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ACOUSTICS KNOWLEDGE ALLIANCE (ASKNOW) PROJECT AS THE LATEST ADDITION TO THE ACOUSTIC COURSEWARE (ACOUCOU) LEARNING PLATFORM

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Abstract: Acoustics is an extensive and diverse field that impacts and improves the overall quality of life of the general public. Despite that fact, the benefits of acoustic research and teaching and the knowledge gained from it are not advertised and conveyed as strongly as they should be. Overall, there is a lack of highly qualified specialists trained to deal with problems in this field, particularly when it comes to providing acoustic comfort as a prerequisite for high quality of living in general. To contribute to solving this issue by developing and disseminating a new kind of attractive teaching materials designed for effective and interactive knowledge transfer, the Acoustic Courseware (ACOUCOU) platform has been established by a group of academic and business institutions. This freely accessible platform already offers different courseware on acoustics that has been developed for specific target groups of users within the scope of already finished projects. The latest addition to the platform will be the teaching materials developed within the scope of the ongoing Acoustics Knowledge Alliance (ASKNOW) project, covering five different topics in as many courses: Acoustic fundamentals, Psychoacoustics, Acoustic simulations and auralisation, Electroacoustics, and Room and building acoustics. This paper presents the structure of this project and its objectives. The approach and the work strategy adopted for achieving the goals of the project are discussed, as well as the difficulties and challenges encountered along the way. Samples of the results obtained halfway through the project are presented in the form of developed materials.

Keywords: acoustics, online learning platform, innovative and interactive teaching materials

1. INTRODUCTION

The overall development of technology is faster now than it has even been in human history. These changes are followed by the changes in demands put on professionals and specialists by prospective employers. Traditional skills based on technology-specific knowledge are still in demand, but the skill that is particularly valuable relies on the ability to master new knowledge in a fast and efficient manner.

The task of the education institutions is to respond to this demand by training the students not only to memorize facts, but also to build a way of thinking that will help them solve specific problems, adopt new skills, do research, and successfully master new technologies.

At present, there is no way to tell where these swift changes will lead to in the future, in terms of technology development and the consequential emergence and/or disappearance of certain areas of expertise and corresponding professions. What can be noticed is the fact that the educational system often cannot respond to these changes fast enough, mostly due to its own inertia and the inherent unwillingness to promptly respond to the current demands of the market, when it comes to introducing new or updating current study programs and/or teaching methods. In that light, companies and organizations that gather professionals in given fields are becoming important contributors to the learning process, especially in the field of engineering, being the principal motivators of life-long learning as the natural extension of formal education.

In general, the ways and methods of knowledge transfer need to undergo modernization. The current situation with the COVID-19 pandemic has sped up this process by forcing the educators to resort to various forms of distance learning, in contrast with the conventional teaching methods they usually employ. The use of open courseware platforms has greatly increased for the same reason. However, specialized courses designed for specific target groups such as engineers or architects still rely on knowledge transfer based on vocational education and training.

In recent years, the entire branch of activity that rests on science, technology, engineering and mathematics (STEM) has suffered a significant lack of interest displayed by young people who reach a milestone in their lives, i.e., when they find themselves in a position to choose their future career path by choosing the direction of their studies and overall development. As a part of this branch of human activity, acoustics is no different.

For all the reasons described above and with the intent of addressing these issues in the field of acoustics, the authors, their colleagues and their respective institutions, along with other partners, have accepted the challenge of creating a niche that would facilitate a novel, innovative and multidisciplinary approach to teaching and e-learning in acoustics. The result of these efforts is the Acoustic Courseware (ACOUCOU) platform [1].

The latest addition to these endeavours is the Acoustics Knowledge Alliance (ASKNOW) project funded by the EU, aimed to covering five topics in the field of acoustics. The goal is to create and develop teaching materials with a structure and quality in line with the already created content in other areas of expertise. The aim of this paper is to present the objectives of this project and the way the project was structured in order to achieve its objectives. The content of the five modules will be briefly described as well. Different approaches to creating teaching materials and the corresponding work strategies exhibited by different partners and working groups will be discussed, and the difficulties and challenges that needed to be overcome along the way will be addressed. The structure of the modules and their building blocks will be explained. As the project has now reached the point where all the teaching materials have been developed and are ready for implementation and testing phase, selected samples of these materials will be shown.

