material, therefore a Course Instruction Guide to the project and the teaching material are written, which should help with the dissemination of the IDES-EDU project idea. All can be found on the project website [42].

3.3 Attitude to the idea of a new way of education in participating countries, implementation

Around the world, the number of specialisation courses on energy in buildings is rising tremendously, and the quality of the educational packages offered is not always secured. Architecture and engineering schools are challenged to rethink their curricula to absorb pressure from the media, the construction industry and students who demand courses in sustainable architecture and engineering. Universities across Europe need to develop extensive co-operation to ensure that best practice becomes standard everywhere.

Generally, the goal is to educate students who are enlightened, innovative and independent when it comes to energy and resource use in buildings. They dare to be critical of new theories and solutions that consistently show up in ever-faster development. Simultaneously, the educational packages developed by IDES-EDU aim to solidify efficient use of energy and resources, and secure a satisfactory indoor environment as an integrated and explicit part of building practice, education and research. This is an on-going process that requires dialogue, reflection and development.

3.3.1 Realisation of educational packages

A first hurdle encountered in the development of IDES-EDU educational packages was the variety of educational cultures and traditions across countries, not only in terms of architecture and engineering departments, but, above all, between teaching-based and learning-based practices. Ideally, academic achievement is related to the facilitation of successful self-reliant students with achieved self-monitoring skills, such as self-evaluation, in-depth understanding and comprehension monitoring [48]. In practice, however, meeting between the fifteen universities quickly exposed large differences in terms of, amongst others, independence of the students' study habits, number of hours of teaching per week, and type of assignments and exams. The challenge consists of producing educational packages that can harbour these differences, while achieving the common goal of creating students with an enthusiastic attitude, good factual knowledge and expertise to transform the wide variety of opportunities available in the market into a successful project.

3.3.2 New Educational Programmes and Integration in Existing Curricula

A second challenge is related to implementation of new educational programmes (master (MSc) and post graduate) and the integration of courses, lectures and workshops on energy use in buildings in established curricula. In practice it proves difficult to include IDES-EDU lectures, let alone entire courses, into established educational programmes. Additionally, building up of new educational programmes does not come over night, as support from faculty is essential and a procedure of accreditation is necessary. In order to support the integration of IDES-EDU courses in established curricula, distribution of topics in distinct courses has been given a lot of thought and discussion prior to the actual development of the educational packages.

Table 3: The challenge related to implementation led to different action levels. Some institutions start with little integration (Action 1) others more. The goal is that over time, greater implementation level will be taken in each institution and non-participating institutions will follow.

Actions	**Level of Implementation**
Action 1- existing learning outcomes	Use several lectures in the existing education BSc, MSc, Post Graduate
Action 2 - common learning outcomes	Use several educational module in the existing education BSc, MSc
Action 3 - common learning outcomes	Use several educational module in the Post Graduate education
Action 4 - common learning outcomes	Use majority of modules in the Post Graduate education

Action 5 - common learning outcomes	Use majority of modules in the MSc education
Action 6 - common learning outcomes	National accreditation for a new MSc course Common accreditation for a new MSc course Implementation after the project

Nevertheless, it is expected that the full integration of IDES-EDU educational packages into established curricula will take several years, beyond the scope of the project itself. Yet, the project's time frame does provide the opportunity to test several lectures, workshops and in some cases entire courses across the participating universities. The construction industry requires a paradigm shift in which energy use in buildings form a natural and explicit part of architectural and engineering education, rather than a particular form of expertise that can only be achieved through voluntary post-graduate specialisation.

