TECHNISCHE UNIVERSITÄT WIEN

DIPLOMARBEIT

Integrating building technology content in architectural curricula: A collaborative effort

ausgeführt zum Zwecke der Erlangung des akademischen Grades einer Diplom-Ingenieurin

unter der Leitung von

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KURZFASSUNG

Diese Diplomarbeit befasst sich mit der Vermittlung technischer Inhalte in der Architekturausbildung. Im Rahmen eines internationalen Projektes ("Integrative Multidisciplinary People-centered Architectural Qualification & Training") soll ein innovativer Zugang zur Architekturausbildung angestrebt werden. Innerhalb dieses dreijährigen, von dem Erasmus+ Programm der europäischen Union kofinanzierten Projektes wird ein integratives, multidisziplinäres und technisch hoch-qualifiziertes Curriculum entwickelt. Bautechnische Inhalte und Gebäudeperformance Evaluierungen sind in den meisten Architekturstudien bereits integriert. Nichtsdestotrotz wird in einem ersten Schritt eine umfassende Hintergrundrecherche und Bestandsaufnahme (Gap Analysis) der Architekturausbildung durchgeführt. Innerhalb dieser Gap Analysis sind unterschiedliche Ansichten und Meinungen sowohl von Studierenden als auch von Lehrenden und demzufolge Defizite ausgewertet und Verbesserungspotentiale aufgezeigt worden. Um den Anforderungen in der Praxis der Architektur und Stadtplanung gerecht zu werden, zielt das Curriculum auf eine enge Vernetzung zwischen sozialen, urbanistischen und technischen Aspekten ab. Ein Konsortium angesehener Partner unterschiedlicher Fachdisziplinen (Architecture and Urban Design, Structural and Construction Systems, Building Physics and Building Ecology, Human Behavior) aus Europa und Ägypten setzen dieses Vorhaben auf mehreren Ebenen um. In diesem Zusammenhang zeigt die Diplomarbeit zunächst eine kurze Zusammenfassung der Resultate der zuvor genannten Gap Analysis. Des weiteren wird die Entwicklung des fünfjährigen Curriculums besprochen und im Speziellen die Sequenz der darin integrierten technischen Inhalte beschrieben. Insbesondere sollen der Aufbau und Inhalt des Building Performance Simulation Kurses eine bedeutende Rolle innerhalb der technischen Kurssequenz einnehmen. Der Einsatz von Gebäudesimulation während des Entwurfsprozesses gibt den Studenten die Möglichkeit, die Performance eines Gebäudes bereits in frühen Entwurfsphasen zu evaluieren.

Keywords

Bauphysik, Gebäudesimulation, Architekturausbildung

ABSTRACT

This master thesis presents an effort towards integrating building technology content in architectural education. The effort is being undertaken within the framework of an international project targeting improvement in architectural education ("Integrative Multidisciplinary People-centered Architectural Qualification & Training"). This three-year project is funded by the Erasmus+ Programme of the European Union and aims to educate architects capable of initiating a paradigm shift toward a more integrative, multidisciplinary, people-centered, and technologically agile professional profile. Aspects of building technology in general and building performance assessment in particular are of course entailed in most architectural schools' curricula. Nonetheless, the background research of previous efforts and the preparatory work (gap analysis) for the development of a curricular proposal, which included views and opinions from both students and faculty of multiple schools, point to a number of shortcomings in this area. The present curricular development effort intends to address some of these shortcomings. Thus, natural and human sciences, aided by information and communication technologies, are deployed in a context-sensitive manner to encounter the challenges associated with sustainable human settlements. A consortium of expert partners in their fields of specialization (Architecture and Urban Design, Structural and Construction Systems, Building Physics and Building Ecology, Human Behavior) from Europe and Egypt came together to realize this vision. In this context, the present thesis first provides a summary representation of the results of the aforementioned gap analysis. Subsequently, the focus lies in the development of a building performance track. The sequence of the components of this track is explained in detail, along with its relationship to the curriculum's other thematic tracks. Specifically, the intellectual underpinnings of the structure and content of the building performance simulation course projected to acquire a special strategic position within the building performance track is explained. A performance-based design workflow would enable architecture students to approach design as an iterative process to balance energy and carbon reduction targets with indoor environmental quality objectives.

Keywords

Building physics, Performance simulation, Architectural education

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First I would like to express my gratitude to my supervisor, Univ. Prof. Dr. Ardeshir Mahdavi for his guidance, continuous support, and the opportunities he has granted me.

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Furthermore, I would like to thank all members of the Department of Building Physics and Building Ecology and all IMPAQT partners for the collaboration and experience within the project.

Finally, I would like to thank all my close friends, colleagues and my beloved family, who encouraged and believed in me throughout my live and studies.

CONTENTS

1 INTRODUCTION

1.1 Summary

IMPAQT (**“I**ntegrative **M**ultidisciplinary **P**eople-centered **A**rchitectural **Q**ualification & **T**raining”) is an ongoing international project targeting improvement in architectural education.

This three-year project, which is funded by the Erasmus+ Programme of the European Union, aims to educate architects capable of initiating a paradigm shift (Berger 2018). The objective is to promote a more integrative, multidisciplinary, people-centered, and technologically agile professional profile. Toward this end, natural and human sciences, aided by information and communication technologies, are to be deployed in a context-sensitive manner to address the challenges facing the building of human settlements that support and promote human values in a sustainable manner.

A consortium of expert partners in their fields of specialization, from Europe and Egypt, come together to realize this vision through two main achievements: On the one hand, the program is planned to result in a 5-year duration towards a B.Sc. in Architecture within the School of Engineering at Nile University. It adopts a multidisciplinary approach that builds upon the wealth and diversity of the project partners to interrelate their specialization (Architecture and Urban Design, Structural and Construction Systems, Building Physics and Building Ecology, Human Behavior, Contemporary City and Practicum) to develop an innovative curriculum. Thereby, an important objective is to bridge the gap between theoretical foundations acquired in the course of undergraduate studies and the expected integrative, multidisciplinary, and people-centered professional role in the practice of architecture and urban planning.

On the other hand, the project targets the development of life-long learning modules in three fields of specialization, drawing upon the specialization of the partners. These include Building Ecology and Building Physics, Human Requirements, and Contemporary City. A general module is intended to round up the architectural education vision with regard to integrative approaches and tools to improve professional performance and outputs (Berger 2018).

Table 1 illustrates the European and Egyptian academic and non-academic partners and their field of specialization.

Table 1 List of IMPAQT partners (adapted from Shehayeb et al. 2017)

	FOCUS / STRENGTH	PARTNER
EUROPEAN UNIVERSITIES	Building Science	Technische Universität Wien, Austria
	Structure and Construction, Architecture and Urban Design	Universitat Politècnica De Catalunya, Spain
	Landscape Architecture and Regional Planning, Urban Regeneration	Universität Kassel, Germany
	Environmental, Architectural and Social Psychology	University of Cagliari, Italy
EGYPTIAN UNIVERSITIES	Communication and Information Technology	Nile University, Egypt
	Mechanical Engineering	Ain Shams University, Egypt
	Coastal and Industrial Architecture, Urban Planning	Suez Canal University, Egypt
	Art and Design	Alexandria University, Egypt
EGYPTIAN PARTNERS NON-ACADEMIC	Construction Engineering, Technical Training, Project Management	Engineering Consultants Group, Egypt
	Facilitator of new approach implementation	Housing and Building National Research Centre, Egypt
	Community-based and participatory development	The Built Environment Collective, Egypt

The Department of Building Physics and Building Ecology at TU Wien contributes expertise in the physical and ecological factors at both building and urban scales. The focus lies on empirical, computational, and theoretical study of the interactions between people, buildings, and environment. Therefore, the department leads the design and development of the course sequence in the fields of building physics and building ecology (Berger 2018).

As the project still proceeds, small changes and modifications can occur in the further process of the project. In the following chapters, the development made so far will be discussed.

1.2 Motivation

Interested in the context of building technology and its integration in architectural curricula, the participation in an international project, which focuses on curricula development, provided a great opportunity. Within a collaborative approach, international partners contributed with different thematic backgrounds and different viewpoints to develop a new architectural curriculum. In the course of this project, the author was able to experience working in international teams and to perform an in-depth study of integrating building technology content in an undergraduate architectural engineering program.

The present work is also motivated to examine the content-related emphasis, subjects and respective weighting in architectural studies. Specifically, the focus is laid on subjects in the fields of building physics and building simulation within an architecture curriculum.

1.3 Approach

In the following chapters, a number of efforts made towards integrating building technology in architectural curricula within the ongoing project IMPAQT are briefly presented.

Firstly, some background information on architectural education including usage of building performance simulation tools and a Gap Analysis made within the project IMPAQT is given.

Furthermore, the development process of the new curriculum and the overall five-year structure are discussed.

Subsequently, the building technology content and its linkage to other courses within the 5-year curriculum are presented. Thematic emphasis and topical sequence as well as teaching resources for the building technology track are described.

Finally, important findings and experiences are summarized and further development of the project is discussed.

2 BACKGROUND

In order to provide some background information, previous efforts made towards evaluation of contemporary architecture education and usage of building performance simulation tools are presented.

These efforts include, on the one hand, the computational tools use by architects as addressed in a study of the use of performance-based simulation tools for building design and evaluation in Singapore (Lam et al. 1999) and an inquiry into the building performance simulation tools usage by architects in Austria (Mahdavi et al. 2003).

On the other hand, the study "Statusbericht 2000plus Architekten / Ingenieure" explores the current state of education and profession of architects and engineers in Europe (Enseleit et al. 2001).

Furthermore, the Gap Analysis towards exploring needs in architecture education within the project IMPAQT is presented.

Study of the use of performance-based simulation tools in Singapore

One of the efforts towards usage of performance-based simulation tools for design evaluation has been made in Singapore in 1999. About 400 architectural and 130 engineering consulting firms participated in a self-administered survey, which was conducted for a period of one month (Lam et al. 1999).

Within this study, some interesting results were analysed and discussed.

Table 2 and 3 illustrate the limitation of the usage of performance-based simulation tools, particularly in the architectural field.

Table 2 shows that the majority of architecture firms did not use energy and HVAC sizing software whereas 46.4% of engineering firms used such software. The result can be explained by the educational background of the software users (Table 3). Mainly mechanical engineers make use of software in energy simulation domain already in their studies.

Table 2 Percentage of the firms surveyed using various performance-based simulation tools (Lam et al. 1999)

Response Group	Percentage of Firms Surveyed (%)	
	Energy and HVAC Sizing	Daylighting And Electric Lighting
Architecture	1.6	11.3
Engineering	46.4	25.0
Statutory Bodies	16.7	0.0
Combine	15.6	14.6

Table 3 Educational background of the software users (Lam et al. 1999)

Educational Background	%	
	Energy and HVAC sizing	Daylighting and Electric Lighting
Architecture	0.0	14.3
Mechanical Engineering	69.2	0.0
Electrical Engineering	7.7	71.4
Building Services Engineering	38.5	28.6

Table 4 shows the usage frequency of different software tools. Among the participants, 66.6% use daylighting and electric lighting software occasionally, whereas 46.2% of the survey participants utilize energy and HVAC sizing software frequently. Lam et al. (1999) explain that the increased usage of lighting software is due to rendering possibilities in order to enhance the visual impression of the design.

Table 4 Frequency usage of the various software tools (Lam et al. 1999)

Frequency Of Usage	%	
	Energy And HVAC Sizing	Daylighting and Electric Lighting
Seldom	30.8	16.7
Occasionally	15.3	66.6
Frequently	46.2	0.0
Always	7.7	16.7

Inquiry into the building performance simulation tools usage in Austria

Another effort towards usage of building performance simulation tools was made in Austria in 2003. About 200 Austrian architects contributed to an empirical study in detailed telephone-based interviews about experience, frequency and pattern of building performance simulation applications (Mahdavi et al. 2003).

Figures 1 to 4 show some of the inquiry results. On the one hand, the vast majority of the respondents evaluate the state of architects´ knowledge as insufficient regarding the use of building performance simulation tools (Figure 1). On the other hand, the importance of university education in view of building performance simulation tools (BPSTs) is evaluated by 50.9% of the participants as very important (Figure 2). Therefore, an improvement in the knowledge of building performance assessment already in the university education should be considered.

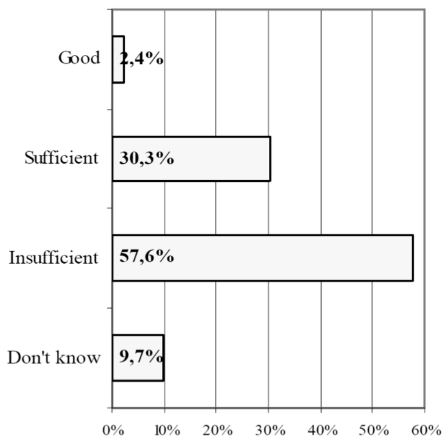


Figure 1 "How do you evaluate the state of architects´ knowledge regarding BPSTs?" (non-users group) (Mahdavi et al. 2003)

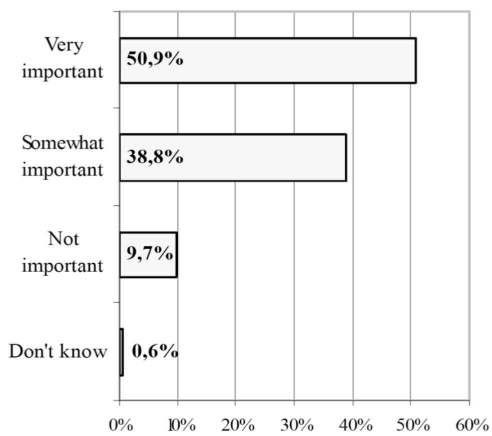


Figure 2 "How important is the role of university education of the architecture students in view of BPSTs?" (users group) (Mahdavi et al. 2003)

In this study, the authors emphasize that a large number of architects do not consider building physics and building performance assessment as part of their professional role.

In this context, Figure 3 displays architects´ almost exclusive use in energy simulation domain (heating and cooling). Only 15.2% employ BPSTs in the building and room acoustics domain. The responses show that the major reason of building performance simulation tools usage is to meet regulatory requirements (Figure 4). Only 3% of the interviewed architects use BPSTs for design quality improvement. Thus, the usage of building performance simulation tools in the design process was found to be almost non-existent.

However, the building performance simulation domain has developed in the past few years and the usage of simulation tools during the design process has increased (Clarke and Hensen 2015).

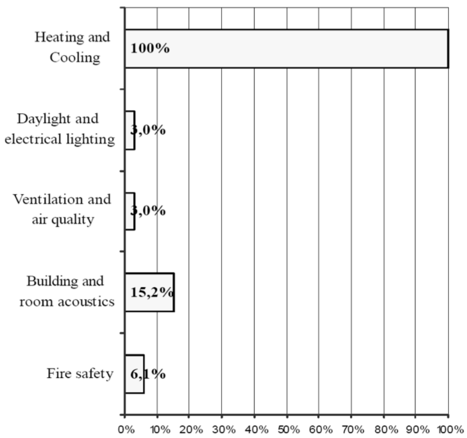


Figure 3 "In which domain does your office employ BPSTs? (users group) (Mahdavi et al. 2003)

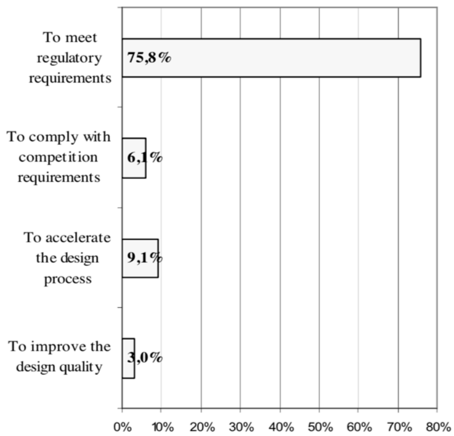


Figure 4 "What are the reasons for the employment of BPSTs in you office?" (users group) (Mahdavi et al. 2003)

Study on education and profession of architects and engineers in Europe

In 2001, a German Research Foundation of the Technical University of Berlin conducted a comprehensive study "Statusbericht 2000plus Architekten/Ingenieure" (Enseleit et al. 2001) on education and profession of architects and engineers.

Within the second chapter of this study ("Rahmenbedingungen der Berufsausübung"), an overview of different educational possibilities of architects and engineers is provided. In particular, instances of teaching content and directives of universities in six different European countries are compared. Two special types of higher institutions in Germany ("Fachhochschule") and in the Netherlands ("Architekturakademie") are also taken into account.

In this context, curricula of different universities, "Fachhochschulen" and "Architekturakademien" and if available requirements of the countries or accreditation organizations are used as sources. (Content-related differences in the selected countries are possible.)

The study focuses only on the mandatory part of studies, specifically on drafting, social, construction-related and economic aspects.

Thus, the teaching content is divided into four main subject categories:

- Design Studio
- Urban / people-centered theory / history of architecture
- Construction / building technology
- Business

Figure 5 shows the percentage of subject categories in the mandatory part of studies in the following institutions:

- Universities in Germany
- "Fachhochschulen" in Germany
- Universities in Austria
- Universities in France
- Universities in Spain
- "Architekturakademien" in the Netherlands
- Universities in the Netherlands
- Universities in Great Britain
- Universities in Finland

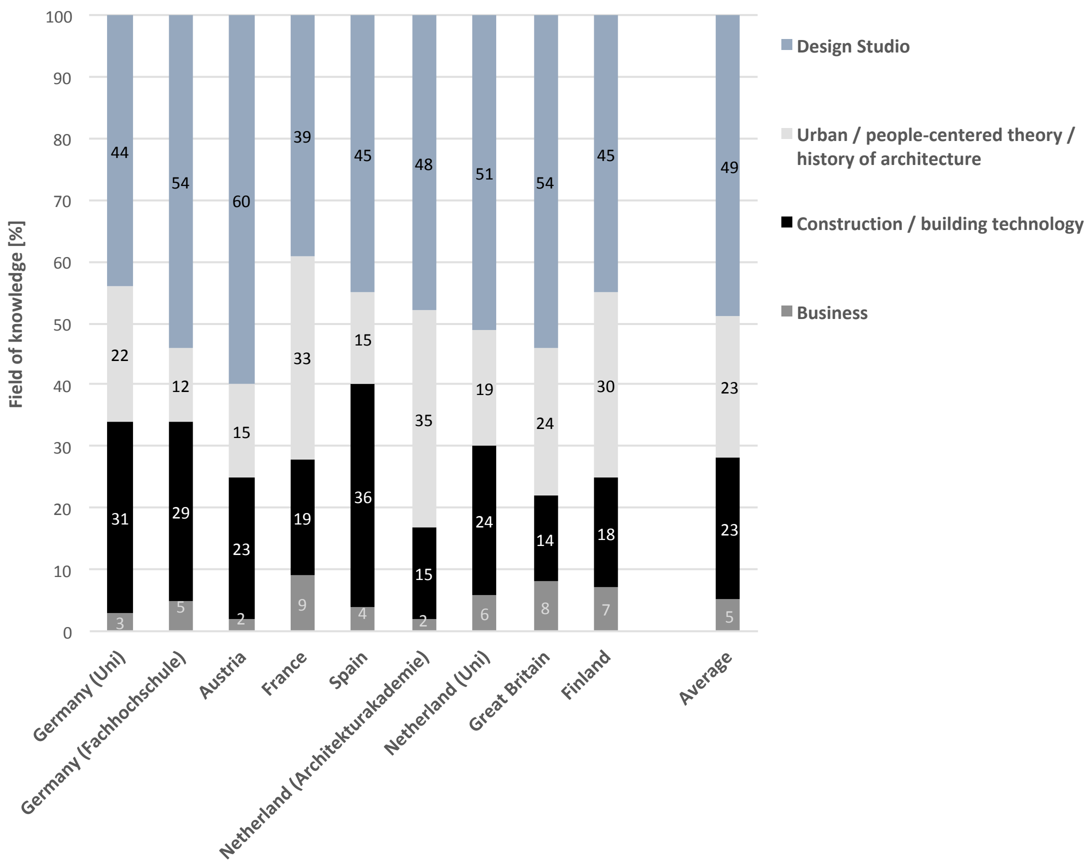


Figure 5 Percentage of subject categories in mandatory part of studies (Enseleit et al. 2001)

All four fields of knowledge are included in the curricula of the investigated countries. Despite different weighting of content in each country, the common teaching objective is design. Almost half of the mandatory part of studies relates to design studios (49% on average). The lowest weighting of 39% can be seen in France, whereas Austria has the highest weighting of 60%.

