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# The development of modern, interactive acoustic courseware material within the Acoustics Knowledge Alliance project

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**Abstract**

The impact of sound and acoustic phenomena on daily life and its overall quality is not sufficiently perceived by the general public. In addition, in practically all fields of acoustics, there is a lack of professionals with the necessary knowledge and training to solve the problems that occur in everyday life. In order to raise general awareness of the importance of acoustics and to disseminate knowledge to both professionals and lay people, several universities and companies have joined forces in a consortium with the goal to facilitate the development and dissemination of contemporary teaching materials that go beyond the usual forms and approaches to knowledge transfer. As a result, the freely accessible platform Acoustic Courseware (ACOUCOU) was launched. Over the years, the consortium has developed different courseware on acoustics for specific user groups within the scope of several projects. The latest, ongoing project is the Acoustics Knowledge Alliance (ASKnow) project, funded by the ERASMUS+ programme. The aim is to develop modern, interactive content that will form a well-rounded package of teaching materials. These materials will be used in five specific areas of acoustics, i.e. in five corresponding courses: Acoustic Fundamentals, Psychoacoustics, Acoustic Simulations and Auralisation, Electroacoustics, and Room and Building Acoustics. This paper provides an overview of the ASKnow project, its tasks and objectives. It describes the nature and structure of the developed materials and discusses the development procedures used in their creation. The challenges encountered along the way are briefly outlined. The project has entered the phase of transforming the developed teaching materials into their final form, i.e. the interactive online content. This provides an opportunity to present selected extracts of the raw materials developed during the first half of the project, as well as examples of the finished prototypes of interactive online lessons.

**Keywords**: online learning platform, interactive teaching materials, freely accessible.

## 1 Introduction

The quantity and diversity of the overall human knowledge is greater than ever before, and it grows faster and faster. While the fundamental postulates in every discipline and field remain the same, their application

branches out at an impressive rate. As a result, good command of the fundamental knowledge is necessary and is still highly valued, but the ability to improvise, adapt and overcome by quickly adopting and applying new knowledge has become just as important, thus leading to a constant and life-long learning process. In any stage of education, e-learning can be a valuable tool. Although the benefits of e-learning have been studied and known for some time [1, 2, 3], a quantum leap in modernization and diversification of the methods of knowledge transfer has been inadvertently induced by the outbreak of COVID-19, as the teaching staff had to turn to distance learning. As a result, all kinds of online teaching materials including open courseware platforms have become an invaluable resource in the teaching process. In the field of acoustics, there seems to be a serious deficiency of highly skilled and knowledgeable specialists who would have the expertise and the ability to tackle the problems that come along in everyday life. To make a contribution to solving these issues, a consortium has been formed by eight institutions the authors belong to, and various associated partners. This consortium has set the goal to devise and develop a tool that would provide the necessary means for facilitating a different, contemporary approach to knowledge transfer in acoustics. As a result, the Acoustic Courseware (ACOUCOU) platform [4] has been established. At present, several projects have already been successfully implemented under the wing of the ACOUCOU platform, namely, the Architectural Acoustics Multibook (ArAc Multibook), the Acoustic Course for Engineers (ACE) and the Acoustic Course for Industry (ACI). Additional information on this courseware and the platform itself can be found in [4] and [5].
This paper presents the Acoustics Knowledge Alliance (ASKNOW) project [6] as the ongoing undertaking of the consortium, funded through the ERASMUS+ programme. The project strives to cover five topics in acoustics by developing online, interactive teaching materials for the corresponding courses, namely, the Acoustic Fundamentals, Psychoacoustics, Acoustic Simulations and Auralisation, Electroacoustics, and Room and Building Acoustics. The content developed for these courses will be briefly illustrated. A description is given of the methods of developing the teaching materials, and the work strategies implemented by different project partners and working groups are presented. The difficulties and challenges that have arisen mostly due to the outbreak of COVID-19 are discussed. The structure of the lessons as the building blocks of the five courses will be explained in detail. At present, the developed teaching materials are being converted into their final form, so that they be ready for the testing phase. Therefore, selected samples of raw materials will be shown, but also the examples of the finished prototypes of ready-to-be-used online lessons.