3.3.3 Feedback from students

IDES-EDU educational packages are tested on a wide variety of architecture and engineering students, in a mixture of domestic students, students who have chosen the Erasmus exchange programme for 1 or 2 semesters, and students following a 2-year international master programme abroad. Facilitating learning among this mixture of students provides an additional challenge for the IDES-EDU project, and it is of vital importance to get widespread feedback on the experiences of diverse students across all participating universities. Hence, to support the integration, testing and validation of the educational packages, an online learning platform is developed to spread various informal shared measures and activities among the students and teachers of the fifteen participating universities. The result is a learning arena that promotes dialogue and discussion on energy and resource use in a visible and explicit manner. This measure aims to support exchange of knowledge and experiences across the participants. Guest lectures, literature databases and other educational material can be shared among students and teachers. In addition, the platform allows students to actively communicate with each other, share opinions and interests, and provide more direct and interactive feedback support on the educational packages. Not only the content of the packages can be discussed, but also experiences with industry, professional ethics related to energy-efficient building design and the role architects and engineers play can be shared. The aim of the programme is to promote understanding, communication and a positive attitude between future partners in building and construction. Such cooperation between architecture and engineering is very labour intensive for both teachers and students. There is a need for much guidance and facilitation in order for the result to actually be a positive experience and not a confirmation of the old prejudices that continue to recur among architects and engineers. In addition, there is a need for a filter in education that can collect, analyse and disseminate available and valid knowledge about energy-efficient building design, and can facilitate the students‘ learning until they eventually manage to orient themselves on their own in the field.

3.3.4 Feedback from teachers

Developing educational material to be used by other teachers has proven to be a considerable challenge. Architecture and engineering professionals often draw upon their own experience when presenting teaching material and this is difficult to transfer to others. Slides that are optimised for showing in the classroom usually require additional text to be read by the teacher. In order to prepare the IDES-EDU educational packages, therefore, many slides had to be developed, even though all participants have long experience in teaching courses in energy-efficient building design.

In addition, most professionals seem to prefer to develop their own material, using the IDES-EDU educational packages as a plug-and-play resource base from which they can choose slides, literature and workshops in a different order, using different references and illustrations. While the educational packages are rarely used in their original state, they provide valuable support in promoting quality assurance and organisation of literature, tools and recommendations. Experience accumulated each semester by students and staff can be made available on the online learning platform in the form of a database in which the use of various resources is evaluated and discussed, and best practice is identified. Presentations by local architects and engineers reflecting on their experiences can be reworked into narratives and cases for use in teaching. Good student assignments in the form of case studies and projects can be made available, showing a diversity of criteria for energy and resource use in buildings. A digital billboard with activities and opportunities that exist at other educational institutions, such as information on scholarships and student contests, can increase and enhance the students' contributions in the field. In order to fully achieve this purpose, students are involved in the development of the online learning platform.

3.3.5 Challenges related to definition and evaluation of learning outcomes

Development of educational packages is irrevocably related to discussion and careful evaluation of expected learning outcomes. Aiming to support the education of architects and engineers with solid competency in energy-efficient building design requires experience and knowledge related to physical projects as well as co-operation processes – cross-disciplinary teamwork. Students might learn more from experimenting and failing than from safely repeating established routines – but how is this learning experience facilitated and graded?

Experience has shown that students usually have very ambitious goals related to energy and resource use, but it is a big challenge for them to translate theoretical knowledge into energy and environmental project design, even in the protective environment that constitutes the design studio. The transition from facts to engineering practices must be planned and practiced through small analysis tasks, case studies and reflection and dialogue for it to make sense. This combination of problem-based learning supported by factual information, often related to a limited subject at a time - such as location, material or design - can help students in a clear manner. Such exercises require knowledge of and close cooperation between building practice and research among the teaching staff [49].

Marshall [50] defines three main approaches to learning: a surface approach, mainly based on repetition and memorisation aiming for reproduction during the exam; a procedural deep approach aiming for familiarity with applications and problem-solving procedures and the ability to transfer them to other, similar problems; and a conceptual deep approach relating learning to underlying theory, aiming to gain a deeper understanding. Ideally, the IDES-EDU educational packages would aim to facilitate all three learning approaches in parallel, accustomed to the performance level of the individual student. However, according to Case and Marshall [51], students appear to tailor their learning mode to the type that is perceived as most appropriate during that course. Students may give up on a conceptual deep approach when they perceive that a procedural deep approach or even pure memorisation is more useful to get good grades, a scholarship or similar type of incentive. A large focus on design procedures, assessment methods and evaluation tools may thus help students to master the tools and skills they need in practice to solve problems, but may also reduce their chances of really understanding the problem, taking a critical point of view, and potentially revolutionise the building industry.

