# Teaching acoustics to students of architecture

**Article** *in* World Transactions on Engineering and Technology Education · February 2021



**1 author:**

Anna Sygulska
Poznan University of Technology

*World Transactions on Engineering and Technology Education*
*Vol.19, No.1, 2021* 

# Teaching acoustics to students of architecture

**Anna Sygulska**

Poznań University of Technology
Poznań, Poland

ABSTRACT: Expectations placed upon professional skills of architects are changing continuously. In Poland, following implementation of legal regulations regarding reverberation noise, requirements related to acoustic solutions in architectural design have increased. Teaching acoustics to students of architecture has become an indispensable part of the teaching process. The curriculum and methodology should be shaped in such a way that they can contribute to the students' acquisition of practical skills. It is also important to teach acoustics independently of a regular study plan. This is possible through engaging students in acoustic research and interdisciplinary activities in connection with other subjects. The author of this article discusses acoustic problems an architect may encounter in relation to design, followed by the scope of knowledge and skills of acoustic design necessary in the profession. The focus is on the methods of teaching acoustics to architecture students aimed at developing their creativity to design high quality architecture incorporating acoustic principles and regulations.

## INTRODUCTION

Educating future architects is a complex process, comprising engineering, humanities, arts and, of course, design courses. Changing expectations with regard to an architect's professional skills mean that the teaching process must be broadened to include more in-depth teaching of new topics, and acoustics is one of them.

In recent years, legal requirements for architectural design in Poland have been extended to include an acoustic function. In 2015, a new Polish standard, PN-B-02151-4 - Building Acoustics - Protection against Noise in Buildings, was implemented. [1]. In the introduction, Part 4: Requirements for Reverberation Conditions and Indoor Speech Intelligibility and Testing Guidelines, it is stated that standards compliance in regard to specific interiors aims at reducing noise level through the reduction of its component, i.e. reverberation noise, thus ensuring speech intelligibility, and enabling the use of interiors designed for verbal communication as intended [1]. However, it was not until 2018 that architects were obliged to apply the provisions in their practice. The standard concerns the so-called non-qualified acoustic interiors, where acoustics are not the leading function.

According to the standard's provisions, an architect is obliged to provide adequate reverberation conditions and speech intelligibility in rooms designed for verbal communication and adequate reverberation conditions in other rooms. Rooms where suitable speech transmission index (STI) intelligibility must be ensured are divided into two categories. The first one comprises classrooms, auditoriums, lecture halls in primary schools, high schools and universities, and other rooms of similar designation. The second group comprises court rooms, conference rooms and other rooms with a similar purpose. The group of rooms where adequate reverberation must be provided comprises, *inter alia,* gymnasiums, swimming pools, art galleries, restaurants, offices, kindergartens and schools. In conclusion, these are public utility interiors on which architects often work in their professional career.

In Poland, the acoustic aspect in public utility buildings has been left out in many cases. Acoustic issues have been taken into account in rooms, where acoustics are the leading function, such as concert halls, opera theatres, cinemas, etc. Nevertheless, serious imperfections in such facilities also occur due to the lack of clear legal regulations. Hence, expectations have recently changed for architectural design, and for the architect who should also take into account the acoustic quality of the space. There has been a move away from the assumption that only prestige structures impose acoustic requirements. The standard stipulates that acoustics should be regarded as a basic functional requirement, not as a luxury. These changes facilitate the redefinition of architectural education with emphasis on teaching acoustics to architecture students, who should definitely be knowledgeable about acoustics.

The Faculty of Architecture at Poznań University of Technology (FA-PUT) has been providing a course in acoustics since 2008. This approach has been inspired by the Faculty of Architecture, Design and Planning at the University of

Sydney, Sydney, Australia, which offers audio and acoustics units as part of their architecture curriculum. In Poland, acousticians are trained at faculties of physics, while in Australia they are trained at faculties of architecture, highlighting the strong link between these two branches of science.

## ACOUSTICAL PROBLEMS

The new standard has provided the much-needed regulation to the often-neglected acoustic function in public utility buildings. Particularly bothersome acoustical problems occur in rooms designed for teaching purposes. In a classroom lacking acoustic adaptation, a catalogue of acoustic problems may occur, such as too long reverberation time, which in turn causes bothersome reverberation noise and difficulty in comprehending verbal messages, especially in back rows. For students it is synonymous with the worst academic performance, fatigue resulting from paying constant and intense attention, tiredness resulting from noise, concentration difficulty and irritation. Likewise, for the lecturer it is synonymous with voice fatigue and, just as in the case of the students, tiredness resulting from noise and irritation. Another common problem is the lack of acoustic adaptation in sports venues. The main issues resulting from such negligence are reverberation time, incomprehensible speech and echo.

