As expected from an academic engineering context, most graduate and undergraduate courses in acoustics are rooted in STEM (Science, Technology, Engineering, Mathematics) teaching. Although our aim is not to criticize such teaching models, they somehow suffer from a weak point observed in STEM teaching. Indeed, this STEM perspective may limit the larger perspective on the topics and may also be less appealing for underrepresented groups in STEM and higher education. With this in mind, a new course was created at Université de Sherbrooke as part of the courses offer related to the Groupe d’Acoustique de l’Université de Sherbrooke. Entitled “Perception, qualité et design sonores” [Sound perception, sound quality, and sound design], this course proposes a transverse and trans/multidisciplinary perspective on sound sciences without any prerequisites. Here, the starting point is not STEM or equations, but personal and perceptual experience with sound. The course proceeds from a progressive mixture of declarative knowledge to integration and experiential learning, it also relies on the diversity of students’ background as a multidisciplinary driving force. Topics range from hearing, sound quality, statistics, programming, sound design and film sound, sound/cultural studies, to sound technology. Using exploratory teaching tools (selfies, digital portfolio, flipped classroom, sound sketches), this learning experience was intended to immerse students in a wide pool of topics and ideas as a starting point. Next, an underlying characteristic of the course is that the student’s assessment is based on appropriation assignments and projects, e.g. students have to be inspired by the various topics and conceptualize a new technology or invention with a creative, cross-disciplinary and critical thinking perspective. In this paper, the course and teaching tools are further presented. Results, example of works, and anecdotal evidence are reported to evaluate the success of this multidisciplinary path and integrated teaching experiment in the classroom.

Keywords: teaching, multidisciplinary, acoustics, sound quality, sound perception

1. Introduction

In most of the current higher-education programs, sound is either taught as part of music, audiology, or engineering programs, and more recently, within the humanities through the emerging and stimulating field of sound studies. Acoustics, i.e. the physical understanding and exploration of sound, are more than often taught within engineering schools or departments. However, as expected from an academic engineering context, most courses in acoustics are created with a STEM (Science, Technology, Engineering,
Mathematics) perspective on teaching. This paper’s aim is not to criticize such teaching models but to think of and explore new and additional teaching models for acoustics. The first problem with classical acoustics courses, is that they somehow suffer from a broader weak point observed in STEM teaching [1]. Indeed, it is now observed and suggested that the STEM perspective may limit the larger view on the topics and may also be less appealing for underrepresented groups in higher education [1]. This potential lack of attraction is having a direct effect on diversity (cultural, disciplinary, social, etc.) that can reduce innovation potentials and recruiting of future acousticians. The second potential problem is that, for newcomers, if the first contacts with acoustics is through equations and simulations, one might loose contact with a fundamental part of most acoustical problems: the human factor. Accordingly, the starting point for this recent course development experiment is not STEM or equations, but personal and perceptual experience with sound with a focus on human perspective and reception of products and devices through sound and audition.

With this in mind, a new course was created at Université de Sherbrooke as part of the courses offer related to the Groupe d’Acoustique de l’Université de Sherbrooke. Entitled ”Perception, qualité et design sonores” [Sound perception, sound quality, and sound design], this course proposes a transverse and trans/multidisciplinary perspective on sound sciences without any prerequisites. This paper describes the development and the first two editions of this course.

To highlight the motivations and initial teaching intentions, Sec. 2 provides detail about the creation of this course. The formal course construction and definition was created from that starting point (Sec. 3) using various theoretical and educational references. The heart of this paper is discussed in Sec. 4 which presents the actual teaching experiment that combined various sources and experiential teaching methods in relation with current literature. Sections 5 and 6 include formal and informal feedback and impressions with respected to the course’s method and content. Identified improvements are reported.