3.3.6 Recommendations to policy makers, external stakeholders and educational institutions not involved in the action

The attention that the topic of energy use in buildings currently receives can be used to build awareness and knowledge about energy and resource use in the building industry and general public. Many experts now make an extra effort to establish solutions that can be implemented in short term, such as guest lectures, and making additional material available online. Such measures are often the result of personal engagement of distinct members of staff, and thus person-dependent and fragmented. In order to have a long-term effect, however, this extra effort that many now provide needs to be supported and institutionalized. IDES-EDU provides an opportunity for investigating such institutionalisation, ensuring the exchange of experiences and development of knowledge between institutions across Europe, including the evaluation and improvement of curriculum, teaching methods, learning and assessment in architecture and engineering education. In addition, a network of national consortia of academic actors, public institutions and the construction industry provide a continuous update of the program's relevance to architectural and engineering practice.

4. Discussion

How can we create space in education schemes for architects and engineers that will allow successful implementation of integrated design programs?
As discussed above is it a challenge to implement the whole IDES-EDU programme for many of the participating educational institutions on master level. However, all institutions implement parts of the educational packages. The least challenging program to implement seems to be within postgraduate education where a training institute or organisation will add this program to its courses and offer it to a wide professional public. In any case the level of success depends highly on the attitude to the integrated approach. People involved – faculty managers, coordinators, teachers etc. – need to acknowledge the importance of integrating knowledge, skills and competences from different disciplines in one education; need to acknowledge the importance of cross-disciplinary teamwork and the importance of learning by doing – e.g. PBL with cross-disciplinary teamwork around a practical building case. It is important that involved parties are open-minded and connect their own field of specialisation with other building disciplines.

What is the role of the student and professionals educated with IDES-EDU packages in future design teams?
In a design team efficient sharing of information is desirable and essential to design energy-efficient (nearly zero) buildings without compromising indoor environment and architectural quality. It is important to have knowledge about dialogue management and skills to determine appropriate timing and assess importance of each partial task in the design and construction

process. Therefore, the educational approach implemented within the IDES-EDU project supports required skills for architects, engineers and other members of the team. Firstly, the student will get a basic knowledge of each professional field. Secondly, absorb the idea of integrated design and practise the ability to engage in cross-disciplinary team work, giving valuable expertise on their own contribution to a building project, and the advantage of timely co-operation with others. As a result, professionals graduated from such an educational program will provide the best prerequisite to become invaluable members of a design team, especially when working on buildings with minimal energy and resource use. The candidate could even hold a role of facilitator or project manager in the design team balancing the broad knowledge field and competences in cross-disciplinary teamwork. However the challenge of distributing and taking on responsibility is always present - responsibility for particular methods, tools, solutions, equipment and their proper functioning. As boundaries between professions become less strict in an Integrated Design Process and a lot of interactions appear, contracts and other forms of working agreements with detail specification of territories are needed. However each discipline should still be open-minded to enter other fields of expertise with new knowledge and allow innovation.

Will the labour market accept integrated specialists?
The building industry has an urgent need for specialists with knowledge and experience in integrated design [52] in order to reach ever more strict building requirements in terms of energy and quality of indoor environment towards the aim of EPBD by 2020, and Low Carbon Europe by 2050. Therefore, it is believed that the demands for the candidates will automatically emerge. Cross-disciplinary teams will provide higher quality work in the design stage, improving buildings' performance throughout their entire life cycle. Although the design process will be more complicated and demanding than most actors in the building industry are used to, hopefully through time the industry will recognise that it will result in reduction of difficulties during project design, construction phase and even during operation of the building – and then again reduce the cost.

