Game-based learning to teach holistic building design

Author(s):
Neubert, Lisa-Franziska; Mehnert, Jan; Endres, Elisabeth

Publication date:
2025-11

Permanent link:
https://doi.org/https://doi.org/10.3929/ethz-c-000785705

Originally published in:
SBE Conference Series

Game-based learning to teach holistic building design

Lisa-Franziska Neubert[1,2*], Jan Mehnert[2] and Elisabeth Endres[1]

[1] Institute for Building Climatology and Energy of Architecture, TU Braunschweig, Braunschweig, Germany
[2] Building technology and climate-responsive design, Faculty of Architecture, FH Dortmund, Dortmund, Germany

[*]E-mail: lisa.neubert@tu-braunschweig.de / lisa-franziska.neubert@fh-dortmund.de

1. Introduction

Building simulations require the involvement of individuals from a range of disciplines (e.g. Architects, Building and MEP Engineers) who are able to utilize and interpret building simulation models and results which are detailed throughout the planning process. Those individuals need to be provided with the essential knowledge and skills to be able to understand and apply a subject with the given complexity. As a result, holistic design and building simulations should be taught fundamentally as part of interdisciplinary education at universities. On the other hand, there is limited consensus on how building simulations are taught to ensure that qualified young designers enter the job market.

Building simulations are a type of dynamic calculation method that can be utilized to generate detailed forecasts of temperatures -as well as heating and cooling loads of single spaces or whole buildings. (3) This goes along with a number of advantages over the primarily static assessment methods for achieving certain energy qualities that are specified by EU EPBD standards.

Throughout different design phases, the entire team must assess the significance and validity of each measure to ensure the creation of a building with future viability such as climate neutrality. Using building simulations, a comparative analysis with alternative strategies is possible. Thus enabling low-tech methods and climate-responsive design by aiding the decision-making processes already in early planning stages. Building simulations are essential to validate the behaviour of buildings to consider e.g. various user scenarios, ventilation strategies or the use of thermal masses. (1) For this reason, building simulations have become a standard tool for integral design considering the building as a complex system. (2)

This abstract summarizes the current status quo and the next steps of research at Technische Universität Braunschweig and Fachhochschule Dortmund to develop a didactic evidence-based teaching strategy for building simulations and holistic building design considering different knowledge levels.

2. Method – Learning from Reality

The research is based on the idea that graduates who enter the working world can only effectively participate in integrated design processes if the current needs and topics are incorporated in the curriculum. Therefore, in order to create suitable and effective teaching methods, it is necessary to gain insights from design practice (reality).

A concise quantitative survey is conducted to determine the present demand for graduates who possess competencies in simulations. The target group of the survey are architects, engineers and consultants who employ simulations in their projects. They either develop the simulations and results (experts) or make decisions based on the simulations results (decision makers). The intent of the survey is to provide insights into the required skill set of graduates presenting a high value for the workforce. Furthermore, this inquiry will gather information about projects that utilize or do not utilize simulations with the aim of identifying reasons for both.

The subsequent step are expert interviews which will provide detailed perspectives and identify factors that contribute to the effective use of simulation tools in real work settings as well as the limitations of these tools. Expert interviews will be conducted using an interview guide based on various approaches from literature (e.g. 4,5). The semi-structured interviews will be analyzed using a qualitative content analysis (6) to extract categories or aspects from the interviews to develop a teaching strategy.

3. Teaching – Current status

Simulations have been incorporated into academic curricula at numerous universities globally, employing a variety of methodologies. A survey with teachers from Australia, India, the UK and the US demonstrated that teaching building simulation tools presents a number of challenges. (7) The skills required extend beyond merely dealing with an unfamiliar software. Rather, the difficulties lie in recognizing relevant parameters, understanding complex interrelationships and critically examining results.

A number of approaches have been formulated and introduced in an attempt to address the complexity in the subject matter: For instance, Charles and Thomas (8) developed a teaching strategy in which the students enrolled in the simulation course acted as consultants for a design course. Hopfe et al. (9) built a virtual reality escape room in order to teach “beyond building physics” with building simulation as its base. Reinhart et al. (10) introduced a course which led to a simulation game where students were challenged to design an office building with the lowest possible GHG-emissions in a timeframe.