In average, the social and construction-related aspects within the curricula are weighted equally. Both subject categories in the fields of urban studies, people-centered theory and history of architecture and in the fields of construction and building technology are weighted at 23% each. Only 14% of the overall curriculum is intended for technological subjects at universities in Great Britain, whereas 36% are estimated at universities in Spain. The economic aspect within the architecture studies is rated far behind at 5% on average.

The study clearly shows that the focus in architectural education in Europe lies on design studios and is considered as the core competence of architects.

Gap Analysis towards architecture education

Prior to the development of a curriculum proposal, a Gap Analysis of the needs and shortcomings in architecture education was made within the project IMPAQT. This preparatory work explores and analyses views and opinions of the current architectural education in an empirical study.

In the course of this, both academics and practitioners were interviewed. Four different instruments were used to obtain a diverse Gap Analysis:

- Online Questionnaire through the IMPAQT website
- Interview Guide for Academics
- Interview Guide for Practitioners
- Expert interviews referring to best and worst pedagogy

(Appendix 10.1-10.5)

The Online Questionnaire was conducted for a period of three months in spring 2018. A total of 107 participated in the Online Questionnaire through the IMPAQT website and about 30 academics and practitioners were interviewed. Within the project IMPAQT, the online survey was designed by Dina Shehayeb (IMPAQT project technical coordinator, Nile University), Yasmine Hafez (contracted consultant) and with contributions from Kamal Shawky (Engineering Consultants Group), Shaimaa Mahmoud (Suez Canal University) and Sherif el Nabarawy (online administration, Ain Shams University).

In this context, a selection of questions of the online questionnaire are presented and discussed, as shown in Table 5.

Figure 6 shows that 24% of the interviewees estimate the lack of awareness of technological advances in building technology or material technology as a major problem. Moreover, 34% of the respondents state the non-integration of design-aid tools (like parametric design tools or environmental simulation programs) in the courses as a crucial problem.

In terms of pedagogy, a poor integration between theoretical courses and their application in studios is seen as a major problem for about 20% of the respondents (Figure 6). Inadequate learning environments are perceived by 19% of the survey participants as problematic (Figure 7).

Other mentioned shortcomings relate to problems concerning the program structure and management. About 38% of the participants experience that multiple assigned submissions cause the students to focus on delivering regardless of the quality of the content. A lack of access to university resources, such as e-lectures or online submissions is estimated by 43% of the respondents (Figure 7).

Table 5 Selected questions of the Online Survey IMPAQT, derived based on information (Shehayeb et al. 2018)

Q1	Lack of awareness of technological advances (in building technology, material technology…)
Q2	Lack of integration between theoretical courses and their application in studios
Q3	Courses did not include design-support tools (parametric design tools/ environmental simulation programs)
Q4	Inadequate learning environment - tools
Q5	Multiple submissions cause the students to focus on delivering regardless of the quality of the content
Q6	Lack of remote communication and access to university resources, ex. Intelligent campus (e-lectures, video lectures, online HW submission, online grading and assessment…)
Q7	Lack of integration between different disciplinary courses (human behaviour – building science – history…)
Q8	Poor knowledge about different jobs available for an architecture graduate in the market
Q9	Unclear vision of the links between studied courses and their application in real market/ jobs

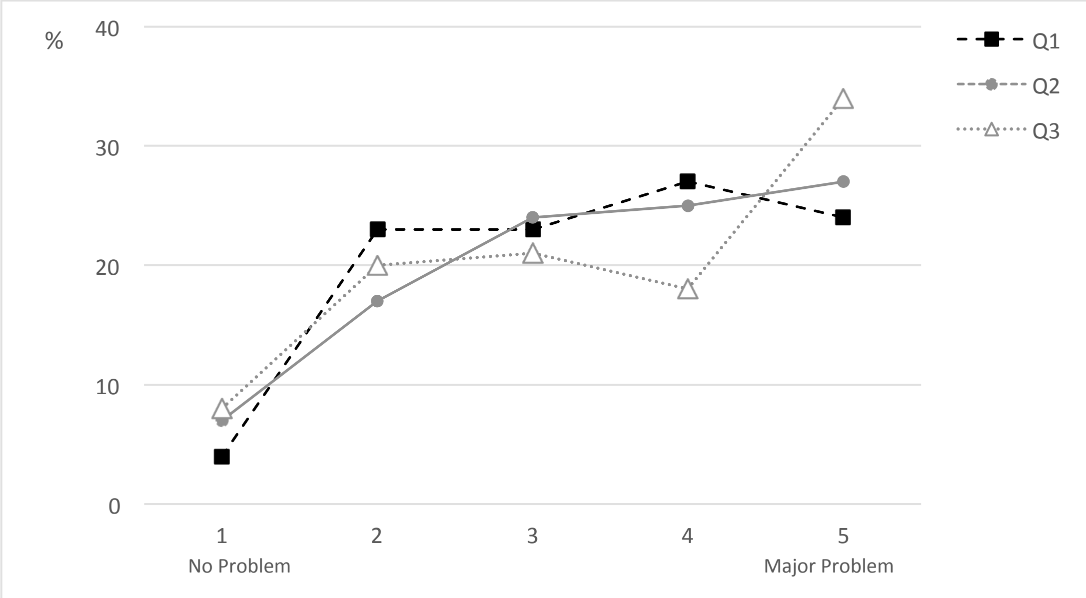


Figure 6 Results Online Questionnaire IMPAQT – Q1 to Q3, derived based on information (Shehayeb et al. 2018)

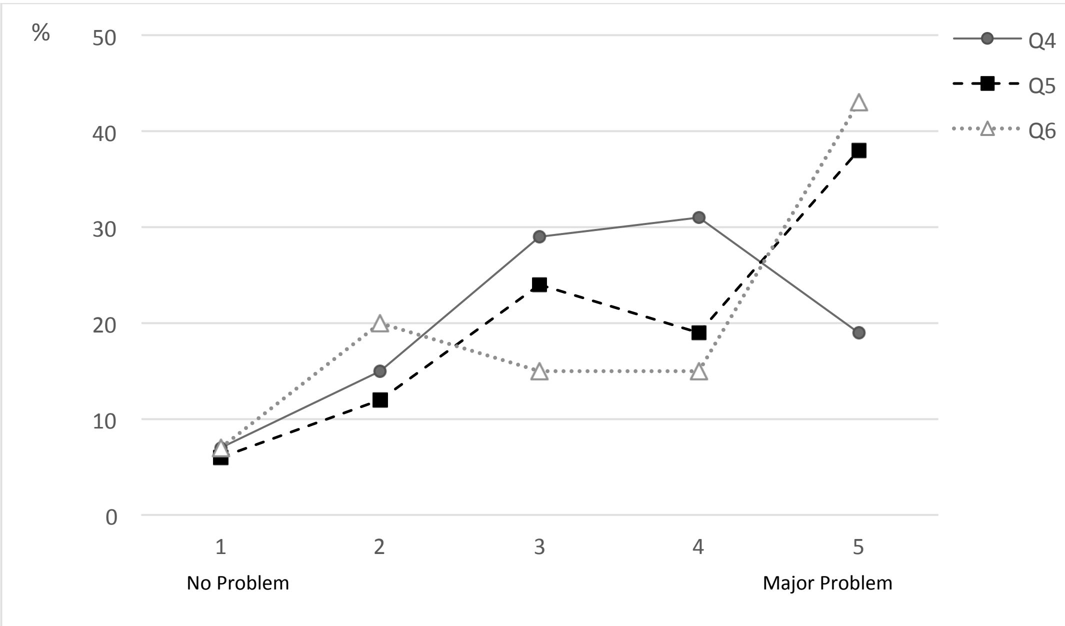


Figure 7 Results Online Questionnaire IMPAQT– Q4 to Q6, derived based on information (Shehayeb et al. 2018)

Furthermore, a lack of knowledge in linkages between university and practice is noticeable. About 30% of the interviewees estimate an unclear vision of the links between studied courses and their application in real market as a major issue (Figure 8). For 23% of the respondents, the poor knowledge about different jobs available for an architecture graduate in the market represents a severe problem.

At the same time, respondents rate BIM knowledge and a connection to the real market as most important items they would introduce or change in architecture education.

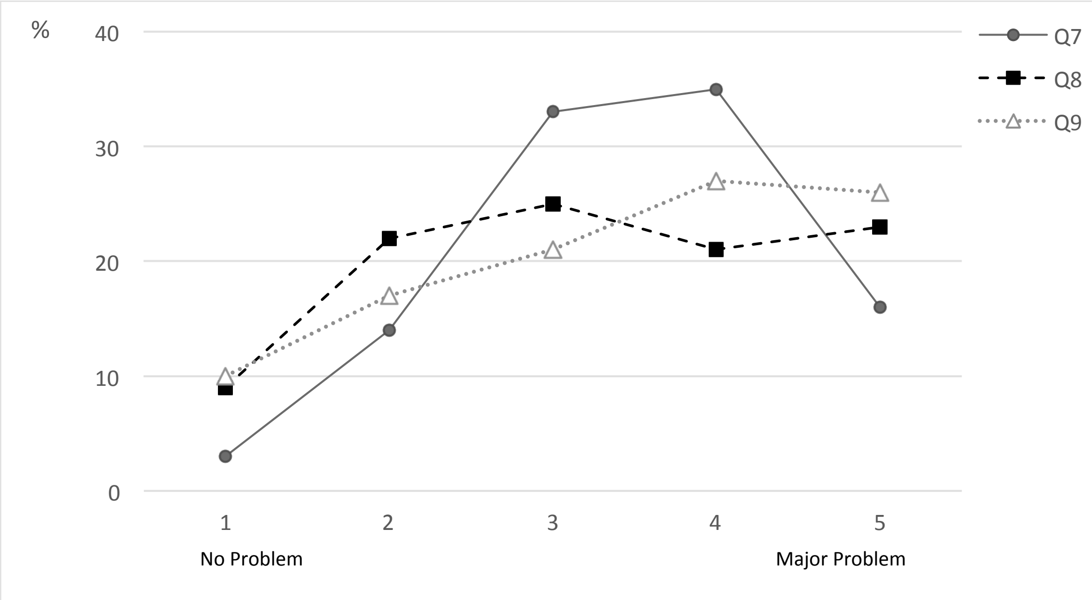


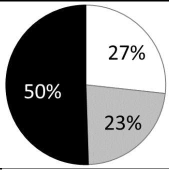
Figure 8 Results Online Questionnaire IMPAQT– Q7 to Q9 derived based on information (Shehayeb et al. 2018)

To illustrate the percentage of people who evaluated the selected questions as a serious problem (4 and 5 in Figures 6 to 8), an additional illustration is given in Table 6, marked in black. Grey denotes option 3 in Figures 6 to 8, and white denotes option 1 and 2 in Figures 6 to 8.

It is noticeable that about half of the survey participants perceive the nine selected statements as a major problem. The most significant problems are ignorance regarding job perspectives and an unclear vision of studies versus real market (58% each). A slightly smaller amount of 49% of the respondents see a lack of course integration as a severe problem.

The responses regarding technological awareness, theory-application divide and usage of design-support tools show that only about a quarter notice no problem. Thus, changes in these areas are welcome and considered as necessary.

Table 6 Selected questions of the Online Survey IMPAQT and responses: major problem (black), neutral (grey), no problem (white), derived based on information (Shehayeb et al. 2018)

<table>
<tr><th></th><th>Selected questions</th><th>Responses</th></tr>
<tr><td>Q1</td><td>Lack of technological awareness</td><td>
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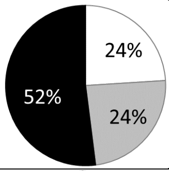
<tr><td>Q2</td><td>Theory-application divide</td><td>
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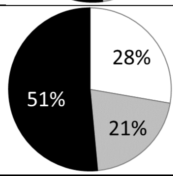
<tr><td>Q3</td><td>Lack of design-support tools</td><td>
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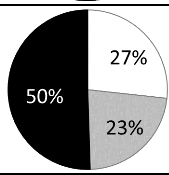
<tr><td>Q4</td><td>Inadequate learning environment / tools</td><td>
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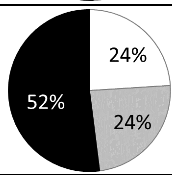
<tr><td>Q5</td><td>Multiple submission pressure</td><td>
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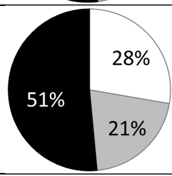
<tr><td>Q6</td><td>Lack of access to resources</td><td>
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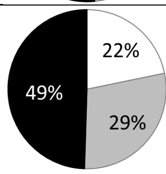
<tr><td>Q7</td><td>Lack of course integration</td><td>
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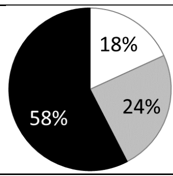
<tr><td>Q8</td><td>Ignorance regarding job perspectives</td><td>
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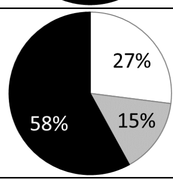
<tr><td>Q9</td><td>Studies vs. real-world market</td><td>
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Moreover, the use of main Egyptian codes related to architecture and urbanism during education and work was examined. About 40% of the Egyptian respondents studied the building code during their education and 30% either know about it but never used it or do not know anything about it. About one third of the interviewees have no knowledge at all about the Egyptian Fire Code and only 7% applied it at work. Thus, an improved integration of building codes and standards in the architecture education should be considered.

For the purpose of estimating the role of the architect, the interviewees rate the more relevant and less relevant task areas of architects by order of relevance. Figure 9 shows that 52% of survey participants rank architecture design for specialized buildings as a most relevant task. Revitalization of parts of cities, participatory design and planning and designing of new urban settlements are estimated for about 30% of the interviewees as most relevant.

Therefore, specific knowledge of technological, social and urban aspects of specialized buildings, such as hospitals, schools or museums, should be integrated in architecture studies.

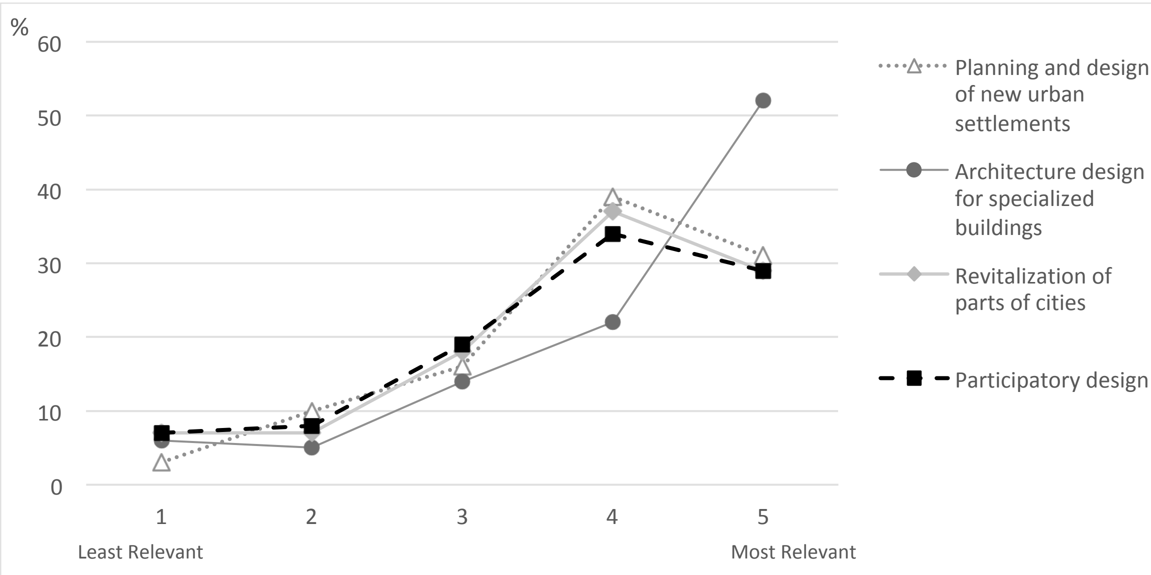


Figure 9 Results Online Questionnaire IMPAQT – Role of the Architect, derived based on information (Shehayeb et al. 2018)

Furthermore, a number of academics and practitioners were interviewed concerning the definition and vision of the role of the architect. A few examples of the statements made during these interviews are provided below:

"The ideal vision is technically competent, culturally sensitive and 'design-wise' creative professions with capability to integrate multiple requirements and competence to work in teams." (Team of TU Wien, IMPAQT 2018)

"Architects have the ability to address issues related to built environment – buildings, public spaces, urban areas – responding to social, environmental needs (climate change), shall deal with economic crises, political changes and the evolving technology." (Team of Universitat Politècnica De Catalunya (ETSAB) and Kassel University, IMPAQT 2018)

"The most innovative practices are usually found in small projects, in the capacity of making the most of architectural and urban tools for improving common places, repairing and restoring more than building and retrofitting urban areas more than designing new developments." (Team of ETSAB, IMPAQT 2018)

"In the last few decades we have moved from the figure of the 'genius' architect (artist and know-it-all professional) to a more cooperative and socially aware architect." (Team of ETSAB, IMPAQT 2018)

"*They don't just design buildings they create total environments, both interiors and exteriors."* (Team of Suez Canal University, IMPAQT 2018)

"Architects are professionals who lead the process of creating functional spaces, from concept and design to a full realization of those designs." (Team of Suez Canal University, IMPAQT 2018)

"The architect has the role to translate urban issues and conditions in a specific context to a physical product." (Team of Kassel University, IMPAQT 2018)

"They need to be able to cover all kinds of different profiles and to specialize." (Team of Kassel University, IMPAQT 2018)

"The architect should take into account the perspective of the different categories of actual and potential users of the target place." (Team of University of Cagliari, IMPAQT 2018)

3 DEVELOPMENT OF THE 5-YEAR CURRICULUM

The curricula development for the five-year undergraduate architectural engineering program intends to pursue a multi-disciplinary and integrative approach. Thus, academic and non-academic partners from Egypt and Europe contribute with different levels of involvement according to their fields of specialization to develop a new curriculum. This collaborative effort enriches the program development by complementing the curricula with diverse thematic strength and knowledge.

Within the curricula development, general requirements of the Nile University regarding the selection of mandatory core courses and the distribution of credit hours are taken into account. The Nile University requests their students to take a certain number of mandatory general courses to broaden their basic knowledge.

In the course of the architectural engineering program, a reasonable and balanced weighting of different subjects is expected to generate a solid knowledge.

Figure 10 illustrates the distribution of credit hours by the three types of requirements (University, Engineering and Program Requirements). About 10% represent University Requirements, such as “Introduction to Ethics”, “Writing Skills”, “English I”, “English II” or “Communication and Presentation Skills”. The middle segment illustrates the Engineering Requirements of 26% within the curriculum. This part includes a sequence of building technology courses as well as structure and construction courses. This distribution indicates a deeper focus on engineering knowledge towards other purely design oriented architectural curricula. About 64% cover Program Requirements, such as design studios or theoretical courses like “Design Thinking” or “Environment Behaviour Studies”.