## 2 What is ASKnow?

### 2.1. The ASKnow consortium

To achieve the goals of the ASKnow project, a consortium has been formed that comprises eight partners. Four of them are academic institutions (universities), namely, the Le Mans Université (France) as project leader, and KU Leuven (Belgium), RWTH Aachen (Germany) and University of Zagreb (Croatia) as academic partners. The remaining four partners are private companies, i.e. small- and medium-sized enterprises (SME), namely, HEAD acoustics (Germany), Kahle Acoustics (Belgium), and KFB Acoustics and Jazzy Innovations (Poland). All academic partners have well-established research and teaching groups that cover different aspects of the five course topics, thus complementing their knowledge and expertise. Three of the four SME partners conduct their core activities in the field of acoustics as well, while Jazzy Innovations is specialized in developing both web and mobile applications.
To complement the knowledge and expertise of the eight partners, a total of 14 associated partners have been asked to take part and support the efforts made in the implementation of this project by taking over the development of very specific parts of course materials, but also by getting involved in different kinds of promotional activities. The associated partners are of very different backgrounds, as follows: the Slovak University of Technology (STUBA), Slovakia, and the Graduate School of Engineering (EPF), France as academic institutions; e.GO Mobile AG (Germany), Harmonia Acústica (Brazil), and R&D Team (Germany) as small and medium enterprises; DOLBY Poland, I.G. Bauerhin GMbH (Germany), Miele & Cie (Germany), PSA Group (France),

STIHL AG (Germany), SOMFY (France), and ZIEHL-ABEGG SE (Germany); the European Acoustic Association (EAA), Spain, and the Audio Engineering Society (AES), USA as professional non-profit associations.

### 2.2. The goals and outcomes

The main outcome of the ASKnow project is to develop interactive online material for five courses, each of them covering a specific topic of interest: acoustic fundamentals, psychoacoustics, acoustic simulations and auralization, electroacoustics, and room and building acoustics. The material is to be made available on the Acoucou platform. In this manner the ASKnow consortium strives to fulfil the main goal of the project, which is to present the knowledge on the selected fields of acoustics in a modern, interactive way that will facilitate efficient learning and to make the developed materials available to specific user groups. The targeted users are first and foremost the students and teachers in universities and other kinds of higher education institutions, but also professionals (engineers, architects, etc.), as well as corporate researchers. The goal is to help them broaden and extend their set of skills and to raise awareness of the importance acoustics has in many different disciplines and aspects of everyday life. The topics of interest that have been chosen by the consortium complement the knowledge collected within the already developed courses that are available on the Acoucou platform and reflect the fields of interest covered by the members of the consortium, taking into account the needs expressed by potential end users.

### 2.3. The structure of the project

The project consists of thirteen work packages, defined, ordered and numbered according to their role in the project. The first work package (WP1) deals with the development of guidelines and templates to be used in the development of raw teaching materials. The second one (WP2) is focused on project management. The next five (WP3 to WP7) are dedicated to the development of teaching materials. One work package is defined for each course. The following two (WP8 and WP9) are responsible for compiling all the materials, making them uniform, and transforming them to their final form. The next three work packages (WP10 to WP12) deal with quality control through testing and adjustments of the developed materials, quality assurance and evaluation. The final work package (WP13) tackles the issues of dissemination and exploitation of the developed materials.

## 3 Implementation

### 3.1. The structure of the developed materials

Each of the five courses consists of thirty lessons and two practical cases. Lessons are the fundamental particles of each course and each one is dedicated to a specific topic. Depending on the topic at hand, the length and the level of complexity change from one lesson to the next, but all of them consist of three parts.
Part A is the theory section, i.e. text complemented with equations and illustrations. Its purpose is to explain the underlying theoretical concept of the phenomenon presented in the lesson. The form of the material is adapted to online use. Part B is the principle section that strives to illustrate the principles established in the theory part using various types of presentation tools. They include, but are not limited to videos, sound samples, charts, illustrations, dynamic interactive calculations in form of applets, etc. The participation of the user is essential, whether it requires browsing through slides, watching videos, listening to sound samples, changing the parameters of a model of a device or a system and observing the changes in the response, etc. Part C is the task section, and, as such, requires the highest degree of interactivity. The user is encouraged to solve tasks in different forms, such as answering multiple-choice questions, ranking or grouping items, performing calculations, etc. The given solutions are validated, and hints towards the correct solutions can be provided if a wrong solution is initially given.
The final, web-based form of each lesson is designed so that the theory section is always visible on screen and is, therefore, always at the disposal of the users. The principle and the task section are displayed on the remainder

of the screen, but not simultaneously. Instead, they are displayed interchangeably, i.e. a switch button can be employed to change from the principle to the task section and vice versa. The designed format is shown in Figure 1.