2. Motivation: Multidisciplinary and diversified views, human-centered

Based on the expertise of the GAUS’s (Groupe d’Acoustique de l’Université de Sherbrooke) members, many courses in acoustics are available at Université de Sherbrooke: fundamentals of acoustics, sound radiation, numerical methods for acoustics, active noise control, and non-destructive testing. Therefore, when it was time to create a new course, two avenues were possible: adding an even more specialized course or offering an introductory course not based on mathematics or engineering. Furthermore, a need for teaching that would fit the training of ”T-shape” [1] profiles was of a general interest. Accordingly, sound perception seemed an interesting and complementary perspective to the existing course offer. Based on that observation, the original idea was to create and develop a course that would offer a multidisciplinary view on sound while using the lived experience and perception of students. The idea was to imagine a course that would be human-centered and based on lived experience as an entry point for newcomers to acoustics, sound, and audio. Although it may not seems like a formal scientific approach, this avenue would, ideally, allow for a personal and individualized engagement with sound and, latter, acoustics. Diversity of disciplines and students’ background was also an important motivation, how can we combine the field of sound perception, sound studies, design, and even music? And how can we create an inclusive course that could welcome any students, with, or without engineering backgrounds. Finally, the aim was also to create an entry point for students who might continue the study of advanced acoustics through the existing GAUS offer.
3. Course construction and definition

The course is divided in four blocks of topics: Sound perception; scientific evaluation of sound quality; sound design history, tools and methods; and sound or audio technologies inspired by the previous topics. The continuum between blocks is created by the relation to, obviously, sound, but also the experience of sound as listeners, as users, musicians or music fans. Accordingly, the course was imagined as a pathway in the realm sound. Typically, each block includes two parts over two or three weeks: a formal content presentation of the principles and a series of applied examples from the scientific literature. Each of the blocks includes a two-fold assessment: (1) a traditional online quiz to evaluate the actual knowledge and learning along with (2) a creative homework for which students are invited to creatively engage with the covered topics.

The course description, here translated to English, is: "What are sound, noise, speech, music? As physical phenomena, they are not limited to physics since they all reach the ear and the human hearing for our pleasure or inconvenience. In this context, acoustics encompass science and sound technologies in a physical and mechanical paradigm. However, for several years, the perceptive qualities of the sounds and sounds produced by mechanical engineering products have become more and more significant in the context of acoustic engineering. But for what purpose? In today’s world, beyond the functionality of products and technologies, it’s an experience that needs to be targeted, designed, and marketed. In other cases, it is an optimization of the sound comfort, or a minimization of the inconvenience, which must be put forward. To reach the targets and fulfill the needs of the industries in terms of sound quality and design, it is useful to have bases in sound quality and design, in psycho-acoustics. But to go further and innovate in this cross-sector context, we must develop an integrated and transverse vision of sound and noise in a global and multidisciplinary context combining pure sciences, engineering, human sciences and even music."

4. Teaching methods: Experiments and multidisciplinary content

This section presents and discusses each of the course elements and teaching methods which combine various forms and methods to reach different learning styles [2].

4.1 Traditional quiz: Different questions

In order to include a quantitative and engineering-like evaluation of the students’ learning and formal knowledge acquisition, traditional quizzes are used for each of the topics. The quizzes are based on a LMS (Learning Management System) and a vast questions database with random versions for each of the students. Question randomization is based on parts. For instance, each quiz includes a given amount of questions on formal knowledge, assigned readings, computation and personal experimentation.

Besides traditional questions, the personal experimentation parts are a way to engage the student with sound and sound perception based on its own experience. Examples of questions in this vein include: "Name and describe one of the sounds that you mostly dislike. Explain why. Try to be as descriptive as possible using your own words." Other questions are related to listening tests or online videos: The student must first listen or check the example and then report his or her interpretation and experience. According to the first editions of the course, I had the impression that these experiential questions were successful in two complementary ways. First, it seems that this helped the students in creating an emotional link between the classroom topics and their own lived experience. Accordingly, I would say (based on informal evaluation) that it helped to enhance the motivation of the students. Second, while completing the review of the students’ answers to these questions, I was surprised to discover a fresh and
human-centered perspective on sound. Something that we may sometimes lose with a purely scientific first encounter with acoustics.