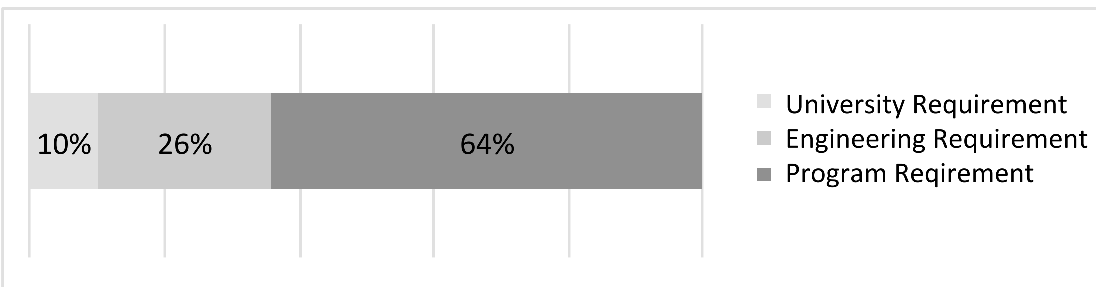


Figure 10 Distribution Credit Hours
(derived based on program description of the Nile University from 2018)

A detailed distribution of credit hours by subject categories is given in Figure 11. The curriculum is divided into seven thematic areas:

- Business (4%)
- Engineering Culture (5%)
- Projects and Practice (5%)
- Applied Engineering and Design (30%)
- Basic Engineering Sciences (28%)
- Humanities and Social Sciences (9%)
- Mathematics and Basic Sciences (19%)

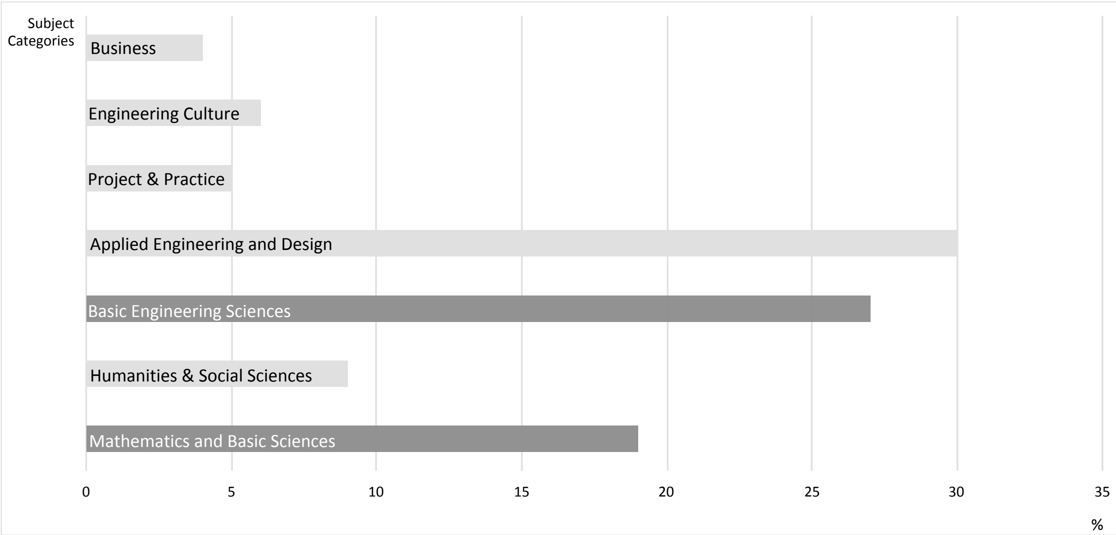


Figure 11 Percentage of subject categories
(derived based on program description of the Nile University from 2018)

The two dark segments “Basic Engineering Sciences” and “Mathematics and Basic Sciences” cover 47% of the overall curriculum. The courses within these two subject categories are given in Table 7.

Table 7 Courses in the subject categories "Mathematics & Basic Sciences" and "Basic Engineering Sciences" (derived based on program description of the Nile University from 2018)

Mathematics & Basics Sciences (19%)	**Basic Engineering Sciences (28%)**
Probability and Statistics	Construction I, II, III
Natural Sciences: Physics Fundamentals	Visual I, II
Computer & Information Skills	Building Types
Building Physics I	Building Performance Simulation
Building Physics II	BIM
Basis for Design Drawing / Modelling	Dwelling & Neighbourhood Design
Structure I	Structure III
Structure II	Spatial & Urban Dynamics
Sustainable Development	People-centered Urban Design
Selected Topics in Social Sciences: Research Methods	Theory of Architecture & Urban Form II: Contemporary
Building Ecology (Elective)	Colour and Art (Elective)
	Mapping Preferences (Elective)
	Architecture Photography (Elective)

In order to develop a curriculum proposal, several meetings and discussions were organized within the project IMPAQT. The following partners participated and contributed to those: Mahdavi A., Berger C., Crosas C., Pardal C., Altrok U., Gotsch P., El Gamal M., Fornara F., Shehayeb D., Allam M., El-Nabarawy S., Badran E., Fouad M., Nasr M., Ali S., Abouelfadl H., Said L., Gharib N., Mahmoud S., Shawky K., Farid E., El Masry M., Seregeldin H., Elnady T., Akl W., Hafez Y., Pinto de Freitas R..

The resulting overall five-year undergraduate curriculum is given in Table 8.

Table 8 Structure five-year curriculum (derived based on program description of the Nile University from 2018)

	YEAR I		YEAR II		YEAR III		YEAR IV		YEAR V	
	SEMESTER 1	SEMESTER 2	SEMESTER 3	SEMESTER 4	SEMESTER 5	SEMESTER 6	SEMESTER 7	SEMESTER 8	SEMESTER 9	SEMESTER 10
DESIGN STUDIO		Basis for Design Drawing / Modelling	Design Studio 1: Residential SITE	Design Studio 2: Public Realm Street Design	Design Studio 3: Dwelling & neighbourhood design	Design Studio 4: Facilities - Public building Public Space	Design Studio 5: Multi-Function Building Ensemble City Extension	Design Studio 6: Multi-Function Adaptive Re-use Urban Regeneration	Graduation Project 1	Graduation Project 2
PEOPLE-CENTERED THEORY (ARCHITECTURE & URBAN)	Ethics Selected Topics in Culture and Diversity: Contemporary City	Critical Thinking Design Thinking I (Inquiry, Process, Design Objectives, Architecture Program)	Selected Topics in Social Sciences: Research Methods			Advanced Design Process				
URBAN	Selected Topics in Humanities: Environmental Psychology		Environmental Behaviour Studies	Dwelling and Neighbourhood Design	Building Types Places for People	People-centered Urban Design	Spatial and Urban dynamics		Urban Planning process: Planning Cities for people	
HISTORY OF ARCHITECTURE		History of Architecture and Urban Form I: Ancient to Renaissance	History of Architecture and Urban Form II: Medieval to 19th Century		Theory of Architecture and Urban Form I		Theory of Architecture and Urban Form II			
BUILDING TECHNOLOGY	Probability & Statistics	Natural Sciences: Physics Fundamentals		Building physics I	Building physics II	Building Systems Integration		Building Performance Computing		
STRUCTURE & CONSTRUCTION			Construction I	Structure I	Construction II	Structure II	Construction III	Structure III	Construction doc BOQ Tender Doc Site Supervision / Project Management	
VISUAL	Computer & Information Skills		Visual I	Visual II				Building Information Modeling		
LANGUAGE	Language I Communication & Presentation Skills	Language II	Writing Skills					Internship		
ELECTIVES				Mapping Preferences Colour and Art Architecture Photography			Sustainable Heritage Conservation Landscape architecture and planning		Sustainable Development Building Ecology	Urban Planning 2 (Transformation, mobility, ···) Informal Areas

The undergraduate architecture curriculum is designed as a five-year program. In comparison, undergraduate studies (bachelor) in European countries have a duration of six semesters, so they last for only three years.

As shown in table 8, a number of courses are planned for each semester, total to 280 ECTS (i.e., 160 Credit Hours). This requires a student workload between 580 and 800 hours each semester.

Apart from the last year, which requires less credit hours in order to focus mainly on the graduation project, each semester covers about 30 ECTS (i.e., 18 Credit Hours). This requires a student workload of about 800 hours per semester. The last two semesters request a student workload of 660 hours (i.e., 12 Credit Hours) in the ninth semester and 580 hours (i.e., 8 Credit Hours) in the tenth semester.

A detailed illustration of the course sequence of the first and second year is shown in Table 9. The curriculum mainly consists of nine course categories:

- Design studio
- People-centered theory (architecture and urban)
- Urban
- History of architecture
- Building technology
- Structure and construction
- Visual
- Language
- Electives

Design studios focus on the designing of buildings and spaces. Social and urban aspects are presented in the course categories “People-centered theory” and “Urban”. The fourth course category discusses the history and theory of architecture and urban form. Basic knowledge in presentation and visualization is covered in “Visual” and “Language”. Finally, a number of electives with different specialization possibilities are provided.

In the first year, general courses give students a basic knowledge and are mostly requisites for further courses. The majority of the courses represent university requirements, such as the courses "Ethics", "Critical Thinking", "Communication and Presentation Skills" and "Selected Topics in Humanities: Environmental Psychology".

In order to focus on human aspects in the architecture curriculum, different integration strategies in all courses are used. Students deal with current social, sustainable and urban issues in a number of classes.

Table 9 Structure Year 1 and 2 (derived based on program description of the Nile University from 2018)

	YEAR I		YEAR II	
	SEMESTER 1	SEMESTER 2	SEMESTER 3	SEMESTER 4
DESIGN STUDIO		Basis for Design Drawing / Modelling	Design Studio 1: Residential SITE	Design Studio 2: Public Realm Street Design
PEOPLE-CENTERED THEORY (ARCHITECTURE & URBAN)	Ethics Selected Topics in Culture and Diversity: Contemporary City	Critical Thinking Design Thinking I (Inquiry, Process, Design Objectives, Architecture Program)	Selected Topics in Social Sciences: Research Methods	
URBAN	Selected Topics in Humanities: Environmental Psychology		Environmental Behaviour Studies	Dwelling and Neighbourhood Design
HISTORY OF ARCHITECTURE		History of Architecture and Urban Form I: Ancient to Renaissance	History of Architecture and Urban Form II: Medieval to 19th Century	
BUILDING TECHNOLOGY	Probability & Statistics	Natural Sciences: Physics Fundamentals		Building physics I
STRUCTURE & CONSTRUCTION			Construction I	Structure I
VISUAL	Computer & Information Skills		Visual I	Visual II
LANGUAGE	Language I Communication & Presentation Skills	Language II	Writing Skills	
ELECTIVES				Mapping Preferences Colour and Art Architecture Photography

In the second semester, the course “Basis for Design” is the first design exercise within the curriculum. It introduces to students the basis needed for design, as the sense of proportion and relations, drawing and modelling. This should raise awareness and understanding of the built environment.

Starting from the second year, each semester includes a design studio with various foci and different scales (from one room to a part of city). In addition, appropriate courses begin with the basis in urban, social, historic, visual and technological fields.

The courses “Ethics”, “Critical Thinking”, “Selected Topics in Culture and Diversity: Contemporary City”, “Selected Topics in Humanities: Environmental Psychology”, “Language I and II”, and “Communication and Presentation Skills” within the first year represent university required courses. These courses provide students a general knowledge at the beginning of their studies.

“Ethics” focuses on ethical issues and problems that arise in professional and business environments.

The course “Critical Thinking” introduces to scientific and critical thinking methods. Within the course “Selected Topics in Culture and Diversity: Contemporary City”, an introduction to the context of cities and urbanization, both globally and in particular in Egypt, is given (Shehayeb 2018).

“Selected Topics in Humanities: Environmental Psychology” and “Environmental Behaviour Studies” emphasize the awareness of human aspects and give theoretical concepts that explain psychological processes in the human mind.

The course “Selected Topics in Social Sciences: Research methods” covers a basic knowledge and competence on how to conduct research in various scientific fields.

Different design methods, tools, techniques and design performance criteria are covered in the course “Design Thinking (Inquiry, Process, Design Objectives)”.

Historic evolution of architectural terminology, building types and significant structures and buildings are discussed in the courses “History of Architecture and Urban Form I and II”.

Furthermore, the course “Computer and Information Skills” introduces standard office software applications for information presentation, web-page design and database management. With regard to architectural visualization and presentation, the courses “Visual I and II” show manual and digital 2D and 3D representation skills and techniques.

The courses “Language I and II” allow students the possibility to improve their English skills. Within the course “Communication and Presentation Skills”, students learn and practice the skills of interpersonal and professional communication. Moreover, an introduction to the use of research and scientific writing is given in the course “Writing Skills”.

In order to provide a basic knowledge in physics, mathematics and statistics for further technological subjects, the courses “Probability and Statistics” and “Physics Fundamentals” are planned for the first year. They give an overview of definitions, calculations, organization, and presentation of statistical data as well as an introduction to physics fundamentals.

One of the main emphases during the curriculum development was to ensure a multidisciplinary approach within the architecture education.

Understanding the role of an architect not in *“the narrow zone of aesthetic design of buildings”*, but in *“designing urban environments compatible and supportive to human needs, lifestyle and aspirations of its inhabitants and future generations”* was a major concern. Students shall *“understand the dynamic relation between people and place that encompasses [...] social, cultural, and psychological dimensions, environmental issues, awareness of the economic and regulatory aspects of city dynamics [...]”* (Shehayeb et al. 2017).

Thus, a good coordination and linkage between all courses was a primary concern.

With regard to the building technology, structure and construction sequence, several discussions were held among project partners. In order to build upon basic construction knowledge, the course “Construction I” starts in the third semester, followed by the two courses “Structure I” (in the fourth semester) and “Building Physics I” (in the fourth semester).

In the course of discussions, it was argued that it is necessary to know firstly the main building materials and understand the basic principles of how a building is constructed before considering structural or physical aspects.

At the beginning of the development of the new curriculum, an additional course in the third semester, covering only building materials, was suggested. Due to a lack of time capacity within the 5-year curriculum and several discussions, the course was not included, but integrated in the course “Construction I”. Within this course, students learn to realize conceptual principles to construction solutions. An overview of the scope of materials used in a building as well as knowledge of the different layers in a building component and details are essential for material choice decisions. On this basis, students are able to consider the thermal, acoustical and visual aspects of building performance. Thus, the building physics courses start after the above-described course “Construction I”. In the fourth semester, “Building Physics I” introduces the fundamentals of the thermal aspects of building performance. (A more detailed description is presented in chapter 4.2.)

Table 10 illustrates the courses in the third and fourth year. After several discussions within all-partner meetings in Germany and Egypt, the design studios 3 and 4 were exchanged in order to provide theoretical, supportive courses in the previous semesters. Therefore, the course “Dwelling and Neighbourhood Design” is planned for the fourth semester and the related design studio 3 in the fifth semester. The same principle can be seen in the sequence of the courses “Building Types: Places for People” (fifth semester) and the design studio 4 (sixth semester).

The course “Dwelling and Neighbourhood Design” gives an introduction to the design of housing with regard to social needs and neighbourhood planning and prepares the students for design studio 3. “Building Types: Places for People” focuses on the design of specific facilities and public buildings (such as schools, hospitals, libraries, hotels). This course gives theoretical background knowledge for design studio 4.

Table 10 Structure Year 3 and 4 (derived based on program description of the Nile University from 2018)

	YEAR III		YEAR IV	
	SEMESTER 5	SEMESTER 6	SEMESTER 7	SEMESTER 8
DESIGN STUDIO	Design Studio 3: Dwelling & neighbourhood design	Design Studio 4: Facilities - Public building Public Space	Design Studio 5: Multi-Function Building Ensemble City Extension	Design Studio 6: Multi-Function Adaptive Re-use Urban Regeneration
PEOPLE-CENTERED THEORY (ARCHITECTURE & URBAN)		Advanced Design Process		
URBAN	Building Types Places for People	People-centered Urban Design	Spatial and Urban dynamics	
HISTORY OF ARCHITECTURE	Theory of Architecture and Urban Form I		Theory of Architecture and Urban Form II	
BUILDING TECHNOLOGY	Building physics II	Building Systems Integration		Building Performance Computing
STRUCTURE & CONSTRUCTION	Construction II	Structure II	Construction III	Structure III
VISUAL				Building Information Modeling
LANGUAGE				Internship
ELECTIVES			Sustainable Heritage Conservation Landscape architecture and planning	

Within the design studio 5, students learn to design multi-functional building ensembles (meaning a combination of housing, public spaces, hotels and different facilities) and city extension. Thereafter, the design studio 6 aims at designing a multi-functional adaptive building re-use and regeneration of the urban environment.

To support the design development process, “Advanced Design Process” demonstrates different concepts and methods for developing, drafting and planning buildings, for example by parametric or participatory design. Design strategies of public spaces are given in the course “People-centered Urban Design”. In this field, the course “Spatial and Urban Dynamics” focuses on urban environments’ spatial and physical dynamics. (A more detailed description can be seen in chapter 4.5.)

“Theory of Architecture and Urban Form I and II” present an overview of social, political, economic and architectural movements.

Structural types, concepts, systems and pre-dimensioning are covered within the courses “Structure I to III”. Construction techniques, materials and systems will be taught in the courses “Construction I to Construction III”. As shown in Table 9, the courses “Construction I to III” and “Structure I to III” alternate in the following semesters. Parallel to these courses, working drawings of selected constructions and structures are an obligatory part in the design studios.

In the fifth semester, the course “Building Physics II” gives an introduction to the visual and acoustical environment. Subsequently, “Building Systems Integration” focuses on the fundamentals of buildings´ technical systems. The course “Building Performance Computing” introduces computational methods and tools for building performance simulation. (More detailed descriptions are presented in chapter 4.3, 4.4 and 4.6.)

Moreover, a major concern was the content-related coordination within the different courses in the same semester. Some linkages implemented this:

- calculating structures of the students´ design projects
- researching an architect, his/her designs, a style, and used building materials
- observing human behaviour in the building ecology course
- sketching in the history of architecture courses
  (Shehayeb 2018)

The last year of the undergraduate architectural engineering program mainly focuses on two graduation projects and a number of electives that provide possibilities for specialization (Table 11). For instance, the elective “Building Ecology” analyses and evaluates ecological performance of buildings and gives sustainability implications of design and construction decisions. (A more detailed description can be seen in chapter 4.7.)

In addition, it is planned within the 5-year curriculum to attend conferences, workshops and national and international study tours outside the university so that students experience diverse environments and fields of specialization.

Table 11 Structure Year 5 (derived based on program description of the Nile University from 2018)

	YEAR V	
	SEMESTER 9	SEMESTER 10
DESIGN STUDIO	Graduation Project 1	Graduation Project 2
PEOPLE-CENTERED THEORY (ARCHITECTURE & URBAN)		
URBAN	Urban Planning process: Planning Cities for people	
HISTORY OF ARCHITECTURE		
BUILDING TECHNOLOGY		
STRUCTURE & CONSTRUCTION	Construction doc BOQ, Tender Doc, Site Supervision / Project Management	
VISUAL		
LANGUAGE		
ELECTIVES	Sustainable Development Building Ecology	Urban Planning 2 (Transformation, mobility, …) Informal Areas

In order to give students an understanding of relating theory to real practice, the course “Construction Documents / BOQ / Tender documents / Site Supervision / Project Management” is planned for the ninth semester. The students gain insight into different responsibilities, roles and functions within a project according to international standards, as well as Egyptian Laws and Construction Codes.

Furthermore, field visits to current projects, participation in workshops within on-going projects and visits to practitioners and experts in urban regeneration and retrofit shall be provided. This provides important links between the studied courses and their application in practice.

In addition, the planned internship in the eight semester can be highly useful, as the students can obtain an impression of working life and apply theoretical knowledge in practice.

In the ninth semester, the course “Urban Planning Process: Planning Cities for People” gives an understanding of the contemporary principles of urban planning by pointing out a number of case studies and certain urbanization trends of cities around the world (Shehayeb 2018). The dimension of the urban planning process in order to understand the role and responsibilities of architects and urban designers in relation to other stakeholders is shown to students.

The graduation project I and II is planned as a two-term design studio in the last year of the undergraduate studies. In a first step, students define main objectives, develop a basic concept of the project and consider construction-related, structural and technological solutions. Subsequently, the design project will be worked out in detail and presented to a jury of professors.