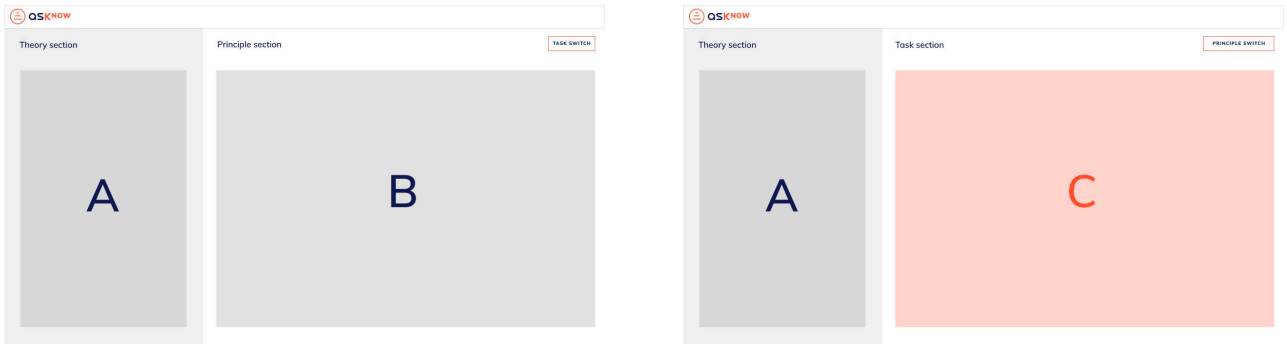


Figure 1: The format of the lessons: the theory part (A) is displayed on the left and is always visible; the principle part (B) and the task part (C) are displayed interchangeably on the right

### 3.2. Work strategy

Based on experience gained on previous projects, the consortium decided to establish a unique set of tools and templates that would facilitate fast and efficient conversion of developed raw material to the final product in .html format. The theory sections of all lessons have been written and edited in Latex format. To facilitate efficient cooperation in producing these materials, the cloud-based LaTeX editor Overleaf was used. To avoid free-from documents, Jazzy Innovations had designed a .tex template and a conversion routine that automatically transforms the .tex documents to .html format. Given the specific nature and appearance of the principle and task sections, Figma was chosen as a web-based or desktop vector graphics editor and prototyping tool. A set of Figma templates was designed for the same reason as above. When necessary, new templates were created on request to accommodate the diverse range of designs used for both the principle and the task sections. To maintain the visual uniformity of design, the consortium also established a unique graphic design charter upon consultations with graphic designers, as shown in Figure 2.

To extend the means of communication both between and within project groups beyond traditional e-mail messages, a free instant messaging software called Mattermost has been used. Within it, a number of dedicated communication channels has been opened that cover specific topics: organization of meetings, dissemination, connection with the funding agency, the content and form of the course materials, etc. The members of the project staff can join any channels they like. The tool also facilitates private messages sent back and forth between individual members of the project staff. This way, the small issues are resolved directly, and the communication through channels remains as clear as possible. For sensitive and official communication, a mail alias that includes all the project staff has been created by the project coordinator.

To facilitate ”face-to-face” communication while adapting it to pandemic conditions, online meetings were organized both at the level of individual work packages and of the entire project. The meetings were held as required by the schedule of the project and as desired by individual working groups.

The overall progress of the project has been monitored using an online spreadsheet as a progress chart, that allowed the project staff to provide information on the readiness of each part (A, B, C) for each of the thirty lessons in all five courses. Besides this, the spreadsheet has also been used for monitoring the reviewing and the final development process. It also contains the list of meetings, the list of contacts, the data on workload for each partner, etc.

