

CLASSE TECHNO "BRUIT": ACOUSTIC WORKSHOP FOR HIGH SCHOOL STUDENTS AT UNIVERSITÉ DU QUÉBEC (ÉTS)

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"Classe Techno," is a science fair originating from the "24 heures des sciences" (www.sciences24heures.com) provincial initiative, and has been organized annually or bi-annually since 2010 by the communication services from École de technologie supérieure (ÉTS), an engineering school part of the Université du Québec network. This event is designed for high school students coming from a variety of socio-economic origins in the greater Montreal area and is designed as a full-day workshop with relevant and interactive hands-on experience for students in upper middle grades (K-8 to K-11). As part of this event, the acoustic team of ÉTS offers a dedicated workshop animated by graduate students and researchers within the well-equipped ICAR (icar.etsmtl.ca) acoustical research labs, on the topic of Noise ("Bruit" in French). The "Bruit" workshop exposes the students to a variety of key-concepts and lab experiments about mechanical and sound waves, noise and music. The 60-minutes long workshop is structured around 3 main activities: a) "What is sound?" b) "What makes sound musical?" and c) "When is it too loud?" and exposes students to several experiments, ranging from the measurement of frequency and magnitude of mechanical waves, to interference of waves, to sound synthesis and Fourier analysis using a sound card, to the assembly and calibration of a sound level meter and to the proper use of hearing protection devices. This paper presents the workshop structure and details each

of the activities. It provides insights on what worked since day one in 2010, what has been improved over the years and what could be done in the future.

Keywords: Acoustics, Education, Teaching, Science Fair, Students)

1. Introduction

1.1 History of "Classe Techno"

1.1.1 *A scientific dissemination exercise*

In 2009, the Communications Department of ÉTS accepted the invitation from the Science for All Cluster to contribute to its annual public science dissemination event: the 24 Hours of Science. For its first participation, ÉTS chose the theme of creativity to draw the public's attention to certain unsuspected aspects of science and technology. By bringing together the creative power of artists and engineers, the organizers of the school wanted to highlight what the two professions have in common.

On the day of the event, about 300 people of all ages enjoyed the demonstrations and performance presented at the activity that ÉTS had then called TECHNO BOULOT ROBOT.

The following year, thanks to the lessons learned from the first edition, the organizers chose to focus more on internal collaborations (staff and students of ÉTS) and to target more precisely the high school students for whom vocational guidance would soon become an issue. Thus, in May 2010, the Classe Techno welcomed 225 participants from the "Commission scolaire Marguerite Bourgeoys" (CSMB), a local school board, for a day of three immersive workshops (selected in advance from 10) in the world of science and engineering.

1.1.2 *A partnership is born*

Satisfied with this first experience, the leaders of ÉTS and the CSMB decided to invest in a long-term collaboration that included a process of continuous improvement. In fact, each Classe Techno was subsequently the subject of a post-event analysis, which made it possible to improve the following edition continuously to this day (2019), and by adding a second day in the year for this event.

1.1.3 *A partnership that radiates*

In March 2012, the organizers had the first opportunity to publicize the concept outside their partnership, at the "Colloque sur les approches orientantes" symposium on guiding approaches from the "Association québécoise d'information scolaire et professionnelle (AQISEP)" a provincial association for educational and professional information. Judged as an interesting development track, this first promotional activity resulted in the creation of a representation committee and the development of a public presentation for professional conferences. The spin-offs were immediate and led to the collaboration with a second school board and the reception of a first group of young drop-in students enrolled in Adult Education. Encouraged by these initial results, the committee has continued its momentum and presented this activity to another group in November 2012 at the annual conference of the Association for Science and Technology Education (APSQ).

The organization of the Classe Techno and the public presentations constitute the essential work of the professionals involved, but the sustainability of the activity is based on their ability to create and renew themselves. School perseverance presents countless challenges while science and engineering

offer infinite solutions. The goal is to improve the formula while maintaining the basic objective of promoting science and engineering and training the next generation.