The examples mentioned above offer interesting insights, three of which are highlighted here: Firstly, the different examples indicate that teaching building simulation is a relevant and eagerly discussed topic. Secondly, the teaching goes beyond simply teaching a software tool and lastly, pedagogical concepts such as serious games are used. Playing has been demonstrated to increase intrinsic motivation, thereby facilitating a more profound engagement with a subject, which can improve the learning outcomes. (11)

Consequently, in conjunction to the survey and expert interviews, the existing strategies for teaching building simulation at TU Braunschweig and FH Dortmund are being refined, with a

focus on adopting game-based learning techniques. Based on the proposal by Reinhart et al. (10) a simulation game was generated and tested out in different courses, depth and with both bachelor and master students. Within the game students try to find a constellation of free parameters that will lead to the lowest specific energy of an office building under the constraint of a limited financial budget for individual measures. The practical approach enhances the often theoretical teaching of the basics of building technology and physics, enabling students to better comprehend the interrelationships between different parameters.

As a result, students will have an opportunity to gain familiarity with an important tool used in the working world, while also facing common challenges in the planning practice at an early stage in their education. The objective of the proposed research is to further develop the game and implement it in a comprehensive teaching strategy which is developed concurrently.

4. Conclusion

Building simulations serve as an effective tool for the comparison and validation of design strategies. However, there is a risk that users with limited experience may not thoroughly question or interpret the results accurately, which could cause decisions that potentially lead to performance gaps. This emphasizes the necessity of integrating building simulations into the curriculum at universities. The integration will empower future talents of the design and construction process to study parameters, acquire fundamental capabilities as well as comprehend limitations of building simulations in order to work successfully towards a climate neutral building stock.

References

1. Antretter F, Pazold M, Künzel HM, Sedlbauer KP. Anwendung hygrothermischer Gebäudesimulation. In: Bauphysik Kalender 2015. John Wiley & Sons, Ltd; 2015.
2. Hiller M, Schulz M. Das dynamische Gebäude- und Anlagensimulationsprogramm TRNSYS. In: Bauphysik Kalender 2015. Berlin: Ernst & Sohn GmbH; 2015.
3. Hausladen G, de Saldanha M, Liedl P, Sager C. ClimaDesign: Lösungen für Gebäude, die mit weniger Technik mehr können. München: Callwey; 2005.
4. Döringer S. 'The problem-centred expert interview'. Combining qualitative interviewing approaches for investigating implicit expert knowledge. Int J Soc Res Methodol. 2021;
5. Przyborski A, Wohlrab-Sahr M. Qualitative Sozialforschung: Ein Arbeitsbuch. In: Qualitative Sozialforschung. 4. erw. Auflage. Oldenbourg Wissenschaftsverlag; 2013.
6. Mayring P. Qualitative Inhaltsanalyse: Grundlagen und Techniken. Weinheim Basel: Beltz; 2022.
7. Hopfe CJ, Soebarto V, Crawley D, Rawal R. Understanding the Differences of Integrating Building Performance Simulation in the Architectural Education System. In: Proceedings of BS2017: 15th Conference of IBPSA. 2017.
8. Charles PP, Thomas CR. Building performance simulation in undergraduate multidisciplinary education: Learning from an architecture and engineering collaboration. In: Proceedings of Building Simulation 2009. Glasgow; 2009.
9. Hopfe C, Gustin M, Arbesser-Rastburg G, Safikhani S, Pirker J, McLeod R. BEYOND building physics - pilot testing of a novel virtual reality-learning environment. In: Proceedings of BauSim 2024. Wien; 2024.
10. Reinhart C, Dogan T, Geisinger J, Saratsis E. Lessons Learnt from A Simulation-Based Approach to Teaching Building Science to Designers. In: Proceedings of BS2015: 14th Conference of IBPSA. 2015. p. 1126–33.
11. Kauffeld S, Othmer J, editors. Handbuch Innovative Lehre [Internet]. Wiesbaden: Springer Fachmedien Wiesbaden; 2019