2. THE ACOUSTIC COURSEWARE (ACOUCOU) PLATFORM

The ACOUCOU Platform is first and foremost a tool that is to be used for transferring the knowledge in acoustics to any user who is interested in learning about this interesting field. The principal task and goal of the participating institutions is to develop new teaching methodologies and attractive content that will evoke the curiosity of the end users and allow the knowledge to be efficiently transferred to them. Although the platform is the fruit of international collaboration, the knowledge can also be transferred at a national level by translating and adapting the teaching materials to any language. The aim of the platform is to facilitate any type of learning, from self-learning to blended learning.

So far, the creators of the ACOUCOU platform have successfully finished several joint ventures aimed at the development of teaching materials for specialized target groups that would help transfer the knowledge to the end users in an innovative, attractive, motivating and effective way. Specifically, the existing materials within this platform include the Architectural Acoustics Multibook (ArAc Multibook), the Acoustic Course for Engineers (ACE) and the Acoustic Course for Industry (ACI).

More information on the ACOUCOU platform and on the already existing materials can be found in [1] and [2].

3. THE ACOUSTICS KNOWLEDGE ALLIANCE (ASKNOW) PROJECT

The ASKNOW project [3] has been devised and executed by the consortium made up of eight partner institutions listed on the title page, from both the academic and the business realm, thus involving the best of both worlds. Its principal objective is to develop a new kind of teaching materials that step away from the usual textbook-type approach, and to present these materials in an attractive way in form of animations, videos, images, sound samples, interactive calculations, etc.

The duration of the project has been set to three years, from January 2020 to December 2022.

The planned result of the project is to cover five common topics in acoustics in as many courses, namely Acoustic fundamentals, Psychoacoustics, Acoustic simulations and auralisation, Electroacoustics, and Room and building acoustics.

3.1. The structure of the project

To ensure the highest possible quality of the developed teaching materials, the work within the project has been distributed between thirteen work packages with the emphasis on the development of teaching materials, their implementation into the final online form, and several stages of quality control. The work packages defined in the project are shown in Table 1.

WP	Name	Type
1	Development of Guidelines	Preparation
2	Project Management	Management
3	Development of Education Materials into "PHYSICAL ACOUSTICS COURSE"	Implementation
4	Development of Education Materials into "PSYCHOACOUSTICS COURSE"	Implementation
5	Development of Education Materials into "ACOUSTICAL SIMULATION AND AURALIZATION COURSE"	Implementation
6	Development of Education Materials into "ELECTROACOUSTICS COURSE"	Implementation
7	Development of Education Materials into "ROOM AND BUILDING ACOUSTICS COURSE"	Implementation
8	Compiling and Adapting Knowledge	Implementation
9	Development of Courseware	Implementation
10	Testing and Adjustments	Implementation
11	Quality Assurance	Quality Assurance
12	Evaluation	Evaluation
13	Dissemination and Exploitation	Dissemination and Exploitation

Table 1. *The structure of the ASKNOW project defined through its work packages*

3.2. The structure of the teaching materials

The basic structure of the teaching materials relies on lessons as elementary particles that cover a specific topic within a course. Each course has 30 lessons. Besides these lessons, two cases are developed for each course with the goal of showing specific hands-on problems and possible solutions that utilize the knowledge gained throughout the duration of the course.

The structure of each lesson consists of three parts: the theory part (part A), the principle part (part B), and the task part (part C). The theory part contains the text required for understanding the phenomenon covered in a particular lesson. The text is equipped with the necessary equations, figures and tables. The principle part makes use of audio-visual learning content such as charts, animations, interactive calculations, videos, sound samples one can listen to, etc. The aim is to illustrate the underlying principle of the phenomenon being described in an intuitive and easily understandable way. The task part contains a short task the users will have to complete at the end of each lesson, so that their knowledge and understanding of a particular topic can be tested. The task can be implemented in many different ways, e.g. questions with multiple choice answers, calculation tasks, grouping of images or other objects into appropriate categories, etc. The indication of correct answer(s) is given, and hints that lead to the correct answer(s) are also given if the user initially provides an incorrect solution.