1.2 The benefits of "Classe Techno"

As student preferences are taken into account, the final assignment of activities has the effect of randomly decomposing and re-composing new groups at each workshop, which adds to the immersive experience. Throughout the day, students rub shoulders with new faces and weave new bonds.

Indeed, the organizers consider that socializing not just with other students, but also with university students, technicians, and engineering professors remains one of the best "guiding approaches" that can be integrated into an immersion activity. Moreover, the selection of ÉTS students hired as guides relies largely on their ability to listen and share with teens, sometimes on their experience as an engineering student, sometimes on their life experience in general. In short, the commitment of ÉTS students in their role as role models is matched only by the commitment of staff to the passion for science and engineering.

1.3 What the "Classe Techno" workshop actually is

All the originality of the Classe Techno lies in the diversity of activities and the possibility for each of the 225 students to choose the workshops that interest them the most, among the following:

- Electrostatics: discovering and understanding the phenomenon of static electricity
- Ice cream: discovering food chemistry, making ice cream
- Solar cars: assembling and testing a mini solar car
- The sound level meter: assembly of a small sound meter and use during the activity "noise"
- Noise: frequency, amplitude, propagation and hearing. The essential notions of acoustics
- Robots: programming of a small robot for the execution of a determined course
- The Pont Pop challenge: design of a computer bridge, according to constraints of materials, budget, topographical profile, etc.

In each workshop, facilitators make a short introduction to introduce the experience, location, equipment, etc. In many cases, the students leave with the object they made in the workshop, which extends the reach of the day to the home and ultimately to the parents.

This article details the organisation of the 60-minutes long "noise" workshop. This workshop is structured around 3 main activities: a) "What is sound?" b) "What makes sound musical?" and c) "When is it too loud?" respectively detailed in Section 2. These activities have evolved since their creation in early 2001, and the evolution and lessons learned are presented in Section 3. A conclusion and perspective, in section 4 provides insights on alternative approaches and what could be done in the future.

2. "Bruit" Workshop Activities

As previously mentioned, there are three main activities in the "Bruit" workshop. They are each explained thoroughly in next several sections. The participating students are divided into three groups and each group starts with one of the activities. The activities are independent and do not need to be in a specific order. A summary of all the activities is shown in Table 1.

2.1 Activity 1: "What is sound?"

The first activity's purpose is to explore the nature of a sound as a wave, a vibration through space and time. In order to visualize its characteristics, different experimental instruments are positioned on a bench as seen in Figure 1a. There are four tools to be used in this activity: a Shive machine [1] also

called a wave generator; a string vibrator made of an oscillating pot, a cord and a signal generator; a Chladni plate [2] and finally a computer with a screen. Two pages were opened on a web browser on the computer, one with animations on wave properties by Daniel A. Russell called "What is a wave?" [3], and one with a video of the Tacoma Narrows Bridge Collapse in 1940 [4].

Before the students start interacting with the equipment, they are asked what they know about sounds, their nature and the physics behind them. Through their answers and suggestions, a few concepts can be introduced. Here, the animations found on the "What is a wave?" webpage [3], are very useful, in order to illustrate the phenomena but also because they contain multiple relatable examples. The important concepts to get to with the students are the following: first, sounds are waves that propagate energy, not matter; second, sounds need a medium to propagate in, solid, air or liquid but there is no sound in space for example; finally waves propagate longitudinally, a disturbance is propagated in the same direction as the wave, particles oscillate and push their neighbour particles before coming back to a resting state.