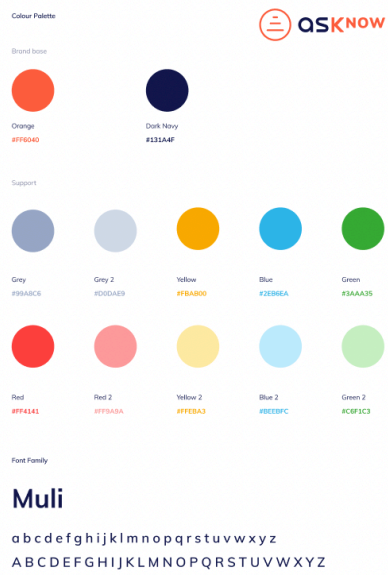


Figure 2: The graphic design charter adopted for the ASKnow project

Each work package dedicated to the development of the teaching materials has chosen and employed the work strategy that promised the best results, depending primarily on the knowledge base of the involved partners. The project partners have chosen the work packages they wish to participate in early on, i.e. during the preparation of the project proposal. The field(s) of expertise of individual staff members was the predominant factor in this work distribution process. The distribution of responsibility was very different from one work package to the next. A centralized responsibility scheme was implemented in certain cases, with one partner being the principal contributor and the developer of an entire course, and other partners being minor contributors, consultants and reviewers. A distributed responsibility scheme had the individual lessons evenly distributed between partners as main contributors. Other partners would review only the content not authored by them and suggest improvements and changes. A highly distributed responsibility scheme had more than one partner working on the development of individual lessons, and strong cooperation between the partners was required and encouraged. All the partners made an effort to unofficially review the developed content.

### 3.3. Challenges in times of the pandemic

The principal challenge and risk to the implementation of the project according to the planned schedule is the outbreak of the COVID-19 virus and the pandemic situation that has been declared in response. The initial lockdown had stopped all travel, thus preventing any and all in-person meetings. Additionally, the academic partners had no choice but to make a swift switch to online teaching. The effort required to convert all the teaching materials they usually use into an online form that would be useful to students was considerable. Consequently, the majority of project activities had to be postponed, especially the ones tied to the development of teaching materials. Most of the project staff have been stricken by the disease at one time or another, which caused short, but significant work-related interruptions, thus causing additional delays. However, the communication network established by the consortium, as well as the use of online tools and templates allowed the development to continue while maintaining the quality of the resulting material. To cover and make up for the delays caused by *force majeure*, the consortium requested a six-month extension of the project at the end of the first reporting period. The request was granted by the funding agency.

### 3.4. Quality control

The process of controlling the quality of the developed materials has a crucial role in the ASKnow project, as the ultimate goal is to develop high-quality content. The process is ongoing, with some phases already finished, and others still to come. All these steps are necessary if the developed material is to be easily understood, have the appropriate level of complexity, and be free of errors.
The first phase of the reviewing process was played out within the project teams assigned to each of the five courses. The developed raw material was made available to all team members (but also to all project staff), who reviewed it and suggested improvements and changes, where necessary. Additionally, one or two experts in each team were asked to review the content of the entire course.
The second phase of the reviewing process was carried out by KFB on all the developed materials, with the intent to detect and correct any errors that may have remained, but also to investigate whether the material is suitable for conversion to its final form.
The third and final phase of the reviewing process is ongoing and involves external review by specialists outside the consortium. Reviewers from universities in Spain, Sweden and Poland have already been recruited.
Once all the material has been converted to its final form, a dedicated work package will implement the testing phase on target groups (students and lifelong learners), with the goal of collecting their feedback. The material will then be adjusted according to that feedback.

## 4 The developed courses

### 4.1. Acoustic fundamentals

The course is aimed primarily at students and professionals at the bachelor level. It leans more towards theory than other courses, and the main goal is to provide an overview of basic terms and phenomena in acoustics. The basics of sound and waves in one dimension (1D) are described, and the expansion to three dimensions (3D) is made, as well as to bounded spaces such as waveguides and cavities. Basic features of acoustic waves are covered: the reflection/transmission on a discontinuity of the tube section and/or propagating media, impedance, the notion of modes, and the acoustic intensity. Fully interactive tools designed with React enable the visualization of each concept so that the students understand it better. The solutions of the equations in 3D in Cartesian (plane wave) or spherical (spherical wave) coordinates are given. The Snell-Descartes' laws are introduced, and the calculations leading to the mathematical expression of acoustic fields radiated by or diffracted on surfaces are proposed. Acoustics in bounded media such as waveguides and cavities is presented for users with intermediate to advanced knowledge in acoustics. The theoretical parts of these lessons are also supported by interactive illustrations to help the users understand these advanced concepts. The final part of the course focuses on specific concepts of importance for any acoustician and leans towards application. Two case studies have been developed, focusing on characterization of acoustic materials and transparency measurements using acoustic intensimetry.