5. Conclusion

In Europe, energy and climate policies started to take shape from the 1990s onwards culminating with the ambitious 20-20-20 climate goals aiming to be met by 2020, and the EU Low Carbon Roadmap 2050 with the ambition of converting EU into a competitive low carbon economy by 2050. As a result, pressure is put on building designers to design buildings with high standards of energy efficiency, performance and comfort [53] [54].

This article has described the effort to support requirements of the EPBD by implementing a integrated approach to energy-efficient building design into architectural and engineering education. It reveals the existing situation in architectural and engineering education across Europe and introduces the EU funded project IDES-EDU which focuses on creating and implementing curricula and training programmes that will educate, train and deliver experts in Integrated Energy-efficient Building Design which are able to work in cross-disciplinary environments. The aim is also to accreditate several new master programmes at a great number of European universities. It will support international collaboration among academic institutions and collaboration with professional bodies.

Real implementation of a new educational approach and designing approach faces several challenges within the current educational system and also in practice. If the integrated design approach and cross-disciplinary teamwork should become a common approach in the building industry, all key actors in the process have to agree on it and require it. By putting 15 European Universities together in a project like this and develop at common idea is one step on the way. Next step is to get the first candidates on the market and influence the existing businesses to agree and require new ways of working and thinking in building design.

The question is whether this approach in education can in fact change existing scheme of building designing process. In the authors´ opinion this is one of the most important steps towards fulfilling the energy and indoor environmental demands of the future. The more people that are acknowledged with the integrated design approach and topics related to that and the more its aspects and benefits are implemented by the design team the better the chances are that EU´s ambitious 20-20-20 climate goals will be met. Nevertheless, the role of the market is considerable.

References:

[1] Energy for a Sustainable Future - The Secretary-General's Advisory Group on Energy and Climate Change (Agecc) - Summary Report and Recommendations, New York, 28 April; 2010

[2] A Roadmap for moving to a competitive low carbon economy in 2050 - Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 8 March; 2011

[3] Directive 2010/31/Eu of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (recast), Official Journal of the European Union, 18 June; 2010

[4] IEA (International Energy Agency) World Energy Outlook 2012. Paris: IEA Publications; 2012

[5] Energy Efficiency Plan 2011 - Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, 8 March; 2011

[6] Löhnert G, Dalkowski A, Sutter W. Integrated Design Process – A Guideline for Sustainable and Solar-optimized Building Design. Berlin/Zug. IEA SHC Task 23 Optimization of Solar Energy Use in Large Buildings. 2003. Available from http://www.iea-shc.org/task23/

[7] Poel B, De Vries G, Van Cruchten G (ed) Larsson N, Esbensen T, Schuler M, Sonnemans E, Bouten E, Löhnert G. Integrated design with a focus on energy aspects, ECEEE 2005 Summer study; 2005

[8] Heiselberg, P. Integrated Building Design - DCE Lecture Notes No. 017, Aalborg University, Department of Civil Engineering, Indoor Environmental Engineering; 2007.

[9] Robinson D, Campbell N, Gaiser W, Kabel K, Le-Mouel A, et al. Suntool - A new modelling paradigm for simulating and optimising urban sustainability In: Solar Energy. Vol. 81, no. 9, 2007, p. 1196-1211.

[10] Tywoniak J.: Navrhování energeticky úsporných budov v širších souvislostech, Český instalatér, 6; 2006.

[11] Šišolák M.: Vesele pasivní budoucnost, 21.1.; 2011

[12] Růžička V.: Evropská směrnice očima stavařů a architektů, 30.1.2011, http://www.tzb-info.cz/ [Accessed 8th of July 2013]

[13] OED Endringar i statsbudsjettet 2012 under Olje- og energidepartementet 2012

[14] ZEB: The Research Centre on Zero Emission Buildings, www.zeb.no, 2012. [Accessed 8th of July 2013]

[15] Wyckmans A. Environmental learning in architecture. From individual choice to collective responsibility. Nordic Journal of Architectural Research 20(3): 2008; 73-87.