Beside the education sector, particularly problematic interiors are public utility interiors of huge internal volume, such as waiting rooms, swimming pools, atriums, art galleries, bus and train stations, restaurants, etc. In such interiors, unresolved issues in the acoustic function are often a source of numerous inconveniences. Another issue that also surfaces here is inadequate acoustic insulation between flats in multi-family buildings.

A question should be asked as to why this is the case. The main issue is the lack of expertise on the designer's part in terms of acoustic solutions. Unfortunately, designers are sometimes not even aware of their acoustic mistakes. Also, they sometimes have incorrect knowledge or are influenced by acoustic myths. Before contemporary acoustic knowledge was established, there had been many false assumptions regarding acoustics. To get a better understanding of the problem, a few examples of acoustic myths are worth mentioning, as designers still tend to believe in some.

One of those myths still persisting nowadays is that covering an interior in thin wood panelling would act similarly to a resonator of a musical instrument, which is incorrect in terms of acoustic relations. In his book *Music, Acoustics and Architecture*, Beranek points out that this could be compared to being inside a musical instrument; for example, a violin [2]. This instrument is made of thin wood to respond to the vibration of the strings, with the sound coming out of the instrument, which would not be possible if the instrument was made of thick wood. The author also states that a concert hall should contain the sound; it should not be transmitted outwards. This is why good concert halls have walls covered in thick wood panelling. Empty wine bottles bricked up in the walls of opera theatres created another myth, since certain acoustic properties began to be attributed to them. However, the bottles had been left in the walls by construction site workers who had been drinking wine secretly [2].

Today, the most common acoustic myth is the assumption made by some designers that in the case of interiors, where acoustics are essential (interiors that belong to the so-called qualified acoustics) co-operation with an acoustician should commence only at the stage of selecting finishing materials. The above-mentioned problems illustrate the necessity of educating architects in the field of acoustics.

## KNOWLEDGE ARCHITECTS NEED TO POSSESS

One should ask a question, what acoustic expertise architects need in their professional career. Three main areas of acoustics can be distinguished in relation to architectural design:

- architectural acoustics - interior design;
- building acoustics - issues relating to building insulation;
- urban acoustics - spatial planning.

All the three areas are components of the curriculum for future architects. Currently, architectural acoustics is the most important area that future architects should study. It is also the most neglected area of acoustics in architecture. New structures with acoustically impaired interiors are still being built with the defects so serious that the interiors cannot be used as intended. The new standard obliges architects to provide adequate acoustic conditions in rooms with the so-called non-qualified acoustics [1]. Acoustic requirements in such rooms can be reduced to avoiding acoustic defects, and to ensuring adequate comfort of use. The learning outcome should be the architect's ability to design acoustics in such interiors single-handedly.

Second-degree students continue with the course in acoustics, learning about issues connected with the so-called qualified acoustics, where acoustics serve the primary function in an interior. Preventing acoustic defects is only one of the components of acoustic design. Advanced acoustic design is necessary as early as in the concept stage [3]. When the acoustic function plays the main role in interiors, negligence in this respect often results in their dysfunctionality. Structures that fall within the scope of qualified acoustics are concert halls, opera houses, multi-purpose halls, churches, etc. While working on such structures, the architect and the acoustician should share the same idea and have a common goal. The architect should also know when their co-operation should commence, and what to expect from the acoustician.

Acoustic insulation is also taught to students through the presentation of the basic notions of protecting rooms against noise. Primarily, the curriculum covers issues related to ceiling and wall insulation, as well as issues related to airborne and material-borne sound transmission. Confusing the notion of acoustic absorption with the notion of acoustic insulation is still common in popular science literature, and therefore, it is important to separate these notions.

The issue of urban acoustics is particularly important due to constantly increasing noise levels. This area of acoustics is specifically addressed in the Spatial Planning postgraduate course at the FA-PUT. The main components of the curriculum include the subject of acoustic ecology [4]. It is vital to raise students' awareness that, contrary to the popular belief, this issue does not only concern protection against noise but also purposeful soundscaping [5]. Examples of incorrect solutions and the most common mistakes are also useful in acoustics education.

## METHODOLOGY

The basis of reliable teaching of acoustics is proper scientific and laboratory knowledge. The FA-PUT has an acoustic laboratory equipped with measuring instruments, which enable measurement of interior acoustics. In addition, acoustic modelling of buildings, those already existing or in the design stage, is software-based. Such research background renders it possible to conduct scientific research in architectural acoustics. The curriculum assumes imparting theoretical knowledge, as well as teaching practical design skills.