The devised general layout of the online materials implemented in every lesson is shown in Figure 1.

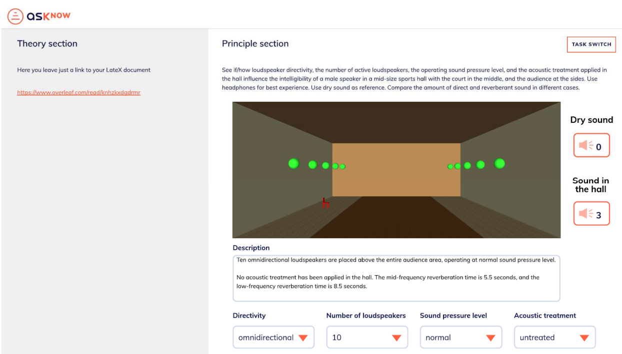

Fig.1. *The devised general layout of a lesson – an example*

The layout is envisioned as a split screen divided into two parts. The left part of the screen (grey) contains the text of the theory part (part A). The right part of the screen contains the principle part (part B) of the lesson, and a switch enables the user to interchange this content with the content of the task part (part C). The idea behind this layout is to always have the theory part at the disposal of the users, so that they can consult it whenever required, whether they are trying to understand the principle or to solve the task at the end of the lesson (small quiz).

3.3. The courses under development within the scope of the project

Acoustics fundamentals - As expressed in the name of the course, its goal is to introduce fundamental concepts and to model acoustic phenomena for the purpose of solving a wide range of acoustical problems. The fundamental knowledge presented here serves as a basis for other fields of acoustics. First of all, main concepts and the appropriate parameters that describe acoustic waves are defined. The ranges of values typically found for these parameters are given as well. The course continues by presenting the development of one-dimensional fundamental equations in acoustics and their respective solutions. The concepts such as reflection, transmission, impedance, eigenmodes, and many others are illustrated using interactive applets that allow the values of different parameters be varied, and the results of these changes can be seen immediately. The fundamental concepts are explained both in time domain and frequency domain. The course evolves by introducing sound intensity, as well as by explaining the ways of modelling the losses in an acoustic system. The fundamental equations are expanded to three dimensions, and their solutions are presented in cartesian, cylindrical and spherical coordinate systems. To introduce the most important types of sound waves, the course materials present the properties of plane waves, cylindrical waves and spherical waves. Monopole, dipole and quadrupole sources are explained as the basic types of sound sources. The development and representation of arbitrary sources based on spherical harmonics is shown as well. After that, the material introduces the directivity of a source, and diffraction as a way of obtaining secondary sound sources. The last part of the course explains the behaviour of sound in finite-size spaces such as cavities and waveguides. Modes that form in both types of structures are explained, and the differences between them are discussed. The concepts characteristic for waveguides are presented, namely, the cut-off frequency and the forming of evanescent waves. After that, the theory of propagation of sound in horn-shaped structures is developed. Cavity modes and resonances are presented with and without the influence of losses.

Psychoacoustics - This course deals with human perception of sound. It begins by explaining the anatomy of the human hearing system, followed by the presentation of the signal processing that emulates the processing of sound into electrical excitation for the brain in the manner performed by the human hearing system. Well-known and widely used psychoacoustic parameters such as loudness, sharpness, roughness, tonality and fluctuation strength are described as a foundation for more complex perceptual dimensions, e.g. annoyance. The concept of binaural hearing is explained both theoretically and through practical applications, most especially binaural recordings using dummy heads and the correct procedure for binaural playback. The course then advances to speech intelligibility and speech production. Finally, the listening tests are explained as the principal tool in every psychoacoustic research. Regarding this topic, guidelines are given on how to perform listening tests. The well-established, common test procedures and appropriate methods of statistical analysis are described. The course culminates with two practical cases as examples of the use of adopted concepts in real-life applications. The first case focuses on the production of aurally correct recordings, so that they can be used in a listening test designed to yield a sound quality metric based on the established psychoacoustic parameters. The second one gives an example of a listening experiment focused on human ability to correctly localize sound sources.