[16] Ministry of Business and Construction. Building regulation 2010 (Bygningsreglement 2010 - BR10), Erhvervs- og Byggestyrelsen, Byggecentrum, Denmark; 2009 (in Danish)

[17] Knudstrup M. How can we adapt education programmes to the architecture of the future? Nordic Journal of Architectural Research. Volume 22, No 1; 2010

[18] Hájek P, Kabele K, Růžička J, Tywoniak J: Sustainable Building Education at Czech technical University in Prague, In: Central Europe towards Sustainable Building. Praha: České vysoké učení technické v Praze, Fakulta stavební; 2010; p. 749-750.

[19] Kabele K.: Application of Computer Modelling and Simulation in the Energy Audit Teaching Process at FCE CTU. In Zborník vedeckých prác. Bratislava: Slovak University of Technology; 1998; p. 52-55. (in Czech)

[20] Friedl-Schafferhans M, Hausegger T, Förschner M. Qualification – Green Jobs Statements and results about the quantitative relevance of Green Jobs and of their qualification requirements (Qualifikation – Green Jobs Aussagen und Befunde zur quantitativen Bedeutung von Green Jobs und deren Qualifikationsanforderungen). Final Report, Prospect Unternehmensberatung GesmbH on behalf of Ministry of Life, Vienna. 2010 (in German)

[21] Bánhidi L,Magyar Z.: State of art of energy certification and audit in Hungary, Magyar Installateur; 2006. p. 8-10. (in Hungarian)

[22] Magyar Z, Bánhidi L, Medgyasszai P, Ronkay F.: Training and exam for energy certification of buildings. Mérnök Újság, 2006. p. 22-23. (in Hungarian),

[23] Institute for Building Efficiency. 2011 Energy efficiency indicator: Global results; June 2011, http://www.institutebe.com/institutebe/media/Library/Resources/Energy%20Efficiency%20Indicator/2011-EEI-Global-Results-Executive-Summary.pdf [Accessed 8th of July 2013]

[24] Ministry of Energy, Environment and Climate Change. Programme for development interventions for the real economy (Πρόγραμμα αναπτυξιακών παρεμβάσεων για την πραγματική οικονομία); July 2010 http://www.ypeka.gr/ [Accessed 8th of July 2013] (in Greek)

[25] Pedro Nunes Institute - https://www.ipn.pt/si/event/dataEvent.do?elementId=503 [Accessed 1st of January 2012]

[26] UTL – Technical University of Lisbon - http://www.utl.pt/pagina.php?area=1812&curso=2008052131 [Accessed 1st of January 2012]

[27] Lawson, B. How Designers Think – the design process demystified. 4th ed. Architectural Press/Elsevier, Great Britain; 2005

[28] Kabele K, Dvořáková P. Modeling of indoor environment quality in sustainable buildings In: Central Europe towards Suistainable Bulding 07 Prague. Prague: CTU, Faculty of Civil Engineering; 2007, vol. 2, p. 437-444.

[29] Hansen, H.T.R. PhD thesis: Sensitivity Analysis as a Methodical Approach to the Development of Design Strategies for Environmentally Sustainable Buildings. Aalborg University, Department of Architecture & Design and Department of Civil Engineering. Aalborg; 2007; p. 95-112.

[30] Brunsgaard C. PhD thesis: Understanding of Danish Passive Houses based on Pilot Project Comfort Houses Institut for Arkitektur og Medieteknologi. 2011. p. 93-96.