In teaching theory and design, it is important to combine acoustics with architectural design. However, acoustic solutions are often applied without relation to the holistic architectural design. There is no firm connection with the general design concept. Acoustic design, detached from the form, style or colour in mind, promotes so-called add-ons. Therefore, integrating acoustic design with architectural design in the teaching process is vital. In addition, students become aware that their architectural design decisions influence the quality of acoustics. It is also important to teach students that design cannot be detached from reality and does not take place in a vacuum. Students are taught that apart from a broad network of participants that are involved in the design process, the clients and users must also be taken into consideration [6]. The aim of such an assumption is to make design solutions cost-effective.

The basic form of imparting knowledge is a lecture, and the way in which acoustic issues are presented to students is the most important factor. Introducing acoustics with too much emphasis on theory will not be useful in an architect's professional career and will definitely discourage students. Theory should be limited to making students familiar with basic acoustic concepts, with practical aims in mind. Students' comprehension of the subject is better facilitated if the lecture features animations and sonic examples. Frequently, students are able to understand the gravity of a problem only after it is presented along with a recording of acoustic defects, particularly regarding speech. At that time, they begin to take more interest in acoustics and expect that the course will provide practical guidelines which can be later incorporated into their own architectural designs. This is why the lectures at a later stage focus on practical issues.

A good example of Polish-language literature that sheds light on the subject and helps students become familiar with acoustic issues is Kulowski's *Akustyka Sal, Zalecenia Projektowe dla Architektów* (Acoustics of Halls. Design Recommendations for Architects) [3]. The first edition of the book was released in 2007, and a new, expended edition in 2011. The publication addresses essential issues regarding architectural and building acoustics and is a response to the current needs of architectural education. It includes practical design issues and is lavishly illustrated.

A very good example of English-language literature, combining architectural and acoustics issues, is Egan's *Architectural Acoustics* [7], while interesting animations and sonic examples are included in *Architectural Acoustics Illustrated* by Ermann [8].

Seminars are held within the subject of acoustic design. Once students complete the course, they possess the skills necessary to design acoustics compliant with the accepted standard single-handedly [1]. However, a holistic approach to educating students is important, as it is not limited to employing acoustic solutions, but promotes complex thinking with regard to architectural design. Students are taught to make calculations unaided, prior to being taught how to design with the aid of a computer program. This helps understand the relation between architecture and acoustics.

Formulas for reverberation time help students fix flawed acoustics of an interior. The draft correction made using the formulas is a rough estimate. A more advanced design of acoustic corrections is possible with the aid of computer programs. To teach acoustic design, CATT-Acoustic is used [9]. This program is based on the ray method. Computer simulations of interiors done with the ray method are deployed for cognitive purposes, but also for designing new structures or implementing acoustic corrections in existing structures. Students design selected interiors within the scope of non-qualified acoustics. They have a chance to find out how their decisions affect respective acoustic parameters. Hands-on experience gained in class is very important. Apart from learning to use professional software, the students also become familiar with acoustic materials. They learn how to read the data in manufacturers' catalogues. Moreover, they are presented with material samples - they examine them closely and can touch them.

Education is not limited to lectures and seminars dedicated to acoustics; beside regular classes scheduled in the timetable resulting from the curriculum, students are also engaged in extracurricular activities within the scope of acoustics. Students' participation in scientific research at the FA-PUT is a good example. One research activity addressed the issue of classroom acoustics, with the main focus on reverberation time. The works involved carrying out acoustic tests of a classroom interior [10]. The selected classroom was problematic due to its too long reverberation time. The tests were carried out both when the classroom was empty and with students in it. For the students, it was a chance to take an active part in acoustic tests (Figure 1).

a) b)

Figure 1: Classroom examination: a) acoustic tests carried out with students in the classroom; and b) empty classroom during acoustic tests (Photographs by the author).

The FA-PUT has also launched interdisciplinary collaboration on acoustics, a good example of which is the students' activity in the field of bionics. A prototype of a sound absorbing panel designed by a student was tested with measuring instruments available at the acoustic laboratory of the FA-PUT.

Talented students who take particular interest in architectural acoustics get formally involved in scientific research [11]. The author carried out acoustic research in a modern Catholic church with acoustic problems, such as excessive reverberation noise. The Church of the Visitation of Blessed Saint Mary is currently the biggest church in Poznań. A computer model of the church was made based on acoustic research of the interior. Next, a series of simulations was conducted in order to design proper treatment, so that satisfactory acoustic conditions could be obtained.