### 4.2. Psychoacoustics

The course is aimed at students and professionals who seek better understanding of the human auditory perception. The anatomy of the hearing system and the signal processing in the brain are linked with the way humans perceive sound. A detailed description of psychoacoustic parameters is given. The binaural dimension of our hearing system is extensively illustrated and explained in multiple lessons, revealing the importance of sound localisation and binaural unmasking in our everyday life. The concept of speech intelligibility is introduced. As this phenomenon is influenced by many factors, including room acoustics and noise, the dedicated lessons in this course are interlaced with the selected lessons in the Room and building acoustics course. The final lessons focus on more diverse topics such as soundscapes, noise perception and noise mapping. These lessons examine practical applications of the learned material and demonstrate the use of psychoacoustics for noise control and

sound design. All lessons are conceived in such a way that the learning curve is adequately designed for beginners. The interactive parts of each lesson allow the users to grasp the presented concepts in an intuitive way. This rather unique approach to teaching acoustics will make the course attractive for people with intermediate and advanced knowledge in acoustics as well.

### 4.3. Acoustic simulations and auralization

The course first explains the basics of signal processing, concerning the impulse response of systems, convolution, Fourier transform and discrete calculations. The second chapter covers different modelling techniques used for room acoustic simulations: The image source model, ray tracing simulations, radiosity methods and wave-based models. With the reverberation time being the most popular parameter of room acoustics, prediction methods of this parameter are discussed as well. Next, the course presents modelling methods for application in noise control and sound design, namely, in areas of environmental sound propagation, airborne and impact sound in buildings, and binaural transfer path analysis. The next chapter of the course deals with auralization as a way of creating sound samples that reflect the behaviour of a system/room and can be listened to. The signal processing methods utilized for (real-time) auralization are presented as well as the acoustical reproduction systems are described, ranging from headphones and binaural loudspeaker setups, through panning techniques such as stereo and Vector-Base-Amplitude Panning (VBAP), as well as panning techniques using object-based audio, to Ambisonics. The final part of the course displays some applications of acoustic simulations and presents the methods of objective and subjective evaluation of the simulations.

### 4.4. Electroacoustics

As a start, the basic concepts in electricity, mechanics and acoustics are presented. Linear and non-linear characteristics of transducers are described. The most common transduction principles are explained, namely, the electrodynamic and electrostatic coupling. The mechanical-acoustic coupling by membrane is discussed. Models of sensors (geophones, and microphones) and sound sources (shakers and loudspeakers) are developed, with the emphasis on directional microphones and on the Thiele and Small parameters of the electrodynamic loudspeaker. The behaviour of common loudspeaker systems such as closed box, bass reflex and passive radiator systems is investigated. The filtering of multichannel speakers is introduced as well. Advanced knowledge is then presented regarding the characterization of loudspeaker drivers. Finally, the systems that use a large number of transducers are described: microphone arrays or loudspeaker clusters. Applications such as line array systems, 2D and 3D multichannel audio systems, and sound zones are presented.

### 4.5. Room and building acoustics

This course is aimed mainly at students and professionals working in the building industry (architecture, M&E, structure, etc.). The course is divided into two parts, one dedicated to room acoustics and the other to building acoustics. The difference between both is explained in the first chapter. The basic principles of room acoustics analysis, design and evaluation are then introduced, followed by practical explanations on the behaviour of sound in closed spaces of different shapes, sizes, and applied acoustic treatment. The concept of reverberation and reverberation time is explained followed by the design of absorbers and diffusers. Design criteria and evaluation parameters, as well as guidelines for achieving good acoustics in a space are presented, directly illustrated by acoustic requirements for the design of spaces specifically dedicated to speech and music. The room acoustics part concludes with a lesson on how acoustics can be integrated into architectural design. The next part brings together all topics related to building acoustics. There are lessons on the concepts of airborne and impact (structure-borne) noise, as well as on direct and lateral transmission paths, on definitions of the transmission coefficient and on the noise reduction index. The specifics of various building elements and their sound insulation properties are also given. This leads to the procedures for measuring and assessing airborne and impact sound insulation. A classification scheme that could be used to assess the quality of sound insulation