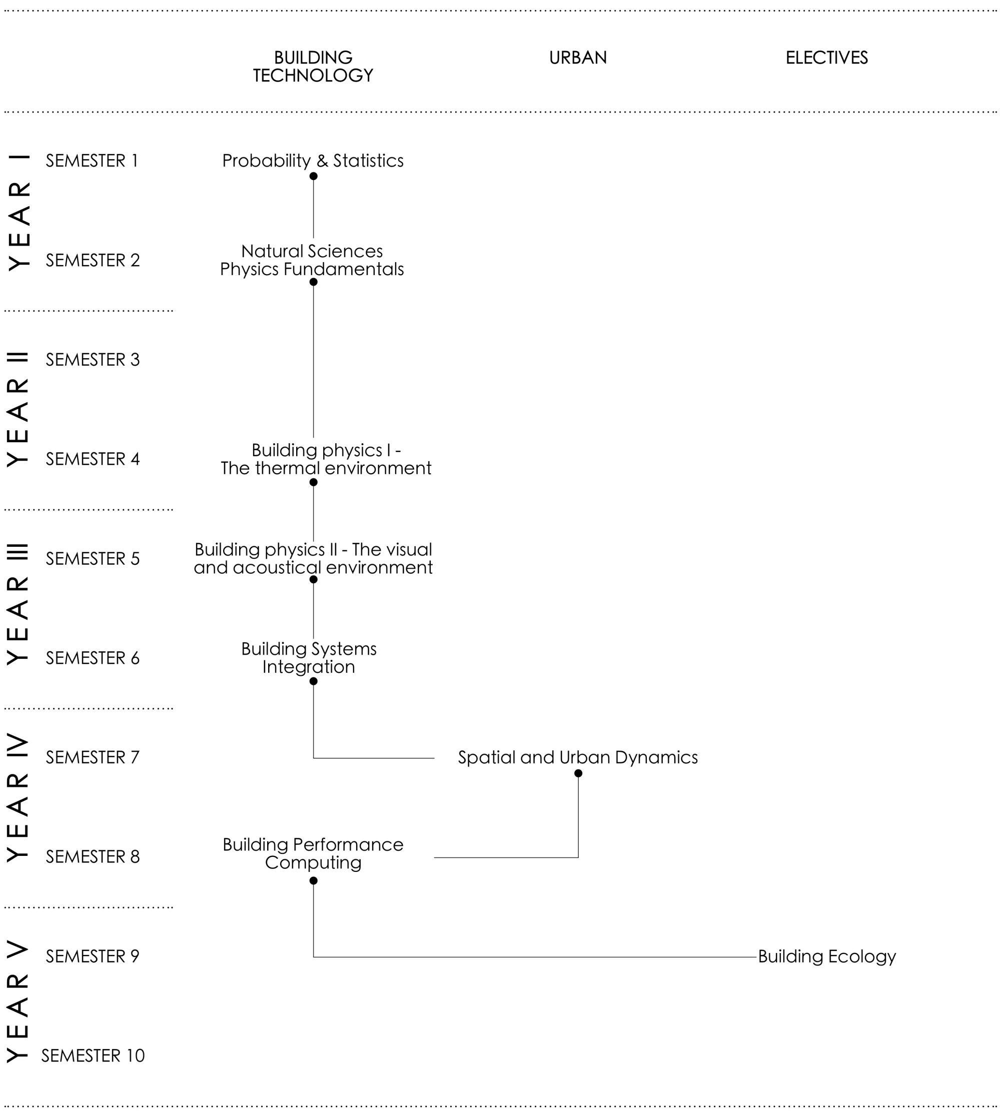
An in depth description of all courses within the building technology track, their content and foci follows.

4 THE BUILDING TECHNOLOGY TRACK

4.1 Overview

Table 12 illustrates the course sequence of the building technology track. Year I provides a basic knowledge in probability, statistics and physics. Based on this, the mandatory courses "Building Physics I – The thermal environment", "Building Physics II – The visual and acoustical environment", "Building Systems Integration", "Spatial and Urban Dynamics", "Building Performance Computing" and the elective "Building Ecology" follow. The development of these courses benefits from prior design and development work within the Master programmes "Building Science and Technology" and "Architecture" at TU Wien by the Department of Building Physics and Building Ecology.

Table 12 Sequence of the building technology courses



Building physics plays a major part in the architectural education. To achieve national and international climate protection goals, the fields of building physics and technical building services have evolved into important disciplines in the last decades and the knowledge has become essential in design, planning, construction, use, demolition and recycling of buildings (Konferenz Bauphysik und Technischer Ausbau 2018).

To provide a comprehensive knowledge in the fields of building physics, thermal, visual and acoustical aspects in building performance are included in the architectural curriculum (as illustrated in Table 13). These three areas cover not only physical foundations, but also human requirements, design / engineering and codes and standards.

Thermal aspects of building performance introduce the basics of thermal aspects in building performance, such as thermodynamics, heat and mass transfer and climatology. Further, human factors such as thermal comfort or heat stress and aspects related to the design of buildings such as energy efficiency and thermal optimization are addressed within this field.

On the one hand, visual aspects of building performance focus on physics of light and visual perception. On the other hand, the visual environment addresses visual comfort, productivity, daylighting and electrical light.

Furthermore, acoustical aspects of building performance give an introduction to the physics of sound generation and propagation. Moreover, acoustical comfort, building acoustic and room acoustics address design quality criteria.

Table 13 Content Building Physics I and II (Mahdavi and Berger 2018)

	Thermal aspects	Visual aspects	Acoustical aspects
Physical foundations	-Thermodynamics -Heat/mass transfer -Climatology	-Radiation, light -Optics	Physics of sound generation/ propagation
Human requirements	-Heat stress -Thermal comfort	Visual comfort, productivity	Acoustic comfort, productivity
Design / Engineering	-Thermal optimization -Energy efficiency	-Daylight -Electrical light	-Building acoustics -Room acoustics
Codes & Standards			

4.2 Building Physics I – The thermal environment

In the second year, the course "Building physics I – The thermal environment" (Mahdavi 2018 a) gives an introduction to the fundamentals of the thermal aspects of building performance.

The content of the lecture can be divided into four main parts: physical foundations, human requirements, design/engineering, and codes & standards (Table 13).

The topics of the lecture include heat and mass transfer in buildings, thermal comfort, thermal properties of building materials and components, climatology, thermal optimization of buildings, energy-efficient and sustainable building design, determination of heating and cooling loads of buildings, solar control and shading, human ecology, climate, moisture control in buildings, and codes and standards.

The "Building Physics I" course covers 5 ECTS (i.e., 3 Credit Hours) and is planned to be taught in spring semester. The students must have completed the courses "Probability and Statistics" and "Selected Topics in Natural Sciences: Physics Fundamentals" in the first year. The course requires a student workload of 125 hours.

A more detailed topical sequence of the overall course is presented in Table 14.

Table 14 Building Physics I: The topical sequence

Week	**Topic**
W1	Motivation, Basics of thermal physics (Part I)
W2	Basics of thermal physics (Part II)
W3	Heat transfer in buildings (Part I)
W4	Heat transfer in buildings (Part II)
W5	Heat transfer in buildings (Part III)
W6	Heat transfer in buildings (Part IV)
W7	Mass transfer in buildings (Part I)
W8	Mass transfer in buildings (Part II)
W9	Mass transfer in buildings (Part III)
W10	Thermal comfort (Part I)
W11	Thermal comfort (Part II)
W12	Climate
W13	Codes and Standards
W14	Preparation Exam
W15	Exam week

4.3 Building Physics II – The visual and acoustical environment

“Building Physics II – The visual and acoustical environments” (Mahdavi 2018 b) is planned for the third year. This course introduces the scientific foundations of building acoustics, room acoustics, daylighting and illuminating engineering.

On the one hand, the topics in visual aspects include an introduction to visual perception, physics of light, daylighting, electrical lighting fundamentals, lighting design, visual comfort and productivity.

On the other hand, the topics in acoustical aspects include an introduction to acoustical perception, physics of sound generation / propagation, building acoustics, room acoustics, acoustic comfort and productivity.

The overall course covers 5 ECTS (i.e., 3 Credit Hours) and requests a student workload of 125 hours. It is planned to be taught in spring semester and requires the course "Building Physics I – The thermal environment" as prerequisite.

Table 13 in chapter 4.1 schematically illustrates the content of Building Physics I and II. A detailed topics distribution of this course is given in Table 15.

Table 15 Building Physics II: The topical sequence

Week	**Topic**
W1	Motivation, Visual aspects of building performance: physical foundations (Part I)
W2	Visual aspects of building performance: physical foundations (Part II)
W3	Visual aspects of building performance: visual comfort
W4	Visual aspects of building performance: daylight, electrical light (Part I)
W5	Visual aspects of building performance: daylight, electrical light (Part II)
W6	Visual aspects of building performance: daylight, electrical light (Part III)
W7	Acoustical aspects of building performance: physical foundations (Part I)
W8	Acoustical aspects of building performance: physical foundations (Part II)
W9	Acoustical aspects of building performance: acoustic comfort
W10	Acoustical aspects of building performance: building acoustics (Part I)
W11	Acoustical aspects of building performance: building acoustics (Part II)
W12	Acoustical aspects of building performance: room acoustics
W13	Codes and Standards
W14	Preparation Exam
W15	Exam week

4.4 Building Systems Integration

In the sixth semester, the course “Building Systems Integration” (Mahdavi and Schuss 2018) introduces the fundamentals of buildings´ technical systems. The lecture includes a fundamental overview on HVAC systems (heating, ventilation, air-conditioning), water and wastewater infrastructure, electrical installations, basics of fire safety (fire alarm systems, sprinkler systems, fire smoke exhaust), transportation systems and an introduction to building controls and automation.
The "Building Systems Integration" course requires 65 contact hours and a student workload of 125 hours. The course covers 5 ECTS (i.e., 3 Credit Hours) and is planned to be taught in fall semester.

A more detailed topical sequence of the overall course is shown in Table 16.

Table 16 Building Systems Integration: The topical sequence

Week	Topic
W1	Fundamental overview on HVAC systems (Part I)
W2	Fundamental overview on HVAC systems (Part II)
W3	Fundamental overview on HVAC systems (Part III)
W4	Water and sewage systems (Part I)
W5	Water and sewage systems (Part II)
W6	Electrical systems (Part I)
W7	Electrical systems (Part II)
W8	Fire safety (Part I)
W9	Fire safety (Part II)
W10	Fire safety (Part III)
W11	Transportation systems
W12	Building control and automation (Part I)
W13	Building control and automation (Part II)
W14	Preparation Exam
W15	Exam week

4.5 Spatial and Urban Dynamics

The fundamentals of urban physics are part of the course “Spatial and Urban Dynamics”, which is planned for the fourth year. This course provides the students a comprehensive understanding of urban environments´ spatial and physical dynamics.

The field of “Spatial dynamics” focuses on transformation and change over time in the existing urban fabric, its use, and its meaning to different users. This part is expected to be prepared by the colleagues of Nile University.

The thematic of “Urban Physics” introduces the fundamentals of urban physics that addresses ambient environmental issues related to urban-level performance of the built form as well as the interrelations among various urban systems including the urban microclimate, energy infrastructure and mobility systems.

Both parts integrate in their impact design and regeneration of parts of cities including infrastructure, mobility, detailed land use, building morphology, and public space.
Exercises in the course include group work on case studies, as well as interacting with visiting practitioners working in local communities.

In a first consideration, the course "Fundamentals of Urban Physics" course was planned as an elective in the seventh semester. After preliminary discussions, many partners saw high relevance in that course so that combining the course with the course "Spatial Dynamics" as a compulsory subject instead of an elective seemed to be an appropriate solution. Further, the course was renamed to "Spatial and Urban Dynamics" to meet the content.

The overall course covers 5 ECTS (i.e., 3 Credit Hours) and requests a student workload of 150 hours. It is planned to be taught in fall semester within 20 hours lectures and 55 hours tutorials. A detailed topics distribution of this course is shown in Table 17.

Table 17 Spatial and Urban Dynamics: The topical sequence

Week	**Topic**
W1 - 7	Spatial dynamics
W8	Fundamentals of urban physics: Urban ecosystems
W9	Fundamentals of urban physics: Urban microclimate / environmental impacts on urban development (Part I)
W10	Fundamentals of urban physics: Urban microclimate / environmental impacts on urban development (Part II)
W11	Urban heat island phenomenon: Intensity, influencing factors, urban microclimate variance
W12	Urban heat island phenomenon: Impact, mitigating urban heat islands
W13	Case study: Microclimatic variance in Vienna
W14	Preparation Exam
W15	Exam week

4.6 Building Performance Computing

In the fourth year, the course "Building Performance Computing" provides an introduction to computational methods and applications for building performance assessment. This course is divided in a lecture part, a tutorial part and exercise work to provide a comprehensive content.

The topics include modelling and design, an overview of thermal and visual simulation methods and an introduction to the application of computational building simulation tools for thermal and visual performance assessment. Moreover, case studies and assignments on the application of simulation in building design and operation are given.

Specifically, the 3D modelling environment Rhinoceros (Rhino 5 2018) along with its visual scripting plugin Grasshopper (Grasshopper for Rhino 5 2018) are used as a basis for development of energy and daylighting models. To this end, the course deploys the Grasshopper plugins provided by Ladybug Tools LLC (Honeybee 0.0.63 2018 and Ladybug 0.0.66 2018) toward climate analysis and generation of EnergyPlus (EnergyPlus 8.9.0 2018) and Radiance (Radiance 5.2.1 2018) models for detailed building performance simulation exercises (Figure 12). Thus, the course benefits from the inherent algorithmic possibilities of Grasshopper and its extensive plugin resource to offer state of the art performance-based parametric design workflows.

The "Building Performance Computing" course requires 65 contact hours (divided into 25 hours lectures and 40 hours tutorials). This results in a student workload of 125 hours within the eight semester. The course covers 5 ECTS (i.e., 3 Credit Hours) and is planned to be taught in spring semester.

A more detailed workload distribution of the overall course is presented in Table 18.

Note that the state of discussion regarding the envisioned tools as mentioned above may undergo changes in the future given the steady process of development in the software teaching.

Table 18 Building Performance Computing: The topical sequence

Week	**Topic**
W1	Fundamentals of building performance simulation
W2	Parametric modelling with Rhino and Grasshopper (Part I)
W3	Parametric modelling with Rhino and Grasshopper (Part II)
W4	Climate and site analysis
W5	Parametric energy simulation (Part I)
W6	Parametric energy simulation (Part II)
W7	Parametric energy simulation (Part III)
W8	Parametric energy simulation (Part IV)
W9	Parametric energy simulation (Part V)
W10	Parametric daylighting simulation (Part I)
W11	Parametric daylighting simulation (Part II)
W12	Parametric daylighting simulation (Part III)
W13	Parametric daylighting simulation (Part IV)
W14	Preparation Exam
W15	Exam week

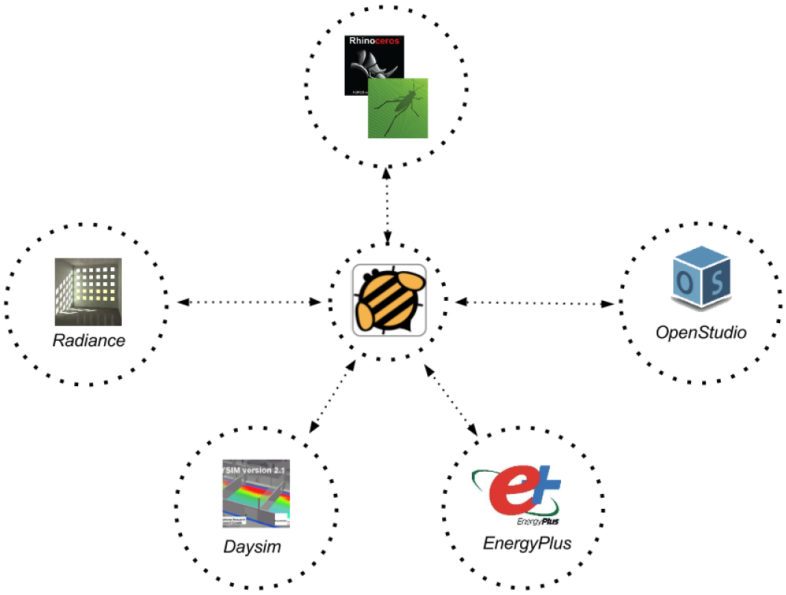


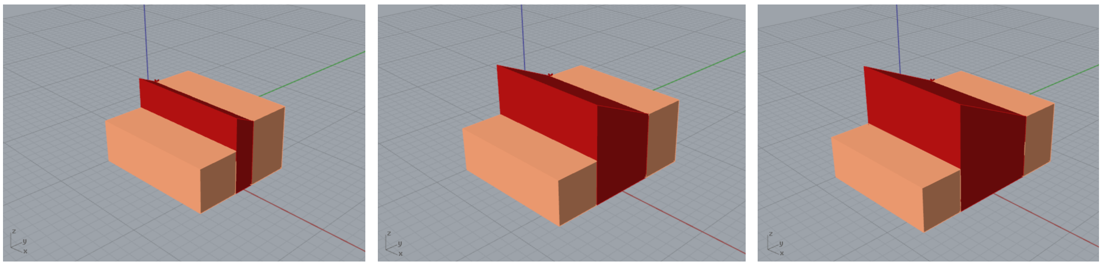
Figure 12 Plugin Honeybee – Connection of simulation engines (GitHub 2018)

Parametric design tools can encourage the students during the design process. Various information and options about buildings´ behaviour are provided during the design development and can lead to an energy-optimized building. Thus, performance-based design informs the students about different implications of design variations with regard to social and environmental aspects, such as occupants´ comfort or the energy performance of a building.

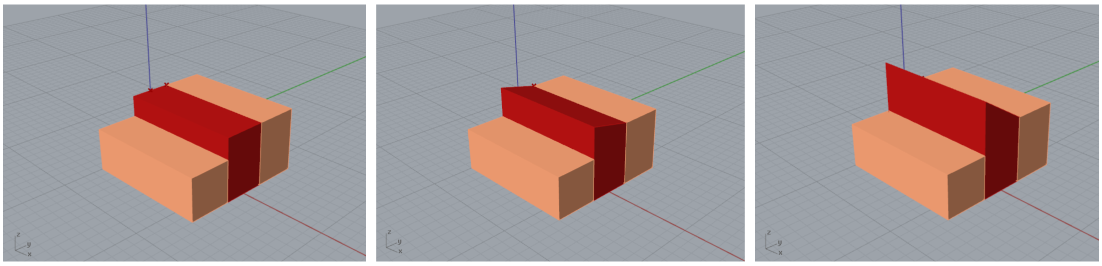
Nevertheless, a fundamental knowledge and understanding in the fields of building physics, but also in construction and architectural design is necessary prior to the usage of such simulation tools. If such a fundamental knowledge is given, results can be validated and proven correctly and provide supportive information of different design strategies and thermal behaviours.

An illustrative example for a parametric building simulation is given in Figure 13. Basic geometry transformations, including variations in the middle zone width, the middle zone roof slope and the height of middle zone and north zone can be done parametrically with the Plugin Grasshopper (Grasshopper for Rhino 5 2018).

Illustrative variations in the middle zone width:



Illustrative variations in the middle zone roof slope:



Illustrative variations in the height of middle zone and north zone:

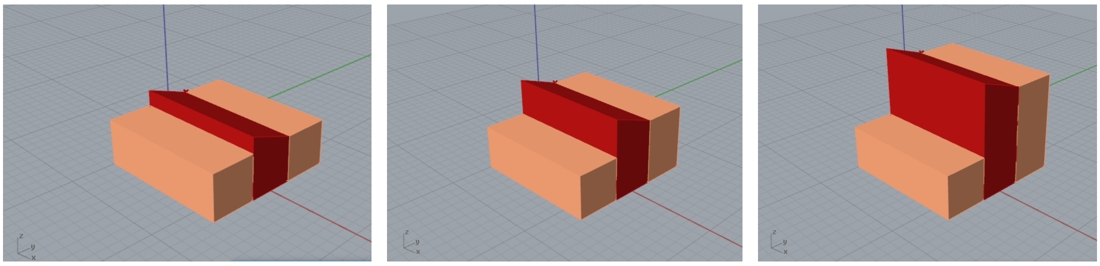


Figure 13 Example Rhino (Rhino 5 2018) - Plugin Grasshopper (Grasshopper for Rhino 5 2018), Honeybee (Honeybee 0.0.63 2018)

4.7 Building Ecology

In the fifth year, the elective “Building Ecology” (Mahdavi and Pont 2018) introduces methods for the description and evaluation of ecological performance of building elements, components, systems and structures. Specifically, the application of LCA (Life-Cycle Assessment) and EIA (Environmental Impact Analysis) techniques in the building domain for analysis of the environmental footprint of buildings and the sustainability implications of design and construction decisions are introduced.

Furthermore, products such as software GEMIS (Global Emissions Model for Integrated Systems) introduce a public domain life-cycle and material flow analysis model and database (GEMIS 2018). The course gives students an opportunity to deepen their knowledge in the field of building ecology with regard to their graduation projects.

"Building Ecology" covers 6 ECTS (i.e., 3 Credit Hours) and requests a student workload of 150 hours. It is planned to be taught in fall semester and gives as an elective the possibility for specialization within 20 hours lectures and 55 hours tutorials. A detailed topical sequence of this course is given in Table 19.