4.2 Surprise! You should react, not learn by heart

I personally like to explore the classroom as a thriller, with rhythm and suspense, and relieves. One of my malicious favorite part is the first course, which is a classical lecture on human ear for three hours. We explore the external, middle, and inner ear through a medical perspective with many terms, definitions, graphs, results. From external ear diffraction, to electrical and mechanical resonances in the hair cells and mechanical models of the cochlea, I typically notice that, over the three hours, some students start to fear that they must learn all these in-depth definitions and graphs. The suspense builds up over the three hours. At the end of the course, some students might even be thinking of changing course. At the end, surprise, as a homework they are not asked to learn all this by heart for evaluation: they are invited to imagine on paper a technology or a device that is inspired by how the ear and hearing are working. At that point, the potential stress vanishes and they start to be creative. In order to complete this free-style homework, they are also provided with supplementary material: (1) an inspiring sound studies writing from the humanities on how understanding sound perception was key for engineering innovation and profits in the history of telephone and (2) a formal reading and quiz combo to actually verify that they understand the principles presented within a traditional lecture format.

4.3 Designing a sound quality study: A broader view on perception evaluation

In the second block of the course, we explore the meaning and scientific methods of sound quality evaluation within an engineering context. After reviewing the established methods and statistics, application examples from the literature are studied by the group: sound quality evaluation of electric cars, sound quality applied to loudspeaker comparison and perceived quality of concert hall. Through these examples, we also focus our attention on the scientific methods of sensory evaluation. Once the related quiz is completed, the students are invited to design a sound quality study either related to the invention or idea they had in the first block or simply inspired by their own interests. They have to conceptualize and design such study while defining it using five phases: (1) objective and what is to be measured, (2) design of experiments, (3) tests with human subjects, (4) statistics and analysis tools, (5) predictive sound quality model. By connecting this homework to their original idea from the previous block (Sec. 4.2) or to their own interest, the intention is to create a continuum through the semester and topics.

4.4 Imagine a sound design: Sound sketches

In the third block, the practices of sound design are explored and explained. Here, sound design is defined as the creative side of sound quality and we focus on sources such as sound design for films, video games, advertising, but also product design and industrial design. This block mostly focuses on hands-on applications and we review audio tools to achieve sound design: (1) audio mixing and editing using Reaper [3], (2) procedural audio and sound synthesis using Pure-Data [4].

A key principle that is introduced is the idea of sound sketches [5]. These corresponds to sound mock-ups created using audio tools, and not acoustical simulation, to create interesting sound for products. In place of starting from mathematics, mechanical designs or simulation, we then focus our attention on how should the product sound. Then, the work of engineers would be to transform that sound sketch in an actual object. As part of the related homework, they must complete several sound designs, one using classical audio mixing and editing for the product of their choice and one using imitative synthesis and procedural audio to design a car sound. For the car sound design, they are first provided with an
Pure-Data patch that they must modify. They are asked to create to different sound sketches of car, each with a different design intention (i.e. sportive, luxurious, comfortable, etc.).

For both editions of the course, I was surprised to receive most of the negative comments for this specific homework. Indeed, some of the students complained that the sound design assignment was too time-consuming ... because they had too much fun with the tools and they spent too much time on Pure-Data or Reaper. In the teacher’s perspective, some of the students’ works went beyond expectation: they completed very realistic and interactive sound designs.

4.5 Make something: Flipped classroom and self-generative group dynamics

The last part of the semester correspond to individual capstone projects over three weeks. In order to stimulate the student’s inspiration, a final lecture on technologies and inventions inspired by human hearing and related topics is provided. Then the students must identify and define their individual project. Project validity is verified beforehand and must: (1) be related to the course or sound, (2) involve a strong part of hands-on work, (3) be well defined and feasible within approximately 18 hours of work (6 hours per week, for three week). The aim of these last three weeks is to rely on flipped classroom so that the students actually make the course and create a group dynamics. To do so, three steps are introduced in the students’ workflow in classroom situation:

1. Week 1: Collaborative project definition. The students must first bring a simple idea or keyword for the definition of their project. At the whiteboard, they are invited to write keywords and other student’s reaction on the left. On the right, they must structure things in five points: objectives, methods, required tools, targeted results, references. The group all work together to help each of the students for 20 minutes. Then, the right part of the white is photographed to initiate the project portfolio of each student.

2. Week 2: Help from the group. After working for a week, each student must bring to the group a faced challenge or problem that they encountered. Next, the group all work together, using laptops, smart-phones, or anything at hand to give 20 minutes of team work to solve the problem and something boost the students’ projects. The aim of this step is to create the group dynamic, promote inclusion and promote a diversity of perspectives.