Acoustic simulations and auralisation - This course deals with the topic of acoustical simulations and the resulting auralisation as a type of signal processing that enables us to understand and perceive the meaning of measured or simulated data by listening to sound samples that stem from that data. To start with this topic, selected chapters of signal processing need to be covered first, as well as the fundamental phenomena of sound propagation. A field that benefits from the use of acoustical simulations and auralisation is room acoustics. To explain and simulate room acoustical phenomena, the simplified concept of sound propagation based on sound rays is often used. Various approaches to predicting the sound field in rooms are explained, including the wave-based models. The course goes beyond room acoustics simulations by explaining concepts such as sound transmission between rooms in buildings or in urban outdoor environments. The progression of the course leads to the simulation of ear-canal-related signals based on binaural synthesis, which is the basis for creating auralisations of virtual rooms. The synthesis of the binaural transfer paths is explained as well, as it is widely used in the automotive industry. At the other end of the signal processing chain, different concepts of spatial audio reproduction are explained, based both on loudspeakers and headphones. The course is finalized with examples of application of this knowledge. The answer to the problem of assessing the validity of an acoustical simulation is offered as well.

Electroacoustics - As indicated by its very name, electroacoustics is a symbiosis of electrical engineering and acoustics, and it connects the electrical, mechanical and acoustical domain. Being so, the course starts with a short training on the basics of electricity, mechanics and acoustics, thus providing the required background for the rest of the course. The lessons that follow allow the end-users to be acquainted with different concepts used in electroacoustics. First, the analogies and relationships between the electrical, mechanical and acoustical domain are discussed as the basis for understanding the operating principles of the commonly used transducers and their interaction with the environment. The course then continues with the characterization of audio systems through both linear and nonlinear parameters. The fundamental principles of transduction, such as electrodynamical and electrostatic transduction are explained. Modelling of common types of transducers such as shakers, geophones, microphones and loudspeakers is presented. A chapter is dedicated to different types of loudspeaker enclosures such as closed-box and vented-box systems, but also other types of enclosures. The chapter on advanced modelling deals with the limits of conventional models of the electrodynamic loudspeaker and presents the influence of nonlinearities on its overall behaviour. The final chapter describes the operating principles of multiple-transducer configurations such as microphone and loudspeaker arrays, as well as playback systems starting from pure mono reproduction to 5.1, 7.1 systems and beyond. Two practical cases use both simulations and measurements to illustrate the effects of different physical parameters on the final response of the system. Moreover, the validity of assumptions made during modelling can be assessed with measurements performed in similar conditions. The ultimate goal is to provide the knowledge to the users that will allow them to comprehend the issues that arise in the design process of electroacoustic sensors and sources. No less important is the understanding of the fine points of integrating these elements into complex audio systems and mastering the ways of optimizing their performance.

Room and building acoustics - This course strives to cover all three main components of the overall acoustic comfort assigned to rooms and/or buildings, i.e. the room acoustics, which tries to achieve appropriate acoustic conditions within a room, building acoustics, which deals with the protection of the room from sound coming from adjacent spaces and/or vice versa, and internal noise generated by noise sources in the room. As many people often struggle to understand the difference between room acoustics and building acoustics, the introductory part of the course explains it briefly. The room acoustics part of the course explains the phenomena that determine the behaviour of sound in closed spaces. The influence of shape, size, and acoustic treatment in a room on its acoustic response is discussed. The interaction between sound sources, including loudspeakers, and rooms is described in detail. The specifics of acoustic elements, namely absorbers and diffusers, are presented. General guidelines for good acoustics are given, as well as room and building acoustics design criteria. Objective and subjective parameters used in evaluation of room acoustics are described. The demands on spaces for speech-based and music-based events are given. Finally, the connection of room acoustics and architectural design is addressed. This part of the course strives to provide understanding of the basic principles of room acoustics analysis, design and evaluation. The building acoustics part begins by describing the concepts of airborne and impact (structure-borne) sound in a building, and it explains direct and flanking transmission paths of sound through building structures. The transmission coefficient and the sound reduction index are introduced as quantitative measures of sound insulation quality. The specifics of different building elements are given regarding their construction and the resulting sound insulation properties, such as single-leaf and double-leaf walls, floors/ceilings, doors/windows, and facades. Measurement and evaluation procedures for both airborne and impact sound insulation is described in detail. A possible harmonized classification scheme for sound insulation quality is presented. Typical materials and special constructions are displayed and explained. The ever-growing influence of the ecological aspect is discussed. The issue of internal background noise is addressed. The connection between room and building acoustics is established. The two practical cases illustrate the implementation of the principles of room and building acoustics to real-life building designs.