After this, students are invited to experiment and observe the properties of a mechanical transverse wave using the Shive machine. Different impulses are shown to have effects on the amplitude of the wave, its frequency and its duration. Explaining that amplitude is related to the loudness of a sound and frequency to the note or pitch, students are invited to create different waves themselves at the Shive machine that would correspond to different sounds. An oscilloscope is also useful at this point to illustrate the concepts of amplitude, periodicity, frequency and wavelength. The next segment of this activity explores natural frequencies and modes using the string vibrator. The concept of modes is explained to the students. Each system where the wave is reflected back to its point of origin, such as a string connected at both ends, a trampoline or a bridge has specific frequencies at which it oscillates or resonates. A student is invited to increase the frequency given to the string until they reach the first mode with the vibrating nodes at each end and a "belly" in the middle, this is the natural frequency. Students can increase the frequency further until they find the following modes. They can realize that each mode is obtained by adding the natural frequency to the one before. More nodes and "bellies" of vibration are observed for each mode and they can experiment with touching the string at these important points to show that there is no impact on the nodes but important changes when applying pressure at the "bellies". Finally, modes are shown on a 2D system, the Chladni plate, which consists of a metal plate with salt on top, connected to a signal generator. Students slowly increase the frequency of the system until modes start appearing. The salt gets distributed on the plate along the nodal lines and patterns emerge for every mode reached. Figure 1b shows students observing the salt change patterns on the Chladni plate. Parallels can be drawn with the nodes and "bellies" of the previous example. The importance of predicting these frequencies in order not to excite them is the last element of this activity. At the computer, the video of the notorious Tacoma Narrows bridge collapse is shown to the students. Because of vibrations from the wind and the cars travelling on it, the bridge enters in resonance. It starts oscillating uncontrollably and distorts wildly until it collapses.

2.2 Activity 2: "What makes sound musical?"

The second activity of the workshop is "What makes sound musical?" in which students are introduced to the notions of acoustical test fixtures (ATF), musical notes and sound synthesis. For this activity, an ATF, a screen and two loudspeakers are used as shown in Figure 2a. The animator explains what an ATF is and highlights the advantages of using it instead of human participants. Students are encouraged to touch the ATF and feel its realistic nature even though it is fabricated with synthetic materials. Right after, the concept of musical notes is introduced by asking the group if anyone plays an instrument and to describe the instrument they play: does it produce a low or high pitch? Does it need amplification? The video "Les harmoniques d'une note" by eduMediaSciences [5] is shown, where sounds produced

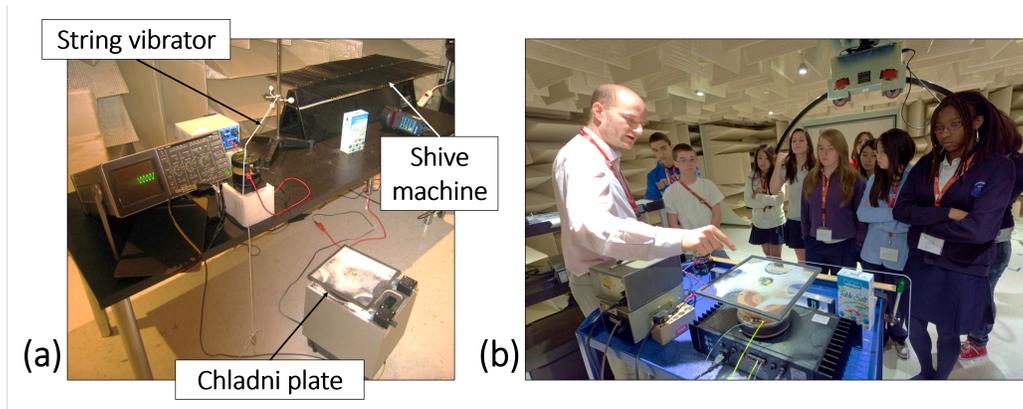


Figure 1: (a) Setup for activity 1 "What is a sound?" (2017) and (b) students observing mode shapes on a Chladni plate (2013).