The main assumption was to deploy a solution that would not spoil the modernist architecture of the church. Hence, studies and simulations were carried out in order to obtain the best effect possible without affecting the modernist interior. Students participated in the creation of the interior's computer model and in conducting simulations in the ODEON program [12]. Figure 2 shows a screenshot of ODEON acoustic simulation inside the church.

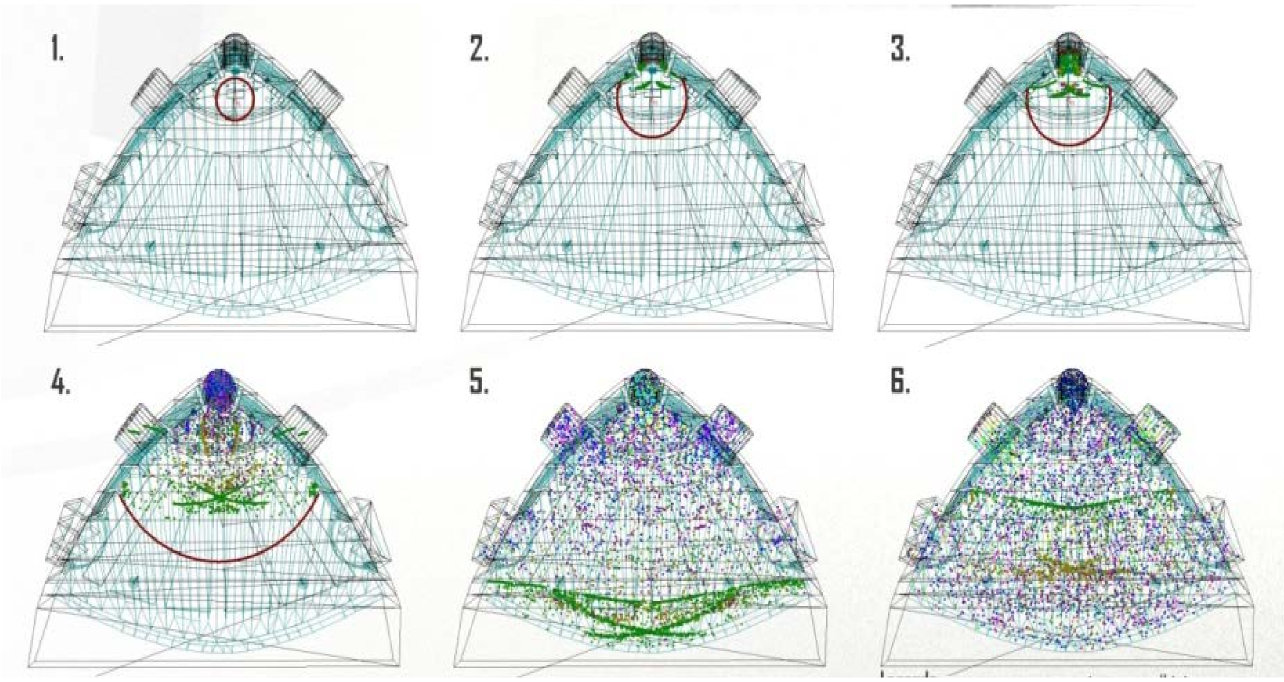


Figure 2: Computer simulation of the Church of the Visitation of Blessed Saint Mary in Poznań developed under the supervision of A. Sygulska, with students: T. Czerniak and A. Czarny-Kropiwnicki.

Imparted knowledge and design skills should be accompanied by an opportunity to get familiar with the field of architectural acoustics. In lectures, students are presented with acoustic equipment of the Faculty laboratory. Moreover, measurements of reverberation time are carried out with the students' active participation. Another teaching component features the opportunity to become familiar with the laboratory background and other scientific units that conduct research within the field of broadly understood acoustics. Visits are organised to the anechoic chamber at the Faculty of Physics of Adam Mickiewicz University (UAM), Poznań (Figure 3a). Those visits feature acoustic equipment displays for students, who can also take part in acoustic experiments carried out in the anechoic chamber.

Launching exhibitions helps to promote architectural acoustics and works by the best students. Students' creativity is additionally boosted by a competitive element [13][14]. Figure 3b shows an exhibition organised at a community centre in Blizanów, Poland, a small town located near Kalisz. The exhibition was carried out within the framework of the Acoustic Design course for first-term MSc students, and it featured their works on the chosen subject, i.e. acoustic design.

a)

b)

Figure 3: a) students of the FA-PUT visit the anechoic chamber at the UAM Faculty of Physics, Poznań; and b) exhibition of students' works from the FA-PUT at the Blizanów Cultural Centre (Photographs by the author).