3.4. Examples of developed materials

In this section we show some examples of the developed teaching materials extracted from individual lessons, in order to present the diversity of different approaches to designing them. As the theory parts of all the lessons are basically the same in nature, consisting of text complemented with figures, tables and equations, the diversity of developed materials is reflected in parts B (principle parts) and C (task parts) of the lessons. Therefore, the examples shown below have been chosen from these parts of the lessons.

Figures 2 to 9 show different method utilized for explaining the underlying principle of an acoustic phenomenon in the process of developing the teaching materials.

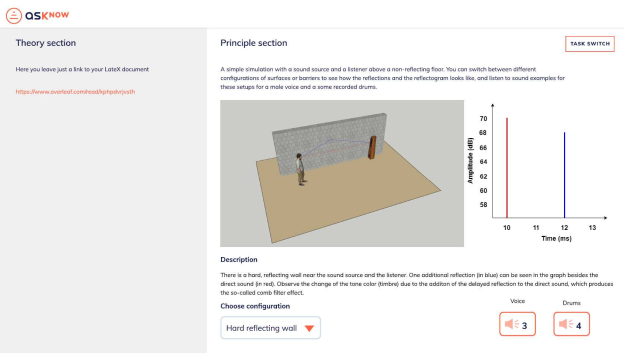

__Fig.2.__ The principle part of the lesson on general acoustics phenomena (absorption, reflection, diffusion, diffraction)

Figure 2 displays the principle part of the lesson on general acoustics phenomena (absorption, reflection, diffusion, diffraction) in which the user can choose between different simple setups (no wall, reflective wall, diffusive wall, absorptive wall, etc.), see how it affects the early part of the impulse response (direct sound and other components) and hear how the sound changes due to the presence of the wall.

Figure 3 shows the principle part of the lesson on the interaction of loudspeakers and rooms. The user can set two different options for directivity (omnidirectional vs. directional, downward-facing loudspeakers), the number of loudspeakers (one or ten), the sound pressure level (normal or high), and acoustic treatment of the room (untreated or treated), thus getting 16 different states. By listening to the sample of speech, the user can get a feeling on how each of these parameters affects the acoustical situation in the room and, consequently, the intelligibility of speech.