[31] Muir T. Rance B (ed.) Collaborative Practice in Built Environment. E & FN Spon, London UK; 1995

[32] Reed B, Boecker J, Horst S, Keiter T, Lau A, Sheffer M, Toevs B. The integrative design guide to green building: redefining the practice of sustainability. Wiley; 2009; p. 398

[33] Integrated Energy Design – IED. Supported by Intelligent Energy Europe; 2009. Web publication: www.intendesign.com. [Accessed 8th of July 2013]

[34] Knudstrup, M. Integrated Design Process in Problem-Based Learning. The Aalborg PBL Model: Progress, Diversity and Challenges. Aalborg University Press, Aalborg; 2004; p. 221-234.

[35] Knudstrup, M. Barriers and Challenges in the Integrated Design Process Approach. Sustainable built environment and construction. Chongqing University, China: Centre for Sino-European Sustainable Building design and Construction; 2006; p. 14-19.

[36] Haase M. Et al. Energy and Architecture -Energy efficient refurbishment design for a sustainable future; 2011

[37] Trebilcock, M. Integrated Design Process: From analysis/synthesis to conjecture/analysis. PLEA2009 - 26th Conference on Passive and Low Energy Architecture, Quebec City, Canada, June 2009

[38] Foldbjerg P, Olesen GGH, Feifer L, Hansen EK. Indoor Environmental Quality of the first European modelhome 2020 : Home for Life; 2011

[39] Brunsgaard C, Larsen TS, Heiselberg P, Knudstrup M. Evaluation of the Indoor Environment in the Comfort Houses : Qualitative and Quantitative Approaches. /. I: Indoor and Built Environment; 2012 Vol. 21, Nr. 3, 06, s. 432-451.

[40] Hillier B, Musgrove J, O´Sullivan P. Knowledge and design. Environmental design: research and practice 2, Proceedings of EDRA 3/AR 8 Conference; 1972; p. 29_3_1-29_3_14.

[41] Bärbel T, Gunther T, Gary F. Defining concepts and the process of knowledge production in integrative research – TRES; 2005

[42] IDES-EDU project. Http://www.ides-edu.eu/ [Accessed 3 September 2012]

[43] The District of Tomorrow programme. Http://www.dewijkvanmorgen.nl/ [Accessed 3 September 2012]

[44] Self-sufficient living cell project. Http://selfsufficientcell.wordpress.com/ [Accessed 3 September 2012]

[45] Kolmos A, red. PBL at Aalborg university: contributions to the International PBL Conference in Lima July 17-24. Aalborg: Technology, Environment and Society, Department of Development and Planning, Aalborg University. 2006.

[46] Kolmos, A., & Graaff, E. D. (2003). Characteristics of Problem-Based Learning. International Journal Of Engineering Education, International Journal Of Engineering Education, 2003(19), 657-662.

[47] Klein SA, Beckman WA, Mitchel JW, Duffie JA, Duffie NA Freeman TL et al. Transient System Simulation Program, V 16; 2006

[48] Gynnild V, Holstad A, Myrhaug D: Identifying and promoting self-regulated learning in higher education: roles and responsibilities of student tutors, Mentoring & Tutoring: Partnership in Learning; 2008; 16: 2, p. 147-161

[49] Wyckmans A: Environmental learning in architecture. From individual choice to collective responsibility. Nordic Journal of Architectural Research; 2008; 20:3, p. 73-87.

[50] Marshall D: The relationship between learning conceptions, approaches to learning and learning outcomes in foundation year engineering students, D.Phil. Thesis, University of Oxford; 1995.

[51] Case J, Marshall D: Between deep and surface: procedural approaches to learning in engineering education contexts, Studies in Higher Education; 2004; 29: 5, 605-615.

[52] E2B Association. Climate change is a reality, which is altering the world around us. Urgent action needs to be taken now. http://www.e2b-ei.eu/default.php [Accessed 7th of July 2013]

[53] Ellis MW, Mathews EH: Needs and trends in building and HVAC system design tools, Building and Environment; 2002; 37: 461 – 470.

[54] Rodrigo M, Girma B, Miljana H: Integrated life-cycle design of building enclosures, Building and Environment; 2011; 46: 1469 – 1479.