Table 19 Building Ecology: The topical sequence

Week	**Topic**
W1	Motivation, Sustainable building design and operation strategies (Part I)
W2	Sustainable building design and operation strategies (Part II)
W3	Sustainable building design and operation strategies (Part III)
W4	Life Cycle Assessment (LCA) and Environmental Impact Analysis (EIA) (Part I)
W5	LCA and EIA (Part II)
W6	LCA and EIA (Part III)
W7	LCA and EIA (Part IV)
W8	Case Study I: Comprehensive building performance evaluation
W9	Case Study II: Environmental impact assessment of building products
W10	Introduction to GEMIS (Global Emissions Model for Integrated Systems)
W11	Examples with GEMIS (products, processes, scenarios, results – Part I)
W12	Examples with GEMIS (products, processes, scenarios, results – Part II)
W13	Examples with GEMIS (products, processes, scenarios, results – Part III)
W14	Preparation Exam
W15	Exam week

5 TEACHING RESOURCES

In order to provide adequate teaching material for the building technology courses, three main resources are prepared for each course:

- Conventional slides
- Literature and web-resources
- Tools and applications

These three types of resources can be seen as suggestions of the current state of knowledge and should provide prospective teachers possible course content. Depending on changes in potential literature, web-resources and tools in the next years, this content can be modified.

An overview of illustrative teaching material and possible resources regarding the courses of the building technology track “Building Physics I – The thermal environment”, “Building Physics II – The visual and acoustical environment”, “Building Systems Integration”, “Spatial and Urban Dynamics”, “Building Performance Computing” and “Building Ecology” is exemplary described below and can be seen in Appendix 10.6 to 10.11.

Conventional slides

Conventional slides provide theoretical content in textual form, as well as mathematical calculations and graphical representation.

Figures 14 to 25 show illustrative teaching material of the course "Building Physics I". The content was developed within the course "Thermal aspects of building performance" by A. Mahdavi at the Department of Building Physics and Building Ecology at TU Wien (Mahdavi 2018 a).

The course “Building Physics I” introduces the fundamentals of thermal aspects in building performance. As described in chapter 4.2, the content of the lecture can be divided into four main parts: physical foundations, human requirements, design/engineering, and codes & standards.

Physical foundations in the thermal environment cover thermodynamics, climatology and heat and mass transfer. Figures 14 to 17 show the basics of thermodynamics and figure 18 gives an overview of heat and mass transfer in buildings.

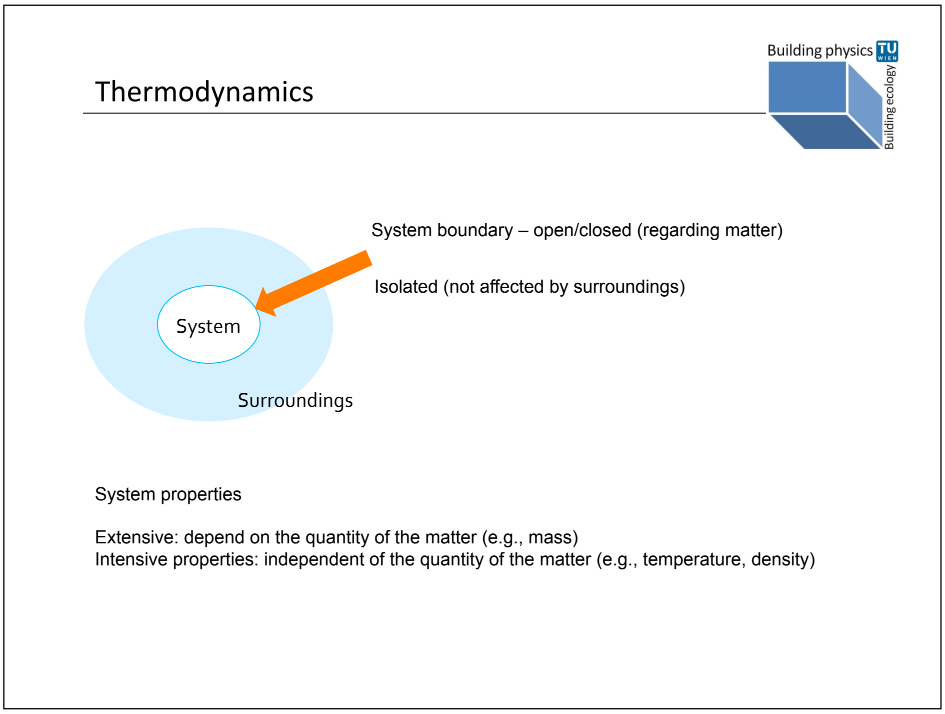


Figure 14 Illustrative teaching material of Building Physics I, Thermodynamics

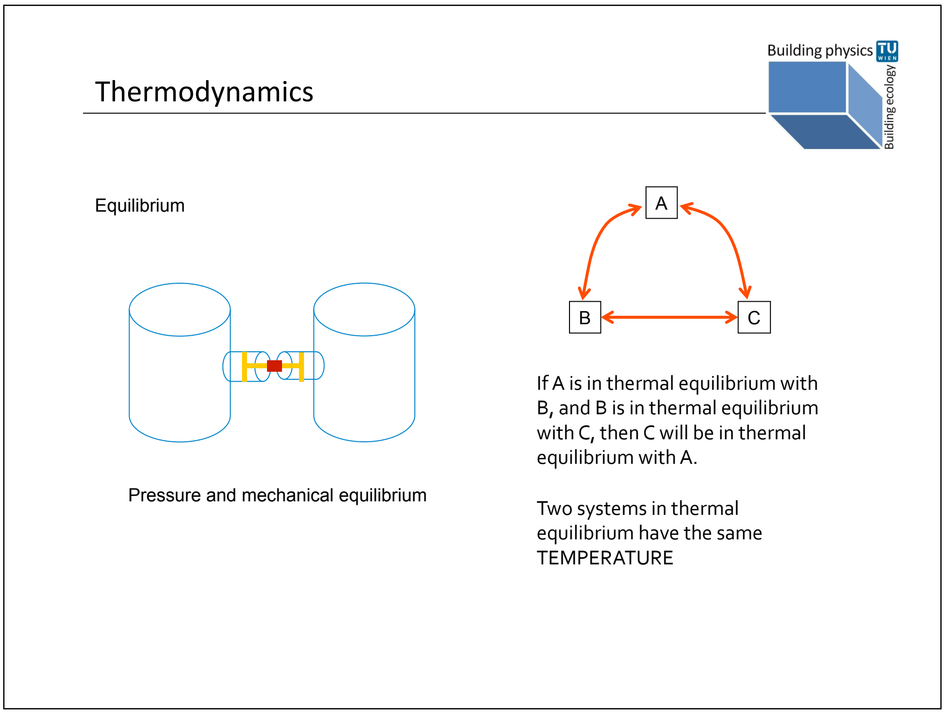


Figure 15 Illustrative teaching material of Building Physics I, Thermodynamics

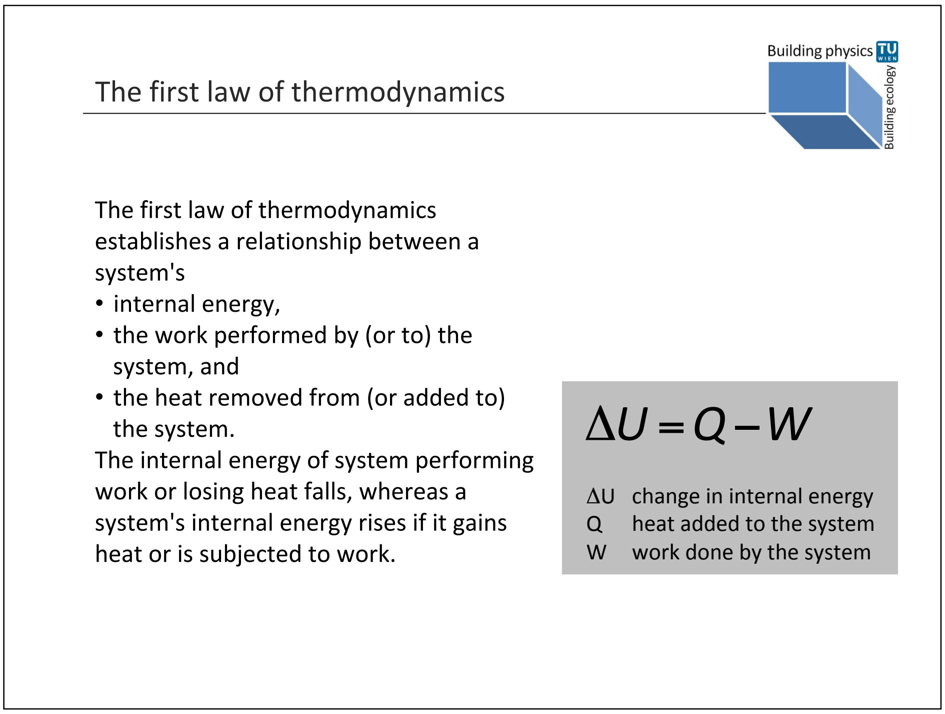


Figure 16 Illustrative teaching material of Building Physics I, Thermodynamics

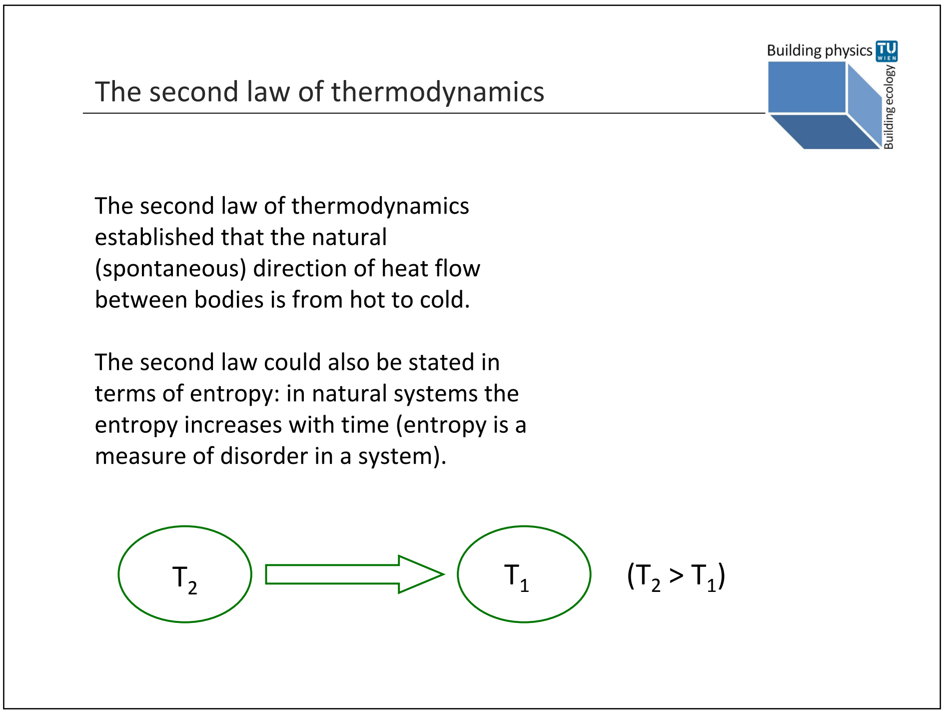


Figure 17 Illustrative teaching material of Building Physics I, Thermodynamics

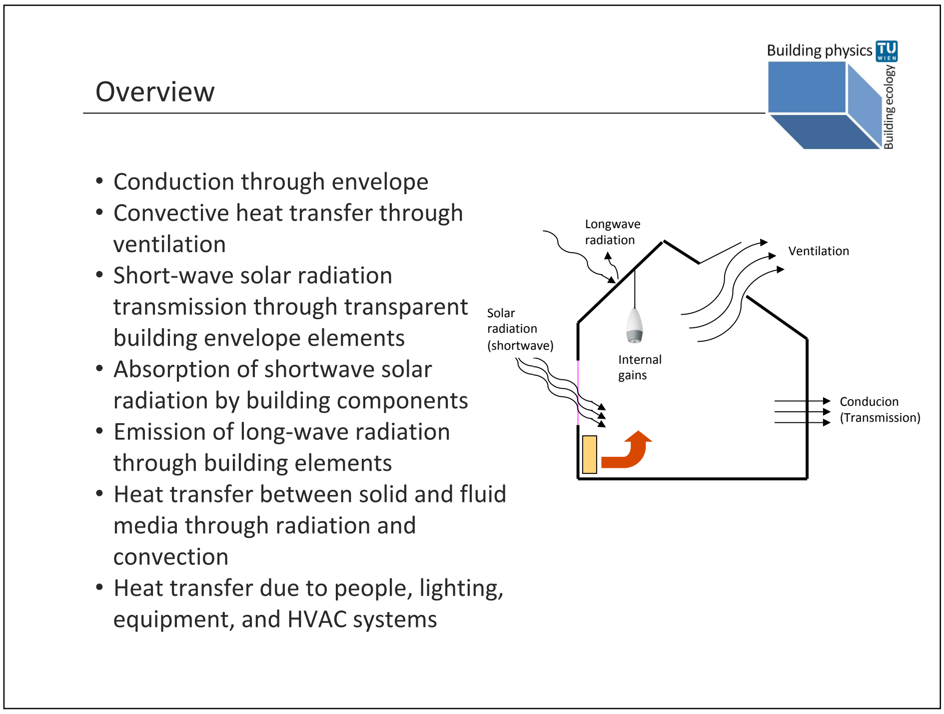


Figure 18 Illustrative teaching material of Building Physics I, Overview heat and mass transfer in buildings

Moreover, calculation examples with prior explanation are given within the course. Figure 19 shows a dew-point temperature estimation.

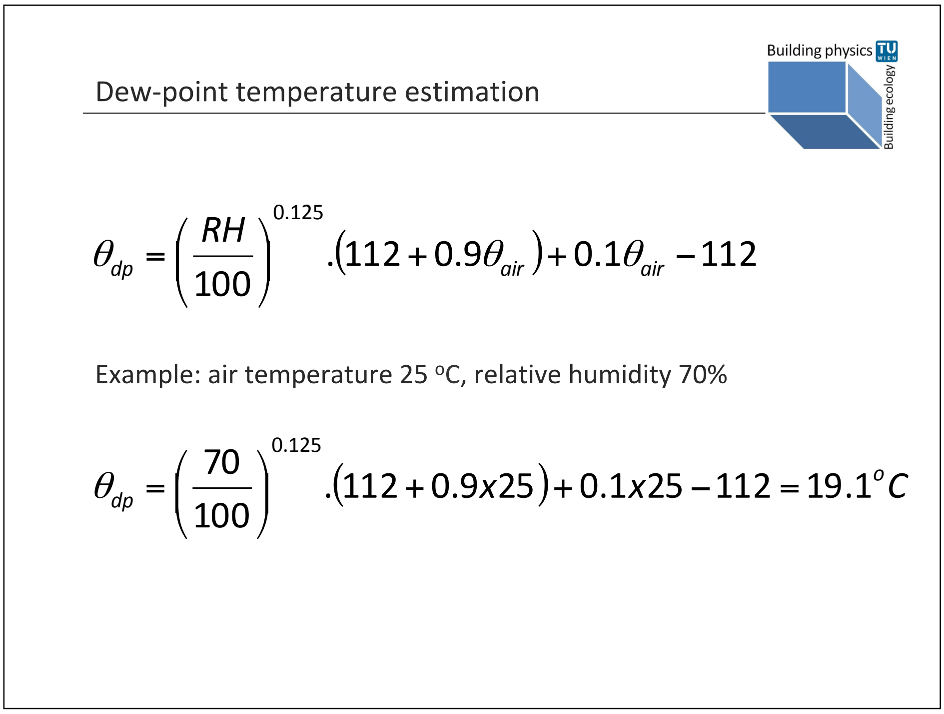


Figure 19 Illustrative teaching material of Building Physics I, dew-point temperature estimation

Another example focuses on diffuse and global radiation. Figures 20 to 22 provide explanation and formulas regarding direct, diffuse and global radiation. The calculation example is given in Figure 23.

Building physics TU
Building ecology

Climate

Main parameters:

- Solar radiation (irradiance)
- Long-wave radiation (ground)
- Daylight (illuminance)
- Cloud cover (fraction of sky)
- Sunshine duration
- Air temperature
- Air movement (wind velocity and direction)

Figure 20 Illustrative teaching material of Building Physics I, climate

Building physics TU
Building ecology

Direct solar radiation

Horizontal component

P/P0 = 1 (see level)

P/P0 = 0.8 (mountain; 2000 m)

T	City	Country
Summer	6	4
Winter	4	2

Intensity of direct horizontal irradiance ($E_{s,H}$) as a function of solar altitude h, turbidity T, and air pressure ratio p/p_0

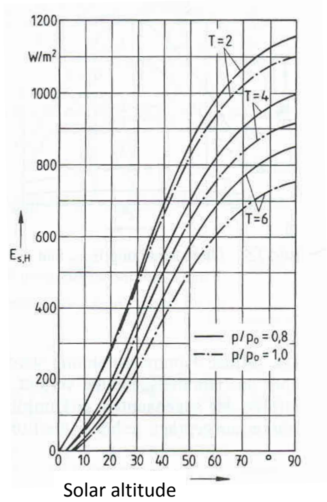


Figure 21 Illustrative teaching material of Building Physics I, direct solar radiation

Diffuse and global radiation

Building physics – Building ecology

Horizontal component diffuse

$$E_H = \frac{1}{3}\left[E_0 . \sin(h) - E_{S,H}\right] \; [Wm^{-2}]$$

Horizontal component global

$$E_{Glob} = E_{S,H} + E_H \; [Wm^{-2}]$$

Figure 22 Illustrative teaching material of Building Physics I, diffuse and global radiation

Diffuse and global radiation

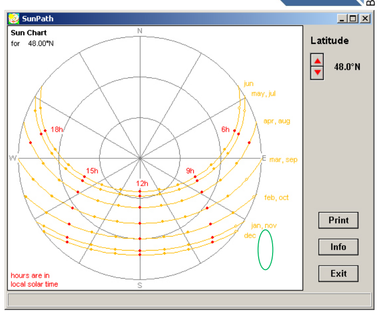
Building physics – Building ecology

Example: Vienna, Austria

Lat.: 48

November 20th, 10:00 h

T: 4 (200 m asl)



$$E_{S,H} = 100 \; Wm^{-2}$$

$$E_H = \frac{1}{3}\left[1390 . \sin(15) - 100\right] \cong 87 \; Wm^{-2}$$

$$E_{Glob} = 100 + 87 = 187 \; Wm^{-2}$$

Figure 23 Illustrative teaching material of Building Physics I, calculation example: diffuse and global radiation

Furthermore, the course “Building Physics I” focuses on human factors, such as thermal comfort or heat stress, as shown in figure 24 and 25.