3. Week 3: Final demonstration within a start-up simulation. For the last lecture, students present their pathway for the capstone project through demonstration and free talks. Here, the idea is to create a sense of peer-review feedback and evaluation to the students. In terms of evaluation, the project and the interaction is evaluated. This last evaluation step is further detailed in Sec. 4.7.

The capstone project is a great success. I have been surprised by how much the group dynamic is developing in this stage and I have been impressed by the quality of some projects that could easily correspond to a scientific conference, or an full-semester trainee project. Few examples of capstone projects are classified according to the themes in Tab. 1. Sound design and technology are the most popular. The following two sections provide more details on the use of digital portfolio for project assessment and on the final participatory presentation of the capstone projects.

4.6 Capstone project evaluation: Using a digital portfolio for learning assessment

In order to focus the capstone project assessment on the learning progress and on the experiential side of the capstone project, the now established and recognized digital portfolio (DP) was used. The DP is a way to collect the student’s self-awareness as learners throughout the entire realization of the project, it is far from a report, much more like an interactive and connected logbook. In contrast with standard evaluation methods or classical LMS (Learning Management System), the DP was used because of its
Table 1: Few examples of students’ capstone projects according to course’s topics

<table>
<thead>
<tr>
<th>Sound perception</th>
<th>Sound quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Java application for listening tests</td>
<td>Sound quality study and design of electric cars</td>
</tr>
<tr>
<td>Matlab sensory profile application for listening tests</td>
<td>Sound quality of aircraft sounds</td>
</tr>
<tr>
<td></td>
<td>Sound quality and reception of drones</td>
</tr>
<tr>
<td></td>
<td>Extended ANOVA study</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sound design</th>
<th>Sound technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helicopter procedural sound design</td>
<td>Sailing sonification for the blinds</td>
</tr>
<tr>
<td>Sound design for a simulation game</td>
<td>Digital Theremin</td>
</tr>
<tr>
<td>Entire re-sound design of a car advertisement</td>
<td>Lost object sonification using Bluetooth</td>
</tr>
<tr>
<td>Musical instrument rapid virtual prototyping</td>
<td>3D music visualization using Blender’s programming</td>
</tr>
<tr>
<td>Storm synthesis using procedural audio</td>
<td>In situ room impulse response modification</td>
</tr>
<tr>
<td></td>
<td>Interactive car sound resynthesis</td>
</tr>
</tbody>
</table>

Inherent advantage in relation with creative and self-reflexive evaluation as a learner [6]. Few of these advantages include:

1. Student centric (*versus* course centric in LMS)
2. Student makes rules (*versus* teacher makes rules in LMS)
3. Student portfolio may be structured, or not (*versus* course structured in LMS)
4. May be institution agnostic and useful for career development (*versus* tied to an institution in LMS)

In this course, the Mahara [7] DP was successfully used since it was already available and installed at Université de Sherbrooke and already connected to the Moodle LMS (used for the entire course). Based on personal and informal experience, the use of DP was highly successful and is therefore recommended for an enhanced engagement of the students. Some students used the Mahara DP as a daily notebook with an impressive amount of notes, references, videos, etc. Some of the most impressive works would have been rich enough to make a conference paper. However, based on observations, instructions and explanations about what is a DP for assessment should be given to students as some seem to have miss the point.

4.7 Start-up simulation: Applying art-critique methods to engineering capstone projects

Besides the portfolio described above, the final assessment is applied to the capstone project and is divided in two participatory parts.

The first part of the assessment corresponds to week 2 as described in Sec. 4.5. In this part, students bring to the group a faced problem or challenge related to their project. In this case, it is the participation that is evaluated as an simple success or fail evaluation corresponding to 10% of the capstone project final score. As long as everybody participate, it corresponds to a success.