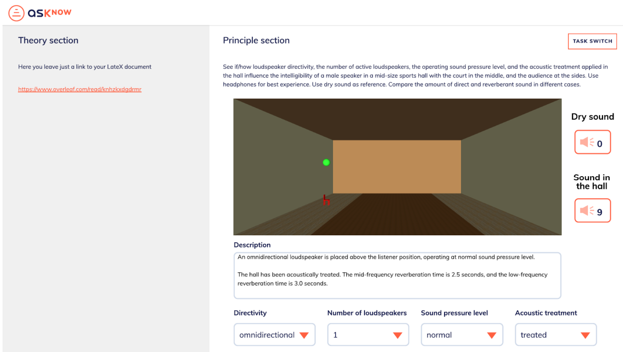

__Fig.3.__ The principle part of the lesson on the interaction of loudspeakers and rooms

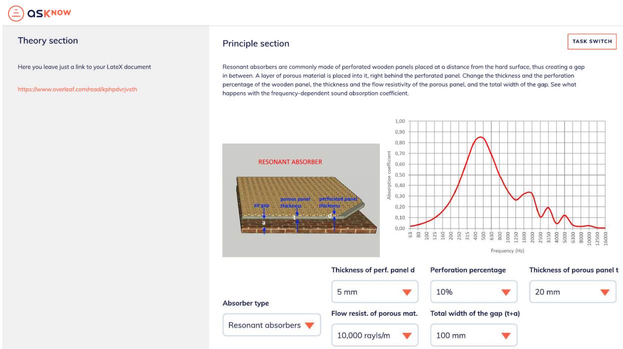

__Fig.4.__ The principle part of the lesson on absorbers

Figure 4 shows the principle part of the lesson on absorbers, specifically, the section on resonant absorbers. Two different values can be assigned to each of the five parameters, resulting in 32 different states that show how the changes of these parameters affect the frequency-dependent sound absorption coefficient of such an absorber, as illustrated with the appropriate chart.

Figure 5 shows the principle part of the lesson on diffusers. The user can change the geometry of the diffuser and the frequency of sound. The chart shows how the selected diffuser configuration scatters the incident sound coming from the sound source located at the lower left corner of the image.

Figure 6 shows the principle part of the lesson on the acoustics of spaces for music. For this purpose, the user advances through different states that show how the geometry of a concert hall and its acoustic treatment can be optimized step by step. Two sound samples, one containing classical unamplified music and the other containing amplified rock music, can be listened to in order to spot the differences in sound brought by each step of the optimization process.

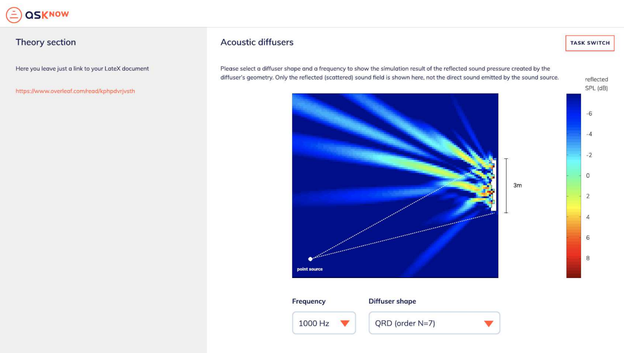

Fig.5 *The principle part of the lesson on diffusers*

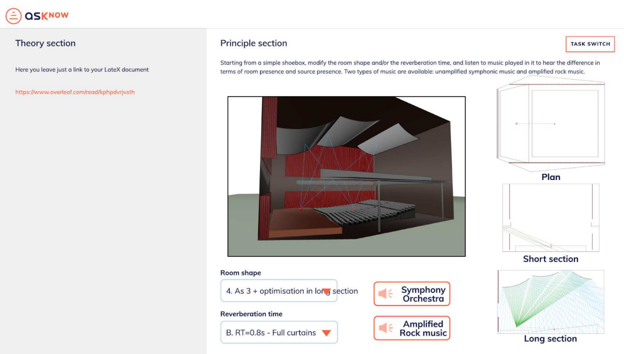

Fig.6. *The principle part of the lesson on the acoustics of spaces for music*

Fig.7. *The principle part of the lesson on room acoustic design elements at the disposal of architectural design*

Figure 7 shows the principle part of the lesson on the inseparable link between acoustics and architecture. The example shown here allows the user to change the curvature of the ceiling from a concave surface through flat ceiling to a convex surface. The effect of this change on loudness, i.e the sound pressure level of sound at the receiving point is then observed, and it depends on the density and the distribution of reflections arriving from the ceiling surface.

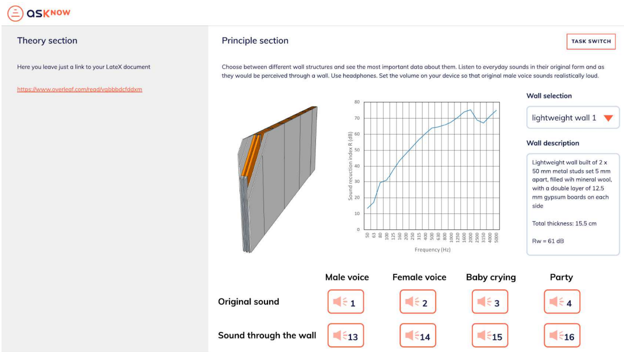

Fig.8. *The principle part of the lesson on single-leaf and double-leaf walls and constructions*

Figure 8 shows the principle part of the lesson on single-leaf and double-leaf walls and constructions. The user can choose between different wall configurations, both massive and lightweight, and a sketch and a short description of such a configuration is then shown, as well as its sound reduction index with the appropriate single-number value. Four different sound samples can be listened to in their original form and level, and in filtered form that simulates the propagation of these sounds through such a wall.