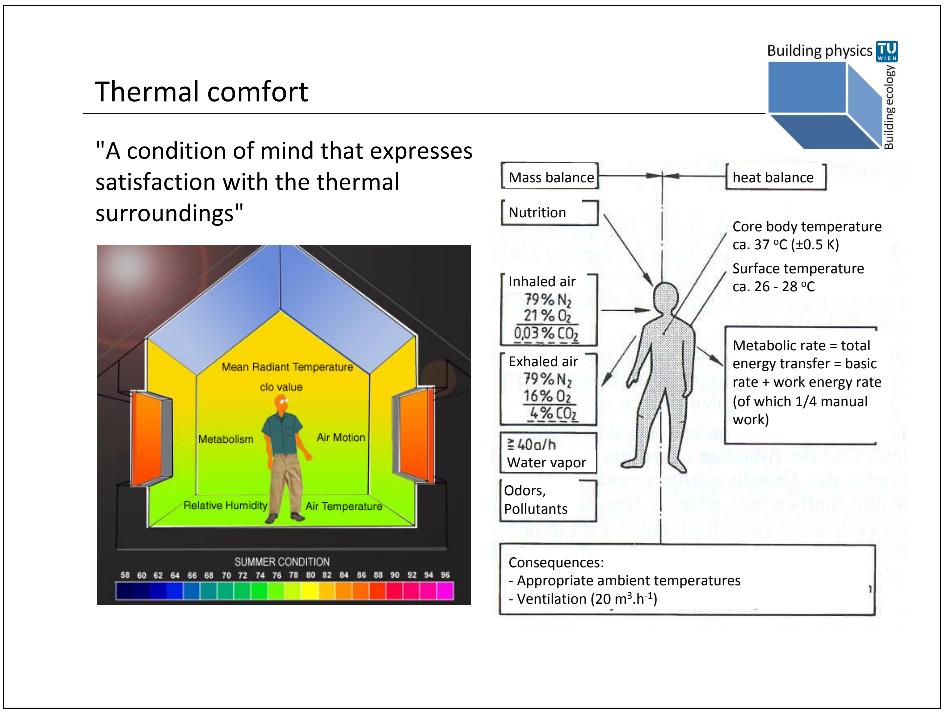


Figure 24 Illustrative teaching material of Building Physics I, thermal comfort

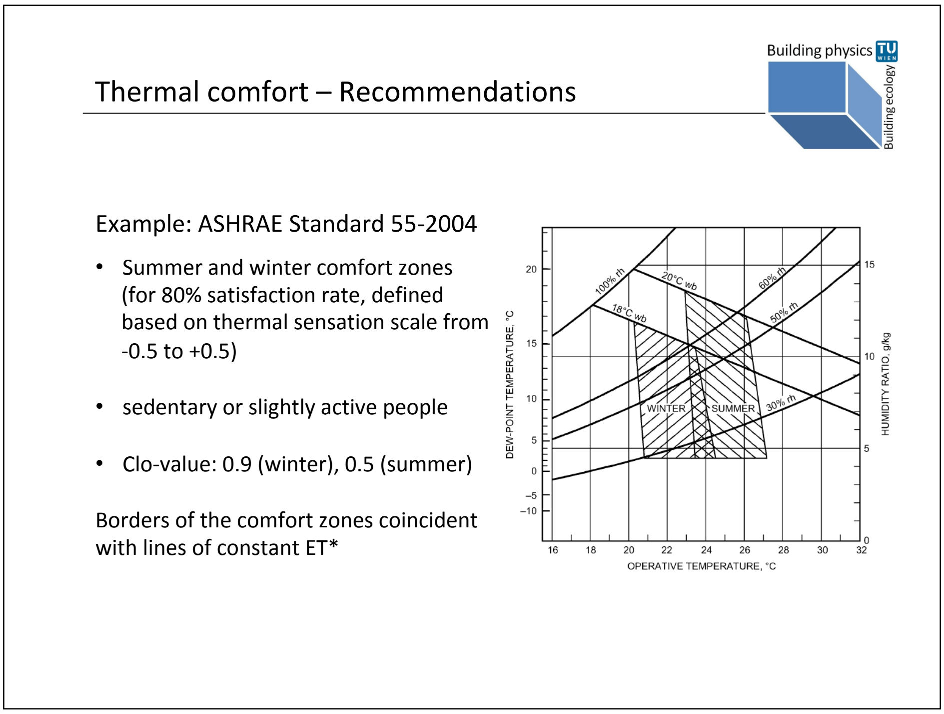


Figure 25 Illustrative teaching material of Building Physics I, thermal comfort

Literature and web-resources

A comprehensive literature and web-survey have been made to provide extensive background knowledge. To address the main content, a selection of literature for each course provides further extension and supplementary data. Key items from the literature selection are listed below.

- Building Physics I and II:

Clarke, J. A. 2011. *Energy simulation in building design.* Abingdon: Routledge

DIN EN ISO 6946: 2017. *Building components and building elements – Thermal resistance and thermal transmittance.*

Hagentoft, C. E., 2001. *Introduction to building physics.* Lund: Studentlitteratur

Hens, H. 2017. *Building Physics – Heat, Air and Moisture: Fundamentals and Engineering Methods with Examples and Exercises.* Berlin: Ernst & Sohn

Lechner, N. 2015. *Heating, cooling, lighting: sustainable design methods for architects.* Hoboken, NJ: Wiley

Long, M. 2014. *Architectural acoustics.* Oxford: Acad. Press

Mehta, M., Johnson, J., Rocafort, J. 1999. *Architectural Acoustics: principles and design.* Upper Saddle River, NJ: Prentice Hall

Stein, B., Reynolds, J.S., Grondzik, W.T., Kwok, A.G. 2006. *Mechanical and electrical equipment for buildings.* Hoboken, NJ: Wiley

Szokolay, S.V. 2014. *Introduction to architectural science: the basis of sustainable design.* London: Routledge

Tregenza, P., Loe, D. 2014. *The design of lighting.* London: Routledge

- Building Systems Integration:

Angel, W. L. 2012. *HVAC Design Sourcebook.* New York: McGraw-Hill

Buchanan, A. H., Kwabena Abu, A. 2017. *Structural Design for Fire Safety.* New York: Wiley

Warburton, P., Butcher, K. J. 2009. *Building control systems.* London: CIBSE

Zito, P. 2016. *Building Automation Systems A To Z: How To Survive In A World Full Of Bas.* North Charleston: CreateSpace Independent Publishing Platform

- Building Performance Computing:

Hensen, J. L. M., Lamberts, R. 2011. *Building Performance Simulation for Design and Operation.* London: Spon Press

Konis, K., Selkowitz, S. 2017. *Effective Daylighting with High-Performance Facades.* Cham Springer

- Building Ecology:

Berge, B. 2009. *The ecology of building materials.* Amsterdam: Elsevier, Architectural Press

GEMIS 2018. *https://iinas.org/gemis.html.* Accessed 10.07.2018.

Hauschild, M., Wenzel, H., Alting, L. 2001. *Environmental assessment of products: 1. Methodology, tools and case studies in product development.* Boston: Kluwer

Hauschild, M., Wenzel, H., Alting, L. 1998. *Environmental assessment of products: 2. Scientific background.* Boston: Kluwer

ISO 21930: 2017. *Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services.* International Organization for Standardization

Kibert, C. J. 2002. *Construction ecology: Nature as the basis for green buildings.* London: Spon Press

- Urban Physics:

Erell E., Pearlmutter, D., Williamson, T. 2011. *Urban microclimate: designing the spaces between buildings.* London: Earthscan

Gartland, L. 2008. *Heat islands: understanding and mitigating heat in urban areas.* London: Earthscan

Oke, T.R., Millis, G., Christen, A., Voogt, J.A. 2017. *Urban Climates.* Cambridge: Cambridge University Press

Tools and applications:

In the following, possible tools and applications for the courses "Building Physics I", "Building Performance Computing" and "Building Ecology" are described.

- Building Physics I:

In addition to theoretical knowledge in the thermal aspects of building performance, examples of good and bad practice provide links between theory and application in real practice. Field visits to current projects, workshops and expert visits give students a further understanding also outside the university. Moreover, the course provides manual calculation examples of simple procedures. These can be additionally supported by web-based computational tools (Cetin 2010).

- Building Performance Computing:

As described in chapter 4.6, the course “Building Performance Computing” introduces computational building performance simulation tools.

By the usage of the 3D modelling environment Rhinoceros (Rhino 5 2018) with the visual scripting plugin Grasshopper (Grasshopper for Rhino 5 2018), the geometrical basis of the building can be modelled. In order to simulate the energy and daylighting performance of the building, the Grasshopper plugins Honeybee (Honeybee 0.0.63 2018) and Ladybug (Ladybug 0.0.66 2018) are used. These plugins connect Grasshopper3D to EnergyPlus (EnergyPlus 8.9.0 2018), Radiance (Radiance 5.2.1 2018), Daysim (DAYSIM 4.0 2018) and OpenStudio (OpenStudio 2.6.0 2018) for building energy and daylighting simulation (GitHub 2018).

Particularly important in the fields of building physics is the energy performance simulation. Students can simulate and evaluate the thermal properties of their designs by the use of EnergyPlus. EnergyPlus is a simulation program for building performance simulation developed by the U.S. Department of Energy. It is free available for non-commercial usage and works with text-based input and output files.

- Building Ecology:

A public domain life-cycle and material flow analysis model and database is GEMIS (Global Emissions Model for Integrated Systems) (GEMIS 2018). This environmental simulation program provides a large database for defining processes and scenarios in various fields.

6 DISCUSSION

Prior to the development of the five-year undergraduate architectural program, previous efforts presented various viewpoints and some shortcomings in the area of architecture education. These provided supportive guidance for considering main emphases and content-related weighting within the curriculum. In comparison to other European studies, the idea of a purely design-oriented architecture education was not pursued. Rather the aim was to pay additional attention to social, urban and technological aspects.

Figure 26 clearly shows the content-related weighting of several architecture studies. Different European universities, "Fachhochschulen" and "Architekturakademien" show a strong focus on design. Between 39% and 60% of the overall curriculum cover design studios.

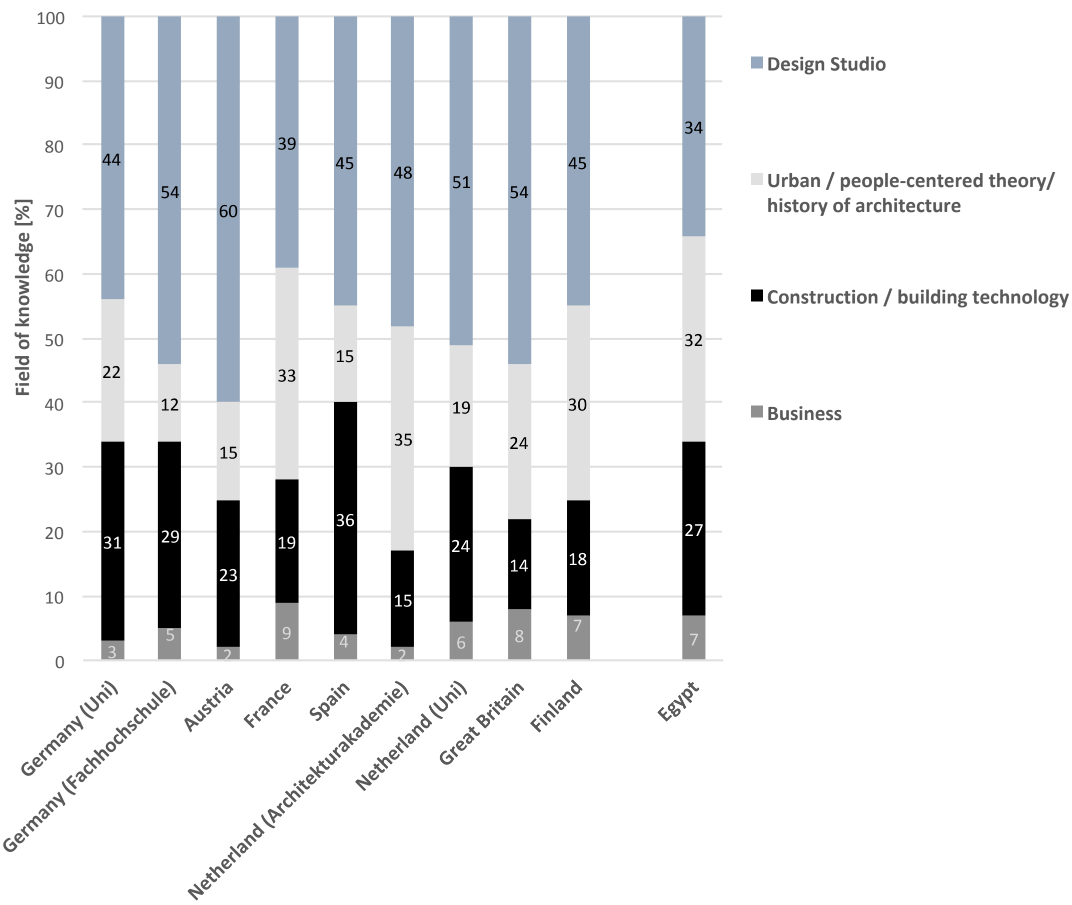


Figure 26 Percentage of subject categories in mandatory part of studies (adapted from Enseleit et al. 2001)

By comparison, the 5-year curriculum in Egypt considers a more balanced weighting of the three main categories "design studio", "urban/ people-centered theory/ history of architecture" and "construction/ building technology". These three categories are considered as equally important and obtain similar significance.

About one third (34%) is assigned to design, another third (32%) includes social and urban subjects and the third main focus (27%) lays on construction and building technology courses. Economic subjects cover 7% within the curriculum in Egypt, similar to European studies.

Nonetheless, it has to be noted that European studies last for only three years and the developed curriculum in Egypt has a duration of five years. These two additional years provide a more flexible design and integration of the different courses and allow a better linkage and coordination between them.

However, a preparatory first year with general courses can be taken into account also for other studies. Most European studies already start in the first year with architectural content, design studios or construction courses.

Basic understanding of physics, mathematics and statistics as well as language and communication skills provide the students with general knowledge and help them to orient at the beginning of the study.

7 CONCLUSION

7.1 Contribution

The presented thesis demonstrated an integrated approach to innovative architectural undergraduate education. Based upon a comprehensive research and analysis of the current architecture education, the potential for improvement was pointed out. To address this potential, IMPAQT project partners came together to design and develop a new architectural curricula. A major advantage during the development of the curriculum was the participation of experts in their fields of specialization. Different viewpoints have led to intensive argumentations and discussions on several topics. These confrontations resulted in critical reflections and developed new solutions, but also compromises.

The sequence of courses within the developed curriculum covered the following considerations:

- multidisciplinary and integrative approach
- usage of state-of-the-art technologies and methods
- content-related coordination and linkage between the courses
- including general courses within the first year
- focus on human, urban and social aspects in a number of courses
- providing theoretical, design-oriented courses one semester before the related design studio
- graduation project is planned as a two-term course and covers the whole last year

In particular, the technological subjects focused on:

- integrating of building performance simulation and parametric design tools in advanced semesters
- content-related coordination between the technological courses (building physics, construction and structure courses)
- integration of building materials in the first construction course
- links between theory and real practice by field trips and workshops outside the university

Specifically the author contributed to the above efforts in multiple ways, including but not limited to the following:

- participation in all meetings and discussions
- close collaboration with A. Mahdavi in special engagement of technology track (pedagogical concept, structure and content)
- acquisition, processing, adjustments, and adaption of educational material of courses at TU Wien ("Thermal aspects of building performance", "Visual aspects of building performance", "Acoustical aspects of building performance", "Thermal building performance simulation", "Building systems and controls", "Building ecology") towards a modified context-sensitive version for the proposed curriculum
- particular contribution to the structure of building performance course
- contribution to logistics and management issues

7.2 Future Research

The presented Gap Analysis, which has been performed within the project IMPAQT, pointed out a number of shortcomings within architecture education. In order to overcome some of these shortcomings, current architectural curricula, both globally and in particular in Europe, needs to be rethought.

During the further process of the IMPAQT project, the next two years will address the implementation of the new undergraduate program at the School of Engineering at Nile University in Egypt. In order to train prospective teachers, intensive courses and ToT workshops will be held by expert partners. Furthermore, the jury of the graduation projects will invite visiting professors from partner universities every year.

The further development of the project will also focus on the design and integration of life-long learning modules. The objective is to offer graduated architects a continuing education program. Practicing architects should be able to obtain, either in individual courses or in a diploma, knowledge they are still missing. Within these life-long learning modules, the fields Building Ecology and Building Physics, Human Requirements and Contemporary City will be covered. Moreover, the use of state-of-the-art technologies will be proposed to address current needs and requirements in the architectural practice.

8 INDEX

8.1 List of Figures

8.2 List of Tables

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Warburton, P. and Butcher, K. J. 2009. *Building control systems.* London: CIBSE

Zito, P. 2016. *Building Automation Systems A To Z: How To Survive In A World Full Of Bas.* North Charleston: CreateSpace Independent Publishing Platform

10 APPENDIX

10.1 Survey on Gap Analysis in Architecture Education

The following survey form is developed for the Gap Analysis within the IMPAQT project (Shehayeb et al. 2018 a).

Basic Info

Name:

Institution/ qualified from

Department/Major: ___________________Faculty/School: _________________

University: ______________________________Country: ___________________

Architecture Program description

Program Name (*e.g. Bachelor of Architecture, etc.*): ______________________________

Total no. of years: ________________________No. of years in Architecture: __________

Graduation year:____________

Career Interests: _______________________________

1. In your opinion, rate the most common problems facing you, concerning the knowledge content in your architecture education

Problem	**Rating**				
	1	**2**	**3**	**4**	**5**
Design					
1.1 Lack of knowledge about principles of architecture design					
1.2 Lack of knowledge of different users' needs and comfort					
1.3 Lack of integration between different disciplines (human behaviour – building science – history…)					
1.4 Lack of awareness of the importance of the built environment in shaping public space and city life					
1.5 Lack of awareness of the impact (positive/ negative) of users on the design over time					
1.6 Overemphasis on aesthetics and innovation in design education					
1.7 Lack of integration between theoretical courses and their application in studios					
1.8 Courses did not include Design-aid tools (Parametric design tools/ Environmental simulation programs)					
1.9 Other (specify)					

1 (no problem) – **5** (major problem)

Problem	Rating				
	1	2	3	4	5
Implementation of Design: Installation, Construction and Implementation skills					
1.10 Poor knowledge about executive/ working drawings					
1.11 Poor knowledge about complementary elements for a project (BoQ/ Specifications)					
1.12 Poor knowledge/practice about other technologic/engineering components (structure, electromechanical, environmental…)					
1.13 Poor clarity of the comprehensive process for implementation					
1.14 Poor knowledge about different jobs available for an architecture graduate in the market					
1.15 Unclear vision of the links between studied courses and their application in real market/ jobs					
1.16 Poor ability to make full use of summer trainings as a student					
1.17 Other (specify)					

1 (no problem) – **5** (major problem)

Problem	Rating				
	1	2	3	4	5
Representation: Communication skills					
1.18 Poor drawing skills and 3D modeling skills as design thinking tools (manual)					
1.19 Poor drawing skills and 3D modeling skills as design thinking tools (digital)					
1.20 Poor overall presentation of design concept skills					
1.21 Courses did not include **teaching** needed computer programs					
1.22 Courses did not include **applying** computer programs needed for an architecture graduate					
1.23 Poor visualization to the design end-result through providing a realistic experience to the users/ client					
1.24 Other (specify)					

1 (no problem) – **5** (major problem)

2 In your opinion, rate the most persistent problems concerning pedagogy

Problem		Rating				
		1	2	3	4	5
2.1 One-way passive methods of education						
2.2 Poor clarity of the Intended Learning Outputs from each course/ project						
2.3 Poor one-to-one interactive student-professor contact						
2.4 Poor effective engagement / motivation of students						
2.5 Poor integration between theoretical courses and their application in studios						
2.6 Inadequate learning environment	2.6.1 Place					
	2.6.2 Tools					
	2.6.3 Methods					
2.7 Other (specify)						

1 (no problem) – **5** (major problem)

3 In your opinion, rate the most persistent problems concerning management

Problem	Rating				
	1	2	3	4	5
3.1 Incoordination of courses at the same time cause confusion for students					
3.2 University system (attendance/ evaluation) does not accommodate different learning pedagogies					
3.3. Staff and Course material is not up-to-date					
3.4 Lack of clarity of the criteria of evaluation of projects (studios)					
3.5 Multiple submissions cause the students to focus on delivering regardless of the quality of the content					
3.6 Inadequate qualifications of some students entering the architecture programs (absence of assessment test prior to admission)					
3.7 Lack of remote communication and access to university resources, ex. Intelligent campus (e-lectures, video lectures, online HW submission, online grading and assessment…)					
3.8 Other (specify)					

1 (no problem) – **5** (major problem)

4. What are the necessary skills/ competences for an architecture graduate?

Specify three most important competences/ skills for a fresh graduate
1.
2.
3.

5. Role of the Architect: Rank by order of relevance

Role	Rating				
	1	2	3	4	5
5.1 Upgrading of informal areas					
5.2 Urban design					
5.3 Urban planning					
5.4 Urban management					
5.5 Planning and design of new urban settlements					
5.6 Architecture design for specialized buildings					
5.7 Interior design for buildings					
5.8 Executive/ working drawings					
5.9 Bill of Quantities and Specifications					
5.10 Graphic Design					
5.11 Project management					
5.12 Drafting, modeling, rendering…					
5.13 Landscape design (Squares, streets, gardens, …)					
5.14 Heritage preservation and Revitalization of historic areas					
5.15 Revitalization of parts of cities (city center, waterfront…)					
5.16 Participatory design					

1 (least relevant) – 5 (most relevant)

6. If you could change one thing in your architecture education experience;

6.1 What would be the most negative thing you would avoid?	6.2 What would be the most important thing you would introduce or change?