is also proposed. Special attention is given to typical building materials, but also to special constructions that contribute to improving sound insulation. The ecological aspect is also addressed in terms of building materials useful for acoustics. Finally, the issue of internal background noise is presented as one of the components of acoustic comfort in a space that is closely related to the design of ventilation and other systems that generate noise. Internal noise, sound insulation and acoustic treatment of a space are (or should be) an integral topic of any building project.

# 5 Examples of developed material

Figures 3 to 7 show examples of the developed raw material. Figure 8 shows how the appearance of raw material is changed as it is converted into a finished prototype.

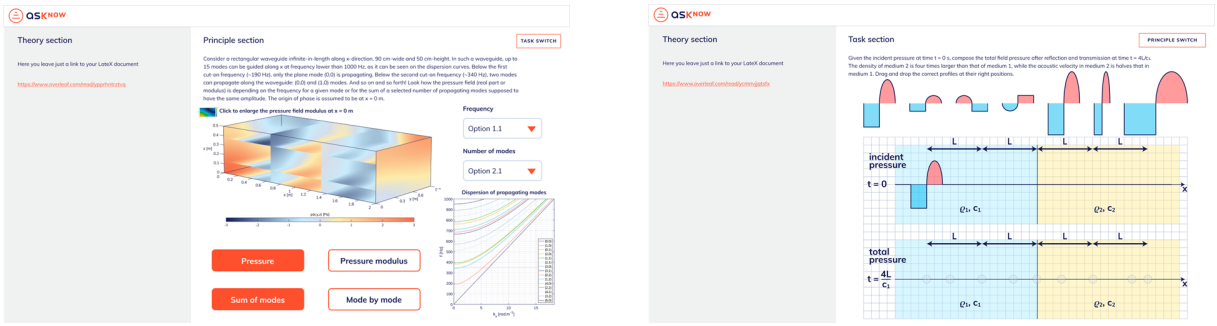


Figure 3: The principle part of the lesson on waveguides (left), and the task part of the lesson on transmission and reflection (right) as examples of material for the Acoustic fundamentals course


Figure 4: Two states in the principle part of the lesson on loudness in the Psychoacoustics course

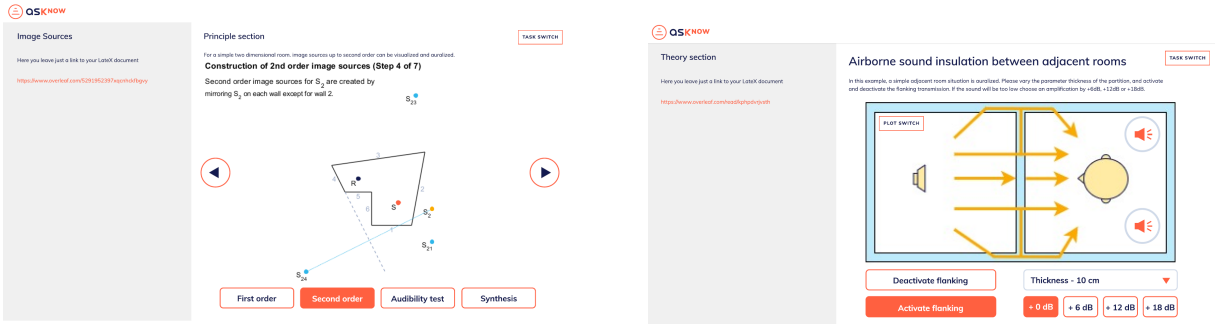


Figure 5: Two examples for principle parts of the course Acoustical simulation and auralization: Image source construction (left) and auralization of sound insulation between rooms (right)


Figure 6: The Electroacoustics course; the principle part of the lesson on electrodynamic loudspeaker (left), the task part of the lesson on transducer limitations (right)