by musical instrument are presented by explaining how the vibration of a cord, membrane or column of air creates a sound. Since instruments have different shapes and sizes, the notion of sounding box is presented; instruments such as a guitar or violin need an amplifier since the cords are not big enough to excite surrounding air. Using the representation of a vibrating cord, musical notes are shown by introducing the notions of octave, third and fifth and how the combination of these can form chords. Although different instruments can produce the same note (frequency), timbre is specific for each instrument. After students have asked their questions, sound synthesis is introduced with a microphone, loudspeakers and a LabVIEW (National Instruments, Austin, Texas, United States) program. With the help of recordings of a cow, a dog, and a donkey, the frequency spectrum of each animal sound is displayed on the screen. Since different animals use distinctive frequencies at different amplitudes, they all sound unique. To include some fun and laughter, the students are then asked to reproduce one of the animal's sounds and using a LabVIEW program, the spectra are compared and displayed to everyone in the room. Figure 2b shows a group of students laughing after one of them imitated the sound from a donkey. Finally, students are introduced to hearing loss and its effects on how we hear. Using the well known voice of Homer Simpson, hearing loss is simulated using low pass filtering. The "severity" of the hearing loss is gradually increased by more aggressive low pass filtering. The students can then detect the changes in Homer's voice and the reduction in intelligibility due to the reduction in high frequencies. This activity aims to raise awareness to the importance of hearing for speech intelligibility and the detrimental consequences of hearing loss.

2.3 Activity 3: "When is it too loud?"

The third activity is "When is it too loud?". The purpose of this activity is to introduce the students to noise levels, how they are measured, and when they become too loud that they are harmful to hearing. Often, this activity takes place in the reverberant room for its diffuse field properties. For this activity, sound files, loudspeakers, and hearing protection devices are used. First the animator introduces the students to what a reverberant room is in contrast to an anechoic room, which they have already visited or will visit after the current activity. The animator explains that the room is built in order to create a diffuse sound field and what that means. The students can see the multiple sound reflecting panels that change the sound incidence regardless of its location in the room as shown in figure 3b. The basic concepts of a sound wave, its frequency and amplitude are introduced or reviewed with the students

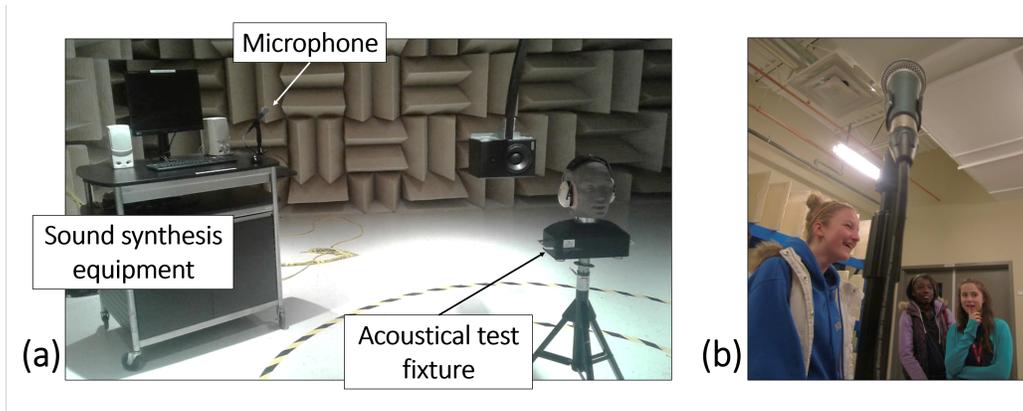


Figure 2: (a) Acoustical Test Fixture and sound synthesis equipment for activity 2 "What makes sound musical?" in the semi-anechoic room (2017) and (b) students observing the sound synthesis of an animal by one of their colleagues (2013).

depending on whether this is their first activity. The students are lead to understand that the amplitude of the vibration or the wave of an object is what defines the sound level of a sound. Next, a video on auditory transduction by Brandon Pletsch [6] is shown to the students about the operation of the ear and how the ear is an acoustic-mechanical-electrical transducer. It shows how a sound wave is converted by the ear into an electrical signal that is interpreted by the brain into sound. To explain this, the video follows the journey of a sound wave trough the ear, going trough each part of its anatomy.