7. What are your recommendations to achieve integration between theoretical courses and their links and application in studios?

8. In your opinion, how do you perceive the difference between architecture graduates from Egyptian universities and those from other universities outside Egypt? Specify the country.

9. What are your recommendations regarding the development of the learning approaches in order to develop a new breed of architects?

10.The following questions are to be answered only by Egyptians:

10.1 Did you make use of any of the Egyptian codes related to Architecture and Urbanism during your educational experience?

☐ Yes ☐ No

10.2 Rank your degree of knowledge/ application of the following codes:

	I don't know anything about it	I know of it but never used it	I used it during my education	I used it in my work/ They apply it in my workplace
10.2.a Fire Code				
10.2.b Roads Code				
10.2.c Electrical Code				
10.2.d Steel Code				
10.2.e Building Code				
10.2.f Handicapped Code				
10.2.g Hospitals Code				
10.2.h Egyptian Code for Ethics and Principles of Practicing the Engineering Profession				
10.2.i Specifications of scope of work Code				

10.2 Gap Analysis Interview guide – Academics

The following interview guide for academics is developed for the Gap Analysis within the IMPAQT project (Shehayeb et al. 2018 b).

Basic Info

Name:

Institution/ qualified from

Department/Major: ________________ Faculty/School: ___________________

University: ________________________ Country: ___________________

General

1. Identify 3 most important challenges facing architects in your country (specify country).
2. Identify 3 most important aspects missing in the architecture education in your institution.
3. What are the competences / skills you seek in the fresh graduate from the architecture program?
4. What are the qualifications the students entering the architecture program should have?
5. What in your opinion are the different jobs that an architect should be able to fulfill?

Course material

1. Which courses must be added / removed and which courses need a shift in their approach, from your experience?
2. To what extent are the theoretical courses integrated into the design studio? How in your opinion can this integration be achieved?
3. To what extent is the material of the different courses up-to-date? How to ensure continuous revision of course content/ materials?
4. How do you suggest to balance directing an instructor while leaving room for her/him to personalize a course?
5. Is the relation between the different courses and real-life practice made clear? How can this be clarified?
6. Which courses impacted your career the most?

Pedagogy

1. In what learning context does the one-to-one student-professor contact occur in your institution? Is it enough?
2. To what extent was the learning process interactive and how?
3. What were the different settings of learning/ teaching experience were you exposed to?
    a. Mention the best experience
    b. Mention the worst experience
4. What are the architecture student needs that should be fulfilled in the learning environment; amenities, services and layout?
5. What would you recommend as the most engaging and effective learning methods?
6. What in your opinion are the assessment methods suitable for architecture education?

Multi-disciplinarity and integration

1. Which theoretical courses did you make use of, and which did you not, in your professional practice?
2. Which disciplines would you have liked to integrate more into your qualification. How do you suggest this should have been done?
3. What disciplines you would have liked to learn about in your architecture education but did not?

ICT Contribution

1. What do you think about the integration of Design-aid tools in Architecture Education (Parametric design tools/ Environmental simulation programs)? Advantages / Disadvantages.
2. What do you think about design visualization tools (Drawing skills and 3D modelling skills/ Virtual reality…) in Architecture Education whether as design thinking tools or for the representation of the end-result? Advantages / Disadvantages.
3. What are your recommendations to integrate ICT contributions in Architecture education?

10.3 Gap Analysis Interview guide – Practitioners

The following interview guide for practitioners is developed for the Gap Analysis within the IMPAQT project (Shehayeb et al. 2018 c).

Basic Info

Name:

Current job

Institution: _________________Title: _______________

Institution/ qualified from

Department/Major: _________________Faculty/School: ___________________

University: ________________________Country: ___________________

Graduation year: __________________

General

1. Identify 3 most important challenges facing architects in your country (specify country).
2. What are the competences / skills you seek in fresh graduates from any architecture program?
3. What are the qualifications the students entering the architecture program should have?
4. What in your opinion are the different jobs that an architect should be able to fulfil?
5. If you look back at your architectural education, which courses impacted your career the most? and how?

Pedagogy

1. Would you like to contribute ideas about effective learning methods for young architects?
2. What in your opinion are the assessment methods suitable for architecture education?

Multi-disciplinarity and integration

1. Which disciplines would you have liked to learn about in your architecture education? How do you suggest this should have been done?

ICT Contribution

1. What do you think about the integration of Design-aid tools in Architecture Education (Parametric design tools/ Environmental simulation programs)? Advantages / Disadvantages.
2. What do you think about design visualization tools (Drawing skills and 3D modelling skills/ Virtual reality…) in Architecture Education whether as design thinking tools or for the representation of the end-result? Advantages / Disadvantages.
3. What are your recommendations to integrate ICT contributions in Architecture education?

10.4 Partner interview on Role of the Architect

The following form regarding the role of the architect is developed for the Gap Analysis within the IMPAQT project (Shehayeb et al. 2018 d).

Name	
Country	
Institute	
Position	
Role of the architect based on your experience and point of view	
What are the urban challenges facing the architect today?	
Explain briefly your vision / definition of the role of the architect / How do you see the changes over time?	
List the non-negotiable qualifications of the architecture fresh graduate to fulfil the role of the architect	(1) …..…………………………………… (2)………………………………………...
Linkages to other disciplines in those qualifications?	Specify the disciplines (1) ………………………………………………… (2) ………………………………………………… (3) …………………………………………………
	what are the intended learning outputs for the student? ………………………………………………… what are the references you recommend? …………………………………………………
Recommendations to consider when developing an architecture program	
Orientation of students towards real roles of the architect / Linkages between university and real practice	
How best to establish linkages to other disciplines and continuous learning	

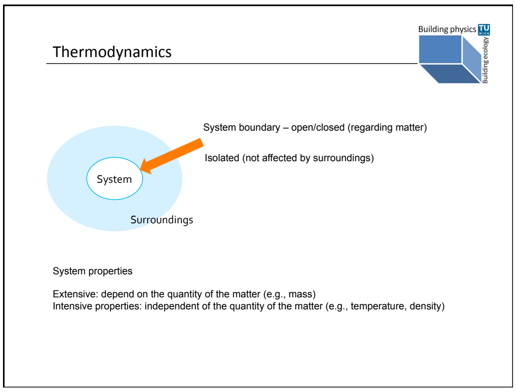
10.5 Best & Worst Pedagogy

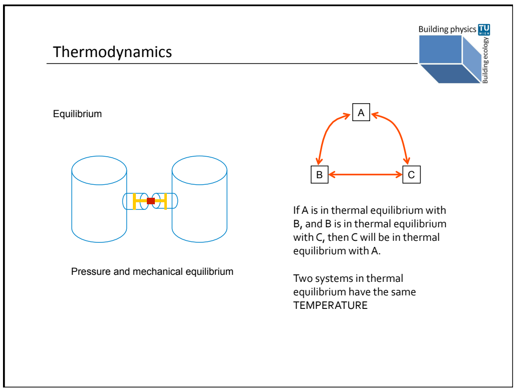
The following form regarding best and worst pedagogy in architectural education is developed for the Gap Analysis within the IMPAQT project (Shehayeb et al. 2018 e).

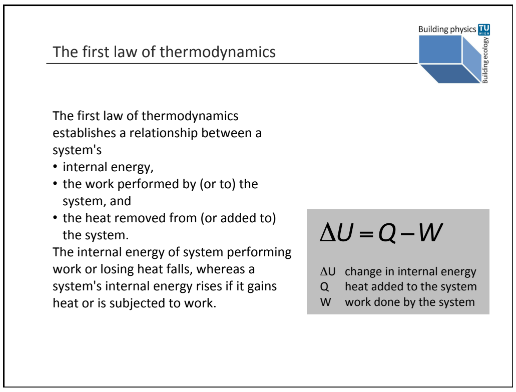
Name					
Institute					
Country					
Position					
Undergraduate Program Length					
Course Title					
Course Type	Core / Mandatory		Elective	Other: specify	
Course Format	Lecture	Studio	Lab	Other: specify	
Year	1	2	3	4	5
BEST EXPERIENCE					
Context					
Description including: setting – teaching/ learning environment – learning methods – means of communication – course material…)					
Advantages/ Positive points (Learning outputs - phenomenon)					
Reasons behind (why do you consider it good - criteria)					
WORST EXPERIENCE					
Context					
Description including: setting – teaching/ learning environment – learning methods – means of communication – course material…)					
Disadvantages/ Negative points (Learning outputs failed – phenomenon)					
Reasons behind (Why do you consider it worst? - criteria)					
RECOMMENDATIONS					
setting – teaching/ learning environment					
learning methods – means of communication					
course material					

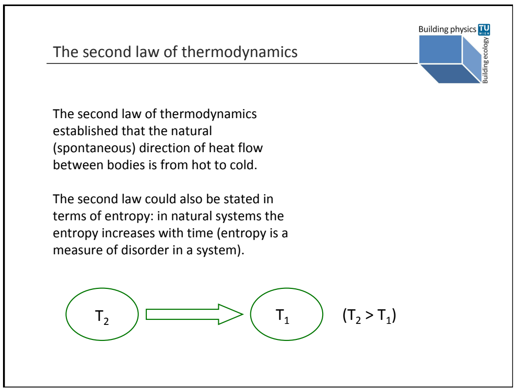
10.6 Illustrative teaching material – Building Physics I

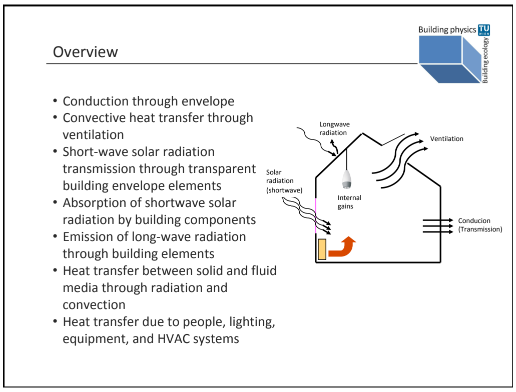
The following illustrative teaching material is developed within the course "Thermal aspects of building performance" by A. Mahdavi at the Department of Building Physics and Building Ecology at TU Wien (Mahdavi 2018 a).

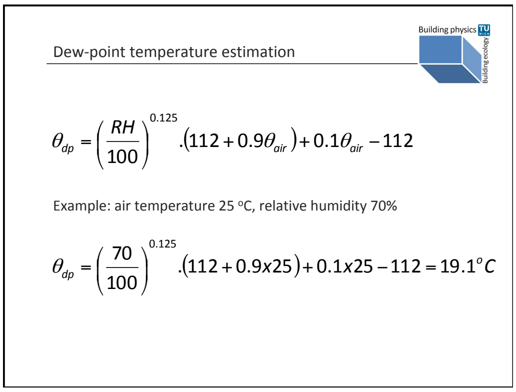






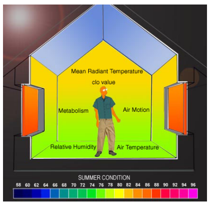


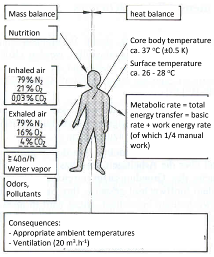




Thermal comfort

"A condition of mind that expresses satisfaction with the thermal surroundings"



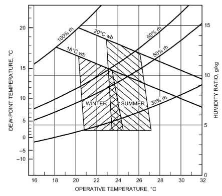


Thermal comfort – Recommendations

Example: ASHRAE Standard 55-2004

- Summer and winter comfort zones (for 80% satisfaction rate, defined based on thermal sensation scale from -0.5 to +0.5)
- sedentary or slightly active people
- Clo-value: 0.9 (winter), 0.5 (summer)

Borders of the comfort zones coincident with lines of constant ET*



Climate

Main parameters:

- Solar radiation (irradiance)
- Long-wave radiation (ground)
- Daylight (illuminance)
- Cloud cover (fraction of sky)
- Sunshine duration
- Air temperature
- Air movement (wind velocity and direction)

Direct solar radiation

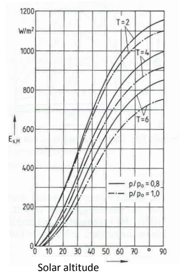
Horizontal component

P/P0 = 1 (see level)

P/P0 = 0.8 (mountain; 2000 m)

T	City	Country
Summer	6	4
Winter	4	2

Intensity of direct horizontal irradiance ($E_{S,H}$) as a function of solar altitude h, turbidity T, and air pressure ratio p/p_0



Diffuse and global radiation

Horizontal component diffuse

$$E_H = \frac{1}{3}\left[E_0.\sin(h) - E_{S,H}\right] \ [Wm^{-2}]$$

Horizontal component global

$$E_{Glob} = E_{S,H} + E_H \ [Wm^{-2}]$$

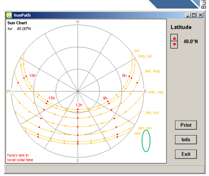
Diffuse and global radiation

Example: Vienna, Austria

Lat.: 48

November 20th, 10:00 h

T: 4 (200 m asl)



$$E_{S,H} = 100 \ Wm^{-2}$$

$$E_H = \frac{1}{3}\left[1390.\sin(15) - 100\right] \cong 87 \ Wm^{-2}$$

$$E_{Glob} = 100 + 87 = 187 \ Wm^{-2}$$

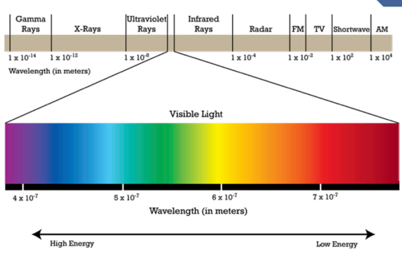
10.7 Illustrative teaching material – Building Physics II

The following illustrative teaching material is developed within the courses "Visual aspects of building performance" and "Acoustical aspects of building performance" by A. Mahdavi at the Department of Building Physics and Building Ecology at TU Wien (Mahdavi 2018 b).

The visual environment

Building physics TU Building ecology

Electromagnetic radiation



4

Electromagnetic radiation

Radiation	λ [µm]
γ, X	<0.001
UV	0.001 – 0.38
Light	0.38 – 0.78
IR	0.78 - 1000
Microwaves, radio waves	>1000

ca. 98% terrestrial solar energy within 0.25 – 3 µm
(under 0.25 µm absorption due to Ozone layer, above 3 µm due to H_2O, CO_2)

5

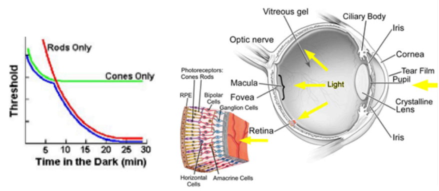
Radiation and light

Φ_e **Radiant flux** [W]
Purely physical

Φ Luminous flux [lm]
Related to human eye sensitivity

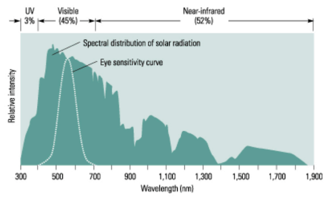
6

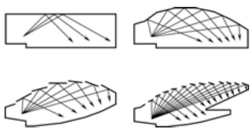
Eye and adaptation



7

Eye and adaptation

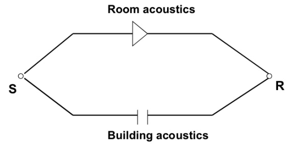




The acoustical environment

Building physics TU Building ecology

Building and room acoustics



90

Dimensions of the music space

- Frequency (pitch)
- Intensity (Loudness)
- time pattern (Rhythm)
- Timbre ("color")

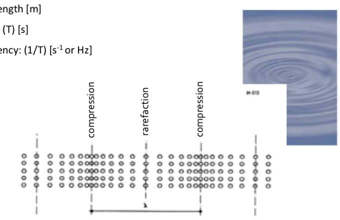
91

Wavelength, frequency, sound speed

wavelength [m]

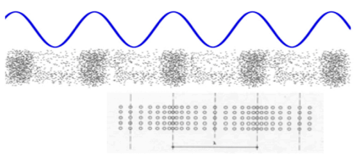
Period (T) [s]

Frequency: (1/T) [s^{-1} or Hz]



92

Wavelength, frequency, sound speed



93

Wavelength, frequency, sound speed

Frequency ranges (in Hz)

	Lower range	Upper range
Infrasound		20
Audible range	20	20 000
Ultrasound	20 000	
Noise control	50	10 000
Room acoustics	63	8 000
Building acoustics	100	3150

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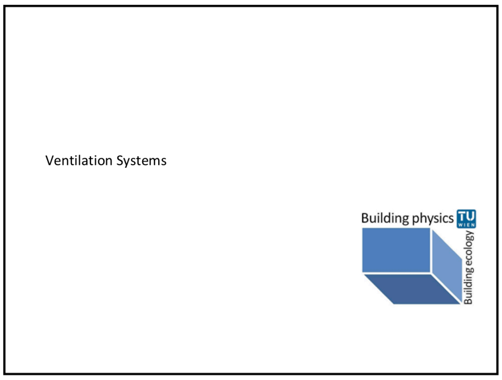
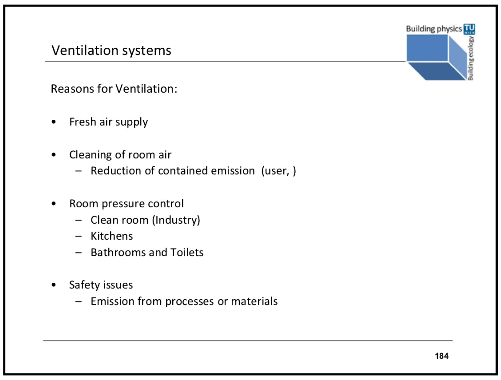
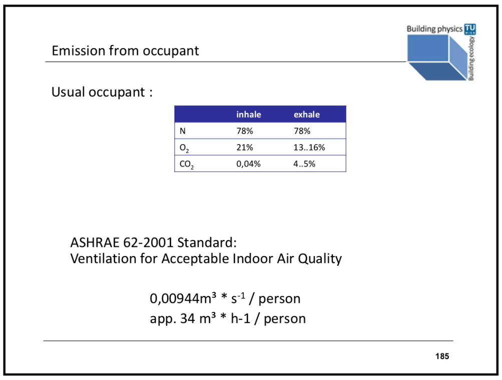
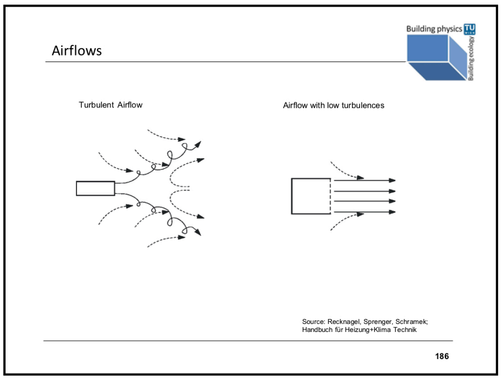
10.8 Illustrative teaching material – Building Systems Integration

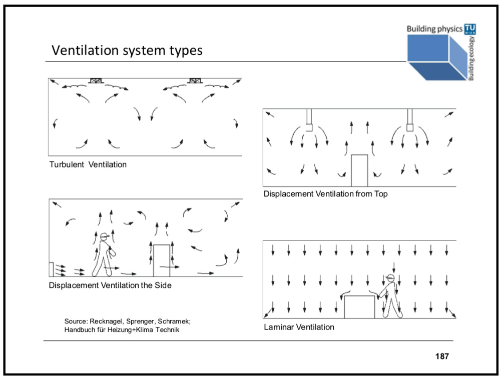
The following illustrative teaching material is developed within the courses "Building Systems and Controls", "Fire Safety", and "Technischer Ausbau" by M. Schuss and A. Mahdavi at the Department of Building Physics and Building Ecology at TU Wien (Mahdavi and Schuss 2018).