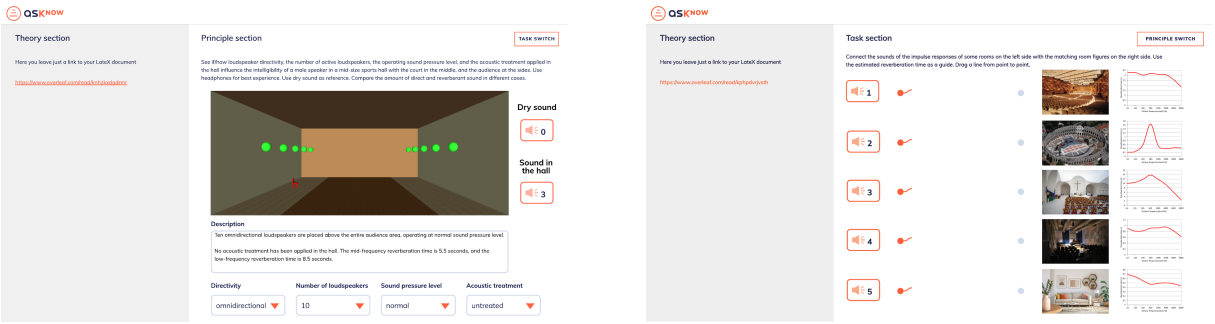


Figure 7: The Room and building acoustics course; the principle part of the lesson on loudspeakers in rooms (left), the task part of the lesson on reverberation time (right)

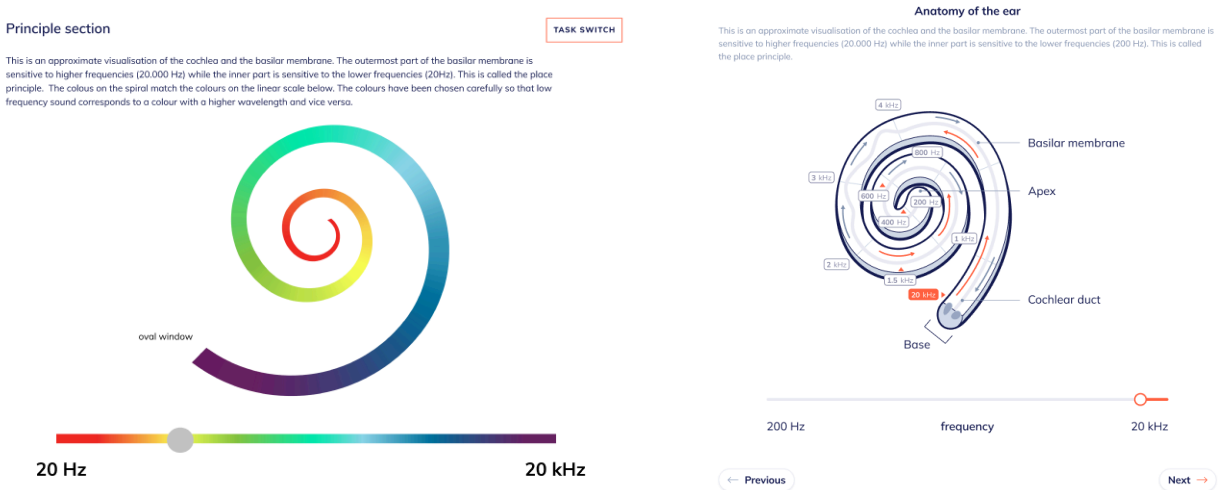


Figure 8: An example of the conversion of the developed material in its raw form (left) to its final form (right)

## 6 Conclusions

At this time, the ASKnow project has reached and passed its midpoint, as all material is now fully developed and compiled. Work has now been turned over to graphic designers and programmers, whose task is to adjust the visual appearance of the material to the accepted design guidelines and to convert it into its final online form,

respectively. The phase of external review will be completed in parallel. The finished product will be tested on a sample of users, and their feedback will be used to make adjustments, if necessary.

Despite the difficulties caused by the *force majeure* circumstances, the consortium managed to stay on track regarding the activities on the project with only minimal delay, due to good organization and communication.

The finalized material is expected to be ready for use by mid-2023. The consortium will continue to carry out dissemination actions to make the potential users aware of the existence of this material, and to promote its use.

## Acknowledgements

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