For the second part of the capstone project assessment, the course concludes with the presentation of the capstone projects. In order to simulate a more realistic and professional situation, this presentation takes the form a demo presentation or a start-up simulation. This simulation context is also enhanced by the fact that the presentation happens in a industrial loft downtown Sherbrooke outside the campus. While being out of campus, the group really get a feeling of an industrial, entrepreneurship or start-up vibe. This is further enhanced the availability of a sound studio, video projectors, decent loudspeakers, coffee and pastries to mark the end of the semester. The format of the presentation imitates a presentation of prototype to a team of colleagues or to a design review. Students are invited to comment and review the proposal’s of colleagues. Here, the teacher acts as a moderator and facilitator. For this part, I typically apply methods of art critique as used in fine art or contemporary art teaching [8, 9]. I found this avenue...
especially relevant because of its focus on diversity of perspectives, a focus on interpreting the student’s intention, and a highlight of positive criticism.

5. Results and observations

Generally speaking, based on informal impression and anecdotal data through students’ unsolicited comments, I consider this teaching experiment as a success. Indeed, although a received some critics and negative comments, they were concerning details, or bugs with the electrical content, or accessibility of the digital portfolio. These critical issues, at least those for which I received explicit comments were never related to the general philosophy of the course or to the multidisciplinary and participatory perspective. In fact, two of the most rewarding comments are worth mentioning. Freely translated and summarized, one of the comments mentioned that the student especially enjoyed the practical exploration of the topics through the applied capstone project along with the participatory format were students acted as peers from various backgrounds for comments on the development of each of the projects. The other inspiring comments were related to a sensitivity breakthrough, indeed, some positively reflected on the need for considering the perception and reception of product before imposing a purely engineering-driven product and solution. If I had to identify one success, that would be the most important: how engineering and perception must work hand-in-hand for an holistic view on engineering technologies and solutions in relation with users’ and third-parties’ perspectives. Here, sound was used as an illustrative case, but this general gait was easily adapted for a more general perspective on perception of engineering products.

Besides this positive overall feeling, some improvements are currently identified and discussed in the next section. Also, formal evaluation of the multidisciplinary and integrative approach should be performed using standardized forms or surveys for comparison with existing evaluation data of multidisciplinary and integrative courses [1].

6. Critical perspective and future improvements

Now reflecting on the first two editions of the course offered in 2018, some parts and methods could be improved.

First, the personal engagement of the students through students’ conferences and capstone projects may appear too late in the semester. Indeed, I had the impression that the first lectures were giving the impression of a traditional lecture in the first weeks. For the next editions, one of the envisaged improvement is to remove one of the lectures in the latter part of the semester and replace it by a participatory course at the beginning of the semester. The aim would be to inject a participatory and inclusive dynamics right from the start and to create a peer dynamics in the classroom [2]. This could also be developed so that all the block topics and semester-long experience culminate in the capstone projects.

Second, for some the lessons on application examples of sound quality studies and sound design, I explored various formats to make a collective reading in the classroom (i.e. individual reading for 20 minutes and then collaborative synthesis of the work, including a critical perspective; collective reading in the classroom). However, these experiments were not optimal in terms of efficiency and experience. For the next editions, these lectures might be replaced by a seminar-like format (inspired from graduate courses in the humanities): students must complete the readings beforehand and classroom time is oriented as a collective discussion of the studies papers.
7. Conclusion

This paper shared an overview of a multidisciplinary course on sound perception, sound quality and sound design as an entry point to the scientific field of acoustics. Based on the first two editions of the course, potential improvements and success were identified. In terms of success, several very positive comments were received. Most of them being related to the flexible and agile approach to the topics with assessments based on personal appropriation and perspective in relation with the topics. Potential improvements include the need to give the sense of flipped classroom or participatory learning earlier in the semester since most of the positive and participatory dynamics progressively appear towards the end of the semester.

Finally, in order to better situate this teaching experiment within the current trend in higher-education with a focus on integrating humanities and arts in STEM curricula (STEM to SHTEAM [Sciences Humanities Technology Engineering Arts Math]) [1], specific evaluations of the course and learning experience are required. Such evaluation are required in order to quantitatively know if this experiment in integrating humanities in an introductory course on acoustics is a real success in terms of learning outcomes. Evaluation following specific and standard evaluation forms or surveys adopted for SHTEAM (as from references in [1] about the integration of humanities and arts in STEM) is planned for following editions in order to collect data that can be compared to other STEM or SHTEAM teaching initiatives.

REFERENCES