After the video, the students are introduced to the concept of a noise dose, and the idea that the question of "when is it too loud?" involves two subquestions: how loud? for how long? They are then presented with hearing protecting devices (HPD), when to use them, and how to wear them properly. The animator shows many different types of HPDs such as earmuff, molded earplugs and classic foam plugs as can be seen in Figure 3a. The students are then taught how to wear each of these devices. The notions of a good fitted earplug and the necessity for it regarding the efficiency of an earplug are presented. A poster demonstrating the method of insertion to get a good earplug fit is also shown. After students have properly worn their earplugs, they are asked to reflect on different common activities and to guess what the level of sound at each of these activities could be. Previously recorded sound samples are played through four loud speakers inside the reverberant room. The students are tasked with adjusting the sound level to what they think resembles the real sound level. The four activities presented to the students are: a) a hockey game, b) a music concert, c) a movie at the cinema, and c) a construction site. Once a noise level is agreed upon by the group, a comparison is made with real measured noise levels to see if the students were close. They are then asked to reflect on the main question of the activity of "when is it too loud?" and to come up with safe time periods for each activity if no hearing protection is worn. This activity makes the students aware of how loud common recreational activities can be and encourages them to properly use earplugs when appropriate to protect their hearing and avoid noise-induced hearing loss.

3. Adjustments and Lessons learned

Classe Techno started in 2010 and the acoustical workshop "Le Bruit" described here-above was included in 2011. Over the last dozen of occurrences (the Classe Techno was sometimes held twice a year, during spring and fall sessions), several adjustments and improvements have been made. Initially, most of

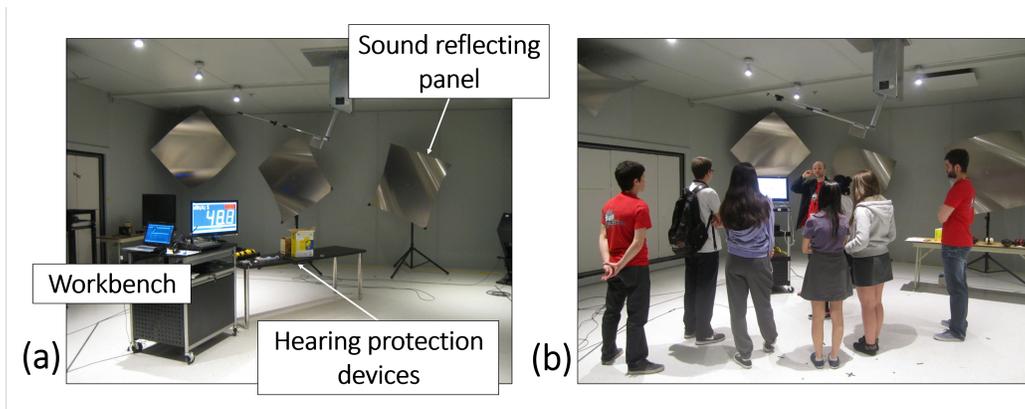


Figure 3: (a) Setup for activity 3 "When is it too loud?" in the reverberant room (2017) and (b) students listening to different sounds inside the reverberant room (2013).

Table 1: Summary of the three activities presented at the "Bruit" workshop.