Fig.9. *The principle part of the lesson on background noise in rooms and the sources that contribute to it*

Figure 9 shows the principle part of the lesson on background noise in rooms and the contributing sound sources. The user is able to change the parameters of an air duct by changing the air speed and by adding different silencers. These changes reflect in the octave spectrum of the generated noise and in the overall NR value that stems from it.

The following Figures 10 to 14 show the examples of different types of tasks that were developed and utilized as a mean of testing the knowledge gained by the user. The tasks are envisioned as very short tests at the end of each lesson. To test the knowledge gained over the entire course, a quiz/exam shall be developed for each course.

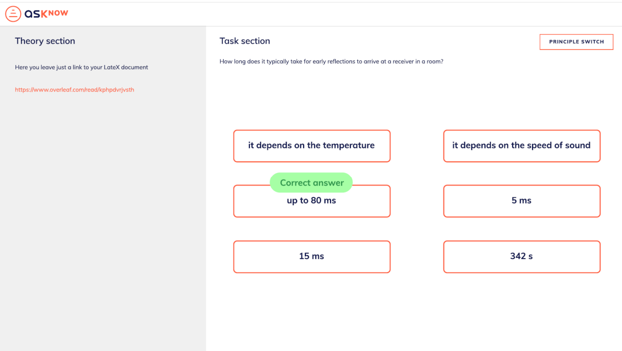

Fig.10. *The task part of the lesson on the general response of a room to sound*

Figure 10 shows the task part of the lesson on the general response of a room to sound. The user is asked to respond to a question by choosing the correct answer. In many cases, this type of task was designed to have more than one correct answer.

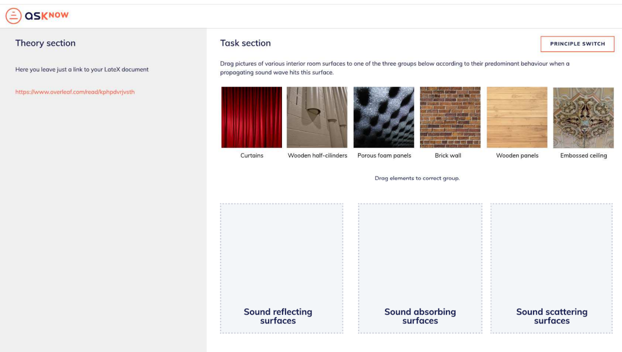

Fig.11. *The task part of the lesson on general room acoustics phenomena (absorption, reflection, diffusion, diffraction)*

Figure 11 shows the task part in which the user is asked to group the items, in this case images, into appropriate categories. This particular task demands that the user recognizes different kinds of materials and groups them according to their dominant behaviour as reflectors, absorbers or diffusers.

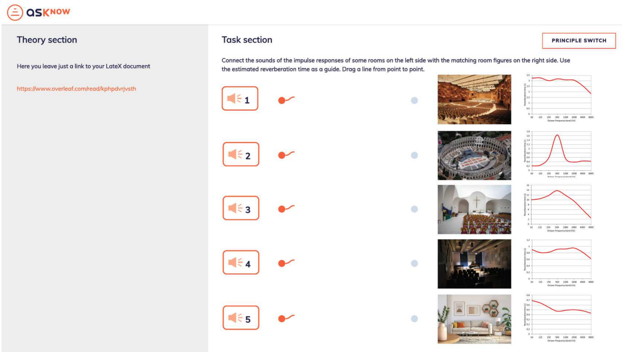

Fig.12. *The task part of the lesson on reverberation time*

Figure 12 shows a task in which the user is asked to listen to sound samples and try to match them with spaces with different reverberation time, depicted with photos and reverberation time charts.