The whole teaching process aims at educating architects, so that they have basic skills in the field of architectural acoustics and are conversant with it. It is worth quoting from Darbellay et al, where they state that *The process of dialogue between disciplines requires that each researcher deploys the analytical skills and tools of one's own discipline while opening one's mind to the methods of other disciplines* [15]. Engaging in a dialogue that deals with teaching acoustics will result in students' awareness that the ultimate success of a designed building also relies on high quality solutions in architecture-related scientific fields.

## CONCLUSIONS

The discussed issues are crucial to the process of educating future architects due to the market's expectations soaring high with regard to acoustics, as well new legal regulations in Poland. An architect in the making must be aware that acoustics depend on the adopted architectural solutions. It is also important to identify the most common acoustic problems in architectural design.

Another step is to determine to what extent, and for what functions, it is possible to prepare students for unaided individual design activities that involve acoustics. On the other hand, for advanced acoustic functions, the learning outcome should be understanding the role of acoustics and knowledge of how to co-operate with an acoustician. The way acoustics is taught should strictly concern practical design issues and should be varied in form to aid the development of students' creativity in this respect. The ultimate goal is to improve acoustic quality of the designed architecture.

REFERENCES


1. PN-B-02151-4:2015. Akustyka Budowlana. Ochrona przed Hałasem w Budynkach. Część 4: Wymagania Dotyczące Warunków Pogłosowych i Zrozumiałości Mowy w Pomieszczeniach oraz Wytyczne Prowadzenia Badań. Polski Komitet Normalizacyjny, Warszawa (2015) (in Polish).
2. Beranek, L.L., *Music, Acoustics and Architecture*. John Wiley and Sons (1962).
3. Kulowski, A., *Akustyka Sal, Zalecenia Projektowe dla Architektów*. Gdańsk: Wydawnictwo Politechniki Gdańskiej (2011) (in Polish).
4. Sygulska, A., *Akustyka w Mieście*. In: Barek, R. and Ast, R., Studia Planowania Przestrzennego: Monografia Wykładów Podyplomowych Studiów Planowania Przestrzennego SP-19 przy Wydziale Architektury Politechniki Poznańskiej. Wydawnictwo Stowarzyszenie Psychologia i Architektura, 313-322 (2019) (in Polish).
5. Tsuchida, Y., *Sound education* in Japan. *Proc. Forum Acusticum*. Kraków, Poland, 1-4 (2014).
6. Olszewski, A. and Pudlowski, Z.J, the outcomes and achievements of the urban design and education programme. *Global J. of Engng. Educ.*, 6, **1**, 7-16 (2002).
7. Egan, D., *Architectural Acoustics*. J. Ross Publishing (2007).
8. Ermann, M., *Architectural Acoustics Illustrated*. Wiley (2015).
9. Dalenbäck, B-I.L., CATT-Acoustic v9.1, User's Manual, CATT, Gothenburg, Sweden (2016).
10. Sygulska, A. and Suchanek, J., *Problematyka Pogłosowości w Sali Dydaktycznej*. In: Integracja Sztuki i Techniki w Architekturze i Urbanistyce. Wydawnictwa Uczelniane Uniwersytetu Technologiczno-Przyrodniczego w Bydgoszczy, 103-110 (2016) (in Polish).
11. Sygulska, A., Czerniak, T. and Czarny-Kropiwnicki, A., Experimental investigations and computer simulations to solve acoustic problems in the modern church. *Engng. Structures and Technologies*, 10, **1**, 34-45 (2018).
12. Odeon, Room Acoustics Software. v.11, Combined Edition by Christensen C.L., Odeon A/S, Scion DTU, Lyngby, Denmark (2011).
13. Haupt, P., Wijas, M., Mochacka, S. and Chyb, A., Teaching architectural design through competition, motivation and challenge. *World Trans. on Engng. and Technol. Educ*., 17, **3**, 338-342 (2019).
14. Białkiewicz, A., Architectural competitions support student creativity. *World Trans. on Engng. and Technol. Educ*., 18, **2**, 157-162 (2020).
15. Darbellay, F., Moody, Z. and Lubart, T. (Eds), Creativity, Design Thinking and Interdisciplinarity. Singapore: Springer Nature (2017), 23 October 2020, https://www.researchgate.net/publication/322202870_Creativity_Design_Thinking_and_Interdisciplinarity