Activity	Tools and Materials	Lessons Learned
What is a wave?	<ul style="list-style-type: none"> • A computer with a screen • A Shive machine • A string vibrator (an oscillating pot, a cord and a function generator) • A Chladni plate (a function generator, an oscillator, and salt) 	<ul style="list-style-type: none"> • What is a wave, a sound wave? • What is a frequency? • What is an amplitude? • What is a natural frequency? • What are modes and harmonics?
What is a sound?	<ul style="list-style-type: none"> • A computer with a screen • A LabVIEW program for sound synthesis • A microphone • Loudspeakers 	<ul style="list-style-type: none"> • What distinguishes one sound wave from another? • What is an acoustical sound fixture? • What is timbre? • What are the effects of hearing loss?
When is it too loud?	<ul style="list-style-type: none"> • A computer with a screen • A variety of hearing protection devices • Loudspeakers • Sound samples of common recreational activities 	<ul style="list-style-type: none"> • How do we hear? • What is a noise does? • How to protect one's hearing? • What are sound levels for common activities?

the tools and gears used for the workshop was coming from recycled material, sometimes even recovered from the university trash bins, and was refurbished, adapted or revived to serve as demonstration tools by the first author, graduate students and volunteers (listed in Table 2). This is the case for example for the oscilloscope, the vibrating "Chladni" plate, and all the PCs used for this workshop. Likewise, a lot of time from a couple of volunteer graduate students was spent on programming in LabVIEW the various

Date	Volunteers Names
20190425	Marine Laplace, Justine Régnier, Valentin Salomon, Grégoire Lehouque
20190424	Michel Demuynck, Elliot Drees, Thibaut Peretti, Valentin Pintat
20180426	Manon Paris, Jacob Bouchard-Roy, Simon Prenant, Hugo Saint-Gaudens
20171102	Manon Paris, Kévin Carillo, Jacob Bouchard-Roy
20170427	Manon Paris, Kévin Carillo, Pierre-Jean Jacquet, Alban Dizin
20161101	Gabrielle Crétot-Richert, Alex Guilbeault-Sauvé, Alexis Martin
20160426	Alexis Martin, Fabien Bonnet, Johan Carioli, Corentin Lavergne
20150423	Alexis Martin, Fabien Bonnet, Johan Carioli, Stevan Chavan
20140424	Vincent Nadon, Rachel Bouserhal, Narimene Lezzoum, Céline Laporte
20131024	Narimene Lezzoum, Romain Dumoulin, Rachel Bouserhal, Rodrigue Sandrin
20130424	Vincent Nadon, Marie-Hélène Faille, Florian Duffner, Nicolas Crochet
20120511	Narimene Lezzoum, Rachel Bouserhal
20110507	Kuba Mazur, Cédrik Bacon

Table 2: List of graduate and undergraduate students who participated in the dispensing of Classe Techno "Le Bruit" workshop since its creation on May 7th, 2011

audio synthesis, recording and playback (seen in Figure 2) and Sound Level Meter (seen in Figure 3). Later, the gear used was upgraded and, for example, new rolling workbenches were acquired by the university in 2013 to offer a more professional look and experience to the audience. Likewise, new demonstration machines, such as the mechanical torsion wave simulator ("Shive Machine") was bought in 2013 to complement the first workshop on "What is a wave?". As the team involved in the animation of the workshop is rotating each time, several slight adjustments and variations are made, and the successful ones are kept for future reference and continuous improvement of the acoustical workshop.

4. Conclusions and perspective

The "Bruit" workshop held at ÉTS is intended to introduce students to fundamental concepts in acoustics and to inspire and motivate them about the field. Through three hands-on activities students are introduced to a nature of a sound, the concept of a wave characterized by its frequency and amplitude, which is later linked to the timbre of an instrument and our ability to distinguish between sounds, thus, reinforcing the importance of our hearing and how to conserve it. This type of pedagogical activity does not only benefit the student participants, it refines the dissemination skills of the graduate students animating the workshop. The future of the "Bruit" workshop will follow the trends in technology and project based learning. Activities where students get to work on and build a project are envisioned in the evolution of the workshop. An example of such an activity would be similar to the "BOSEbuild" [7], which are low complexity building projects designed for youth. These type of hands on activities could increase retention and help motivate student engagement. As any pedagogical activity, the "Bruit" workshop must constantly evolve and adapt to the technological resources available and the interests of its audience.

5. Acknowledgement

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