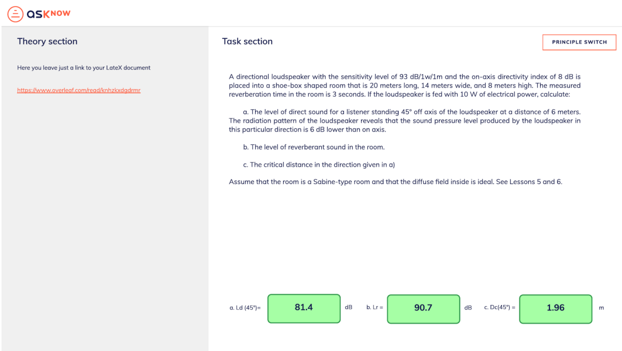

Fig.13. *The task part of the lesson on the interaction of loudspeakers and rooms*

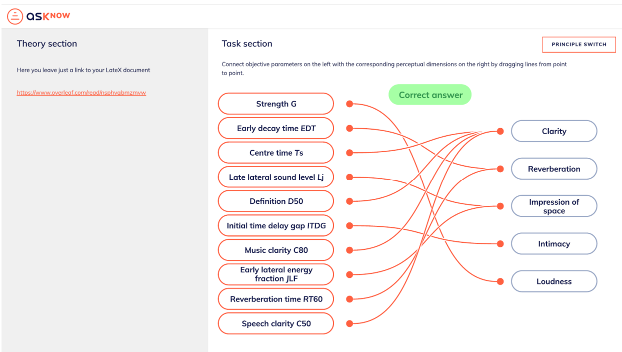

Fig.14. *The task part of the lesson on the objective and subjective parameters in room acoustics*

Figure 13 shows a task in which the user is required to make certain calculations and provide answers in numerical form.

Figure 14 shows a task that challenges the user to group common objective parameters in room acoustics listed on the left by connecting them with the corresponding perceptual dimensions listed on the right.

3.5. Work strategy and challenges

The work strategy enforced during the development of the teaching materials was by no means unique and identical for all work packages dedicated directly to the development of the teaching materials. The choice of the work strategy depended mostly on the existing knowledge possessed by each partner involved in a certain work package. The involvement of each partner in a certain work package was determined in the planning stage, mostly by personal preference and the area of expertise of individual staff members.

In light of this, some work packages divided the work so that one partner acted as a principal contributor and the developer of all lessons, whereas other partners acted as minor contributors to the content, and more as consultants and reviewers. Some work packages had the lessons evenly distributed between partners, and the partners took full responsibility (and credit) to develop only the lessons assigned to them. Other partners would then review the content and suggest improvements and changes. Some work packages had their assignments distributed so that more than one partner would be involved in the development of individual lessons, and the partners would actively help and support each other in making these efforts. Moreover, all the partners would take an active role in reviewing the developed content.

To maintain active communication in the troublesome pandemic times, regular online meetings were organized to discuss and exchange ideas, thus improving the developed content already in the early stages of development. The frequency of these meetings varied from one work package to the next, ranging from occasional meetings to regular (bi)weekly sessions.

The main factor that hindered the efforts of all partners, both academic and business, was the outbreak of the COVID-19 virus and the declared pandemic. This caused the initial lockdown in all partner countries, stopping all travel and making any in-person meetings virtually impossible. Moreover, it forced the academic partners to switch entirely to online teaching and to convert their teaching materials in an extremely short timeframe in order to adapt to this situation. As a consequence, the project suffered a 6-month delay in all project activities.

4. CONCLUSION

The ASKNOW project is currently at halfway, with virtually all teaching materials either fully developed or in final stages of development.

The next step in project activities is to compile all the materials, unify their format and visual appearance and turn them over to the programming staff responsible for the implementation of the materials into the final online form.

After that, the developed materials shall be tested for functionality and ergonomics by a population of beta-users, and their responses will be used to make adjustments in the content itself, but also in the navigation through it.

The finalized materials are expected to be ready for use in 2023.

5. ACKNOWLEDGMENTS

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