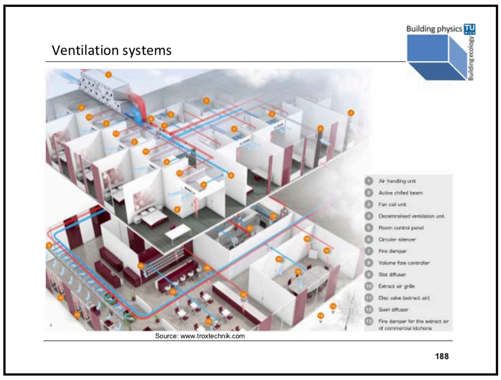


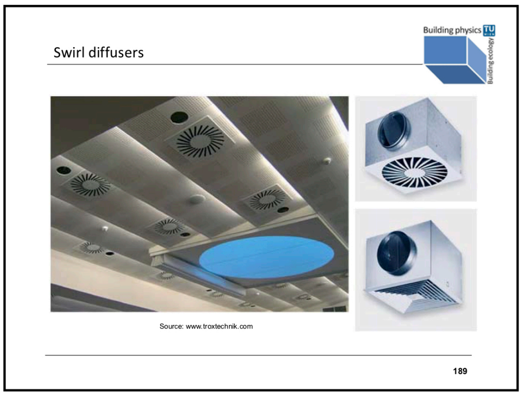


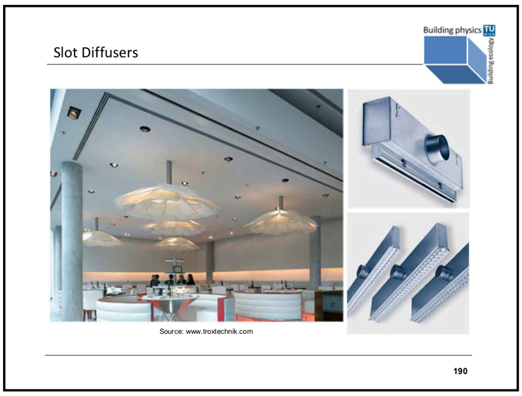


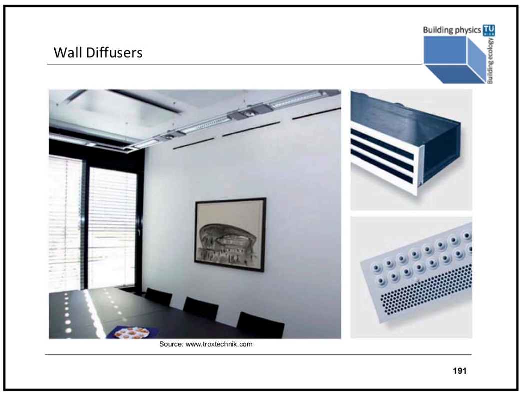


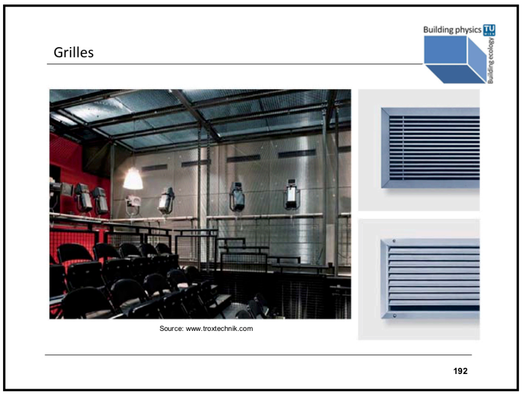


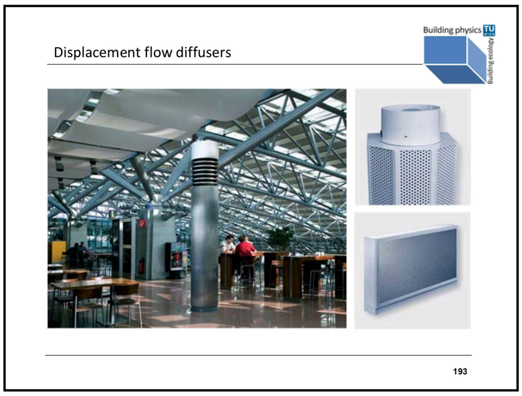


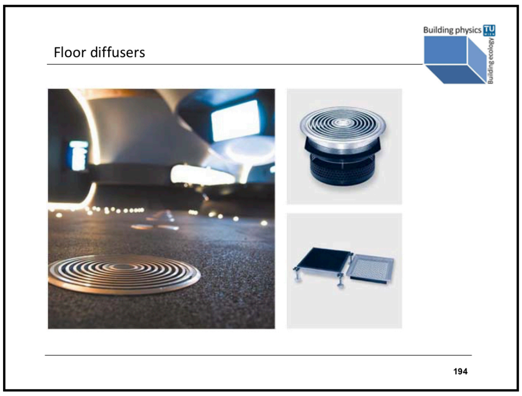

Building physics TU
Building ecology
Swirl diffusers
Source: www.troxtechnik.com
189


Building physics TU
Building ecology
Slot Diffusers
Source: www.troxtechnik.com
190


Building physics TU
Building ecology
Wall Diffusers
Source: www.troxtechnik.com
191

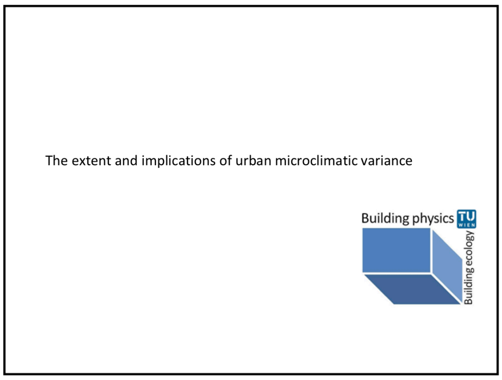

Building physics TU
Building ecology
Grilles
Source: www.troxtechnik.com
192

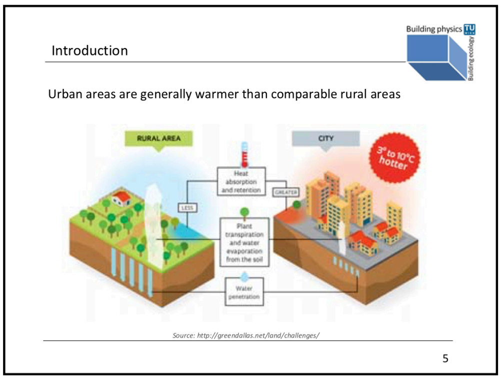

Building physics TU
Building ecology
Displacement flow diffusers
193

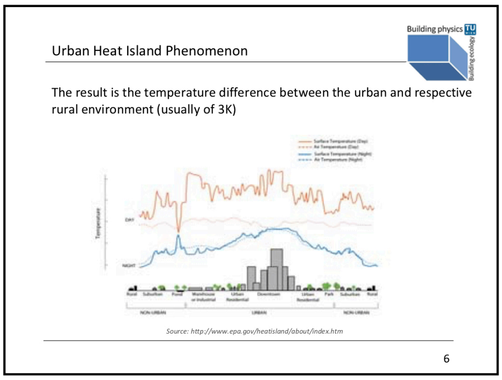

Building physics TU
Building ecology
Floor diffusers
194

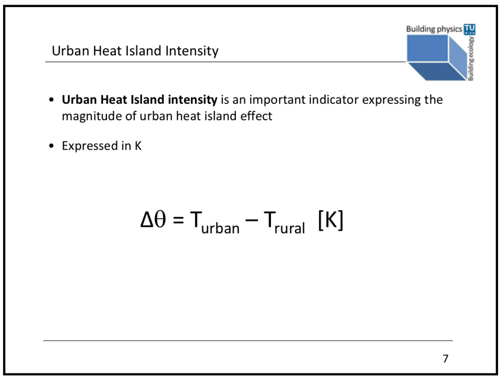
10.9 Illustrative teaching material – Urban Physics

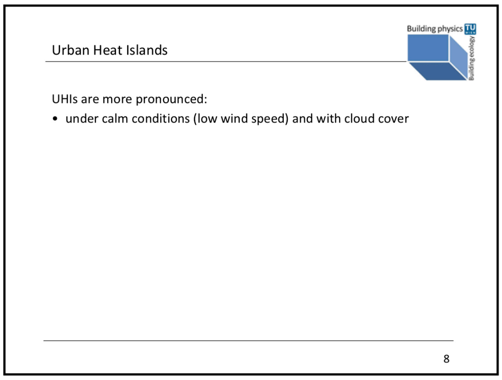
The following illustrative teaching material is developed within the course "Current Topics in Building Performance" by M. Vuckovic and A. Mahdavi at the Department of Building Physics and Building Ecology at TU Wien (Mahdavi and Vuckovic 2018).

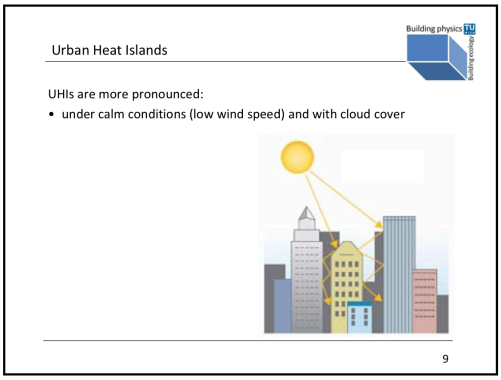








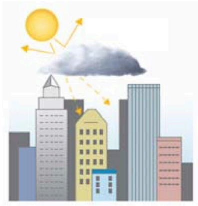




Urban Heat Islands

UHIs are more pronounced:

- under calm conditions (low wind speed) and with cloud cover



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Urban Heat Islands

UHIs are more pronounced:

- under calm conditions (low wind speed) and with cloud cover

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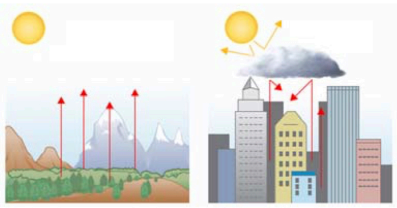
Urban Heat Islands

UHIs are more pronounced:

- under calm conditions (low wind speed) and with cloud cover



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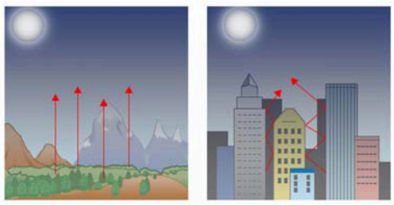
Urban Heat Islands

UHIs are more pronounced:

- under calm conditions (low wind speed) and with cloud cover
- during the night-time



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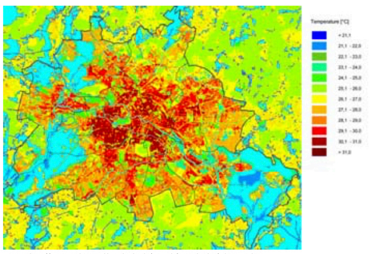
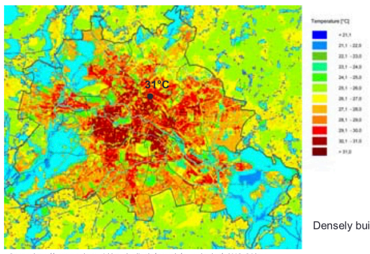
Urban Microclimate Variance



Source: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/ed412_04.htm

14

Urban Microclimate Variance



Densely built urban area

Source: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/ed412_04.htm

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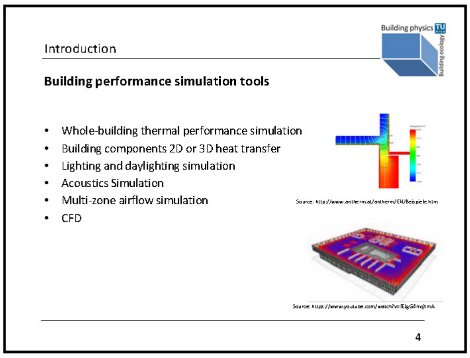
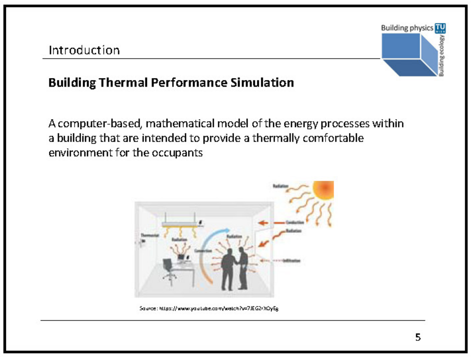
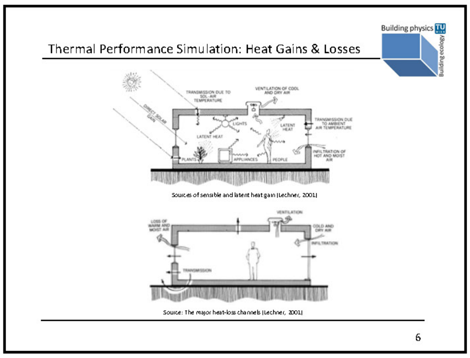
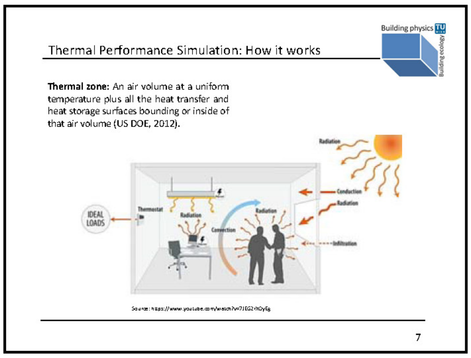
10.10 Illustrative teaching material – Building Performance Computing

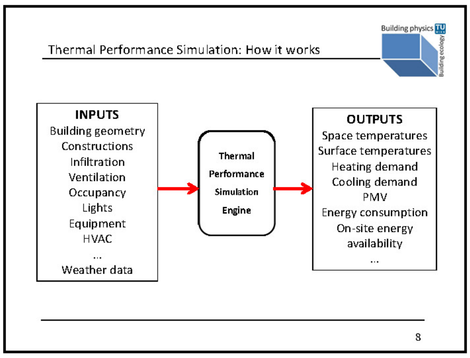
The following illustrative teaching material is developed within the course "Thermal building performance simulation" by F. Tahmasebi and A. Mahdavi at the Department of Building Physics and Building Ecology at TU Wien (Mahdavi and Tahmasebi 2018).

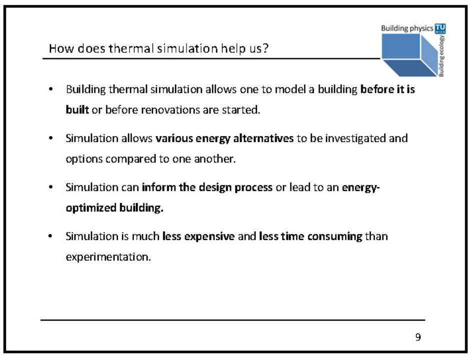






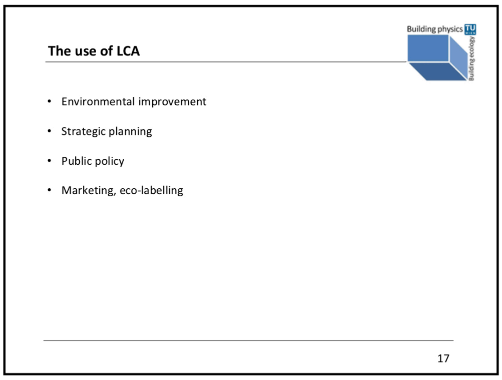


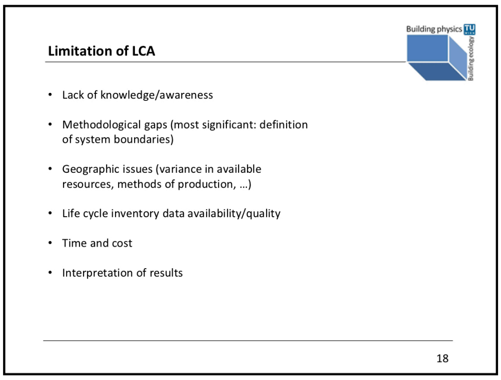


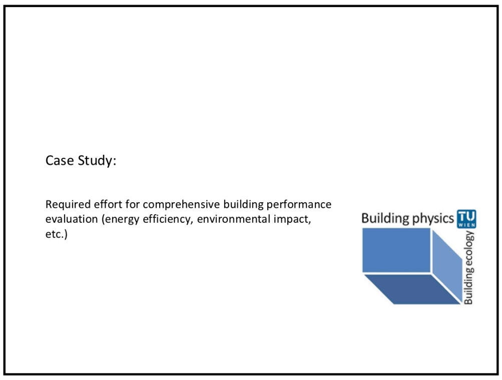


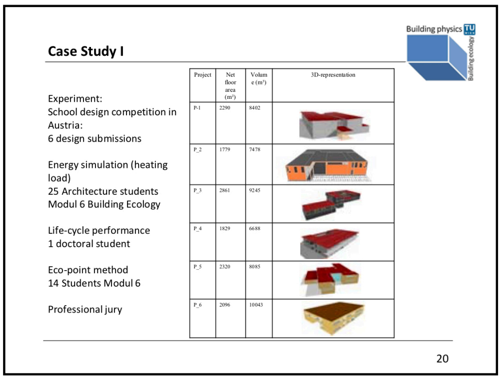
10.11 Illustrative teaching material – Building Ecology

The following illustrative teaching material is developed within the course "Building Ecology" by A. Mahdavi and U. Pont at the Department of Building Physics and Building Ecology at TU Wien (Mahdavi and Pont 2018).

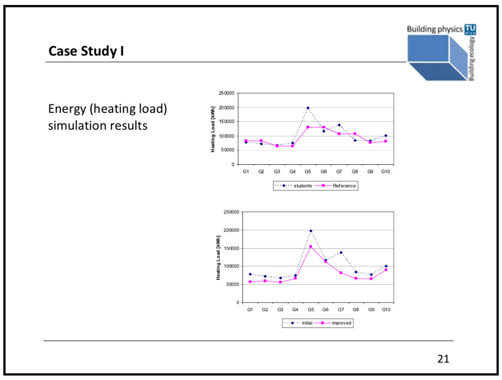


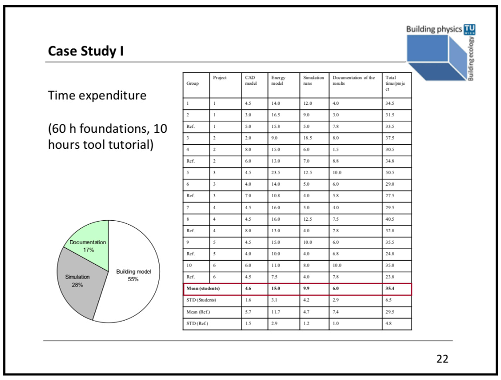






Project	Net floor area (m^2)	Volume (m^3)	3D-representation
P-1	2290	8402	
P_2	1779	7478	
P_3	2861	9245	
P_4	1829	6688	
P_5	2320	8085	
P_6	2096	10043	





Group	Project	CAD model	Energy model	Simulation runs	Documentation of the results	Total time/project
1	1	4.5	14.0	12.0	4.0	34.5
2	1	3.0	16.5	9.0	3.0	31.5
Ref.	1	5.0	15.8	5.0	7.8	33.5
3	2	2.0	9.0	18.5	8.0	37.5
4	2	8.0	15.0	6.0	1.5	30.5
Ref.	2	6.0	13.0	7.0	8.8	34.8
5	3	4.5	23.5	12.5	10.0	50.5
6	3	4.0	14.0	5.0	6.0	29.0
Ref.	3	7.0	10.8	4.0	5.8	27.5
7	4	4.5	16.0	5.0	4.0	29.5
8	4	4.5	16.0	12.5	7.5	40.5
Ref.	4	8.0	13.0	4.0	7.8	32.8
9	5	4.5	15.0	10.0	6.0	35.5
Ref.	5	4.0	10.0	4.0	6.8	24.8
10	6	6.0	11.0	8.0	10.0	35.0
Ref.	6	4.5	7.5	4.0	7.8	23.8
Mean (students)		**4.6**	**15.0**	**9.9**	**6.0**	**35.4**
STD (Students)		1.6	3.1	4.2	2.9	6.5
Mean (Ref.)		5.7	11.7	4.7	7.4	29.5
STD (Ref.)		1.5	2.9	1.2	1.0	4.8