**Teaching Acoustics under COVID: Lab in a Box for Experiments at Home**

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**Abstract**

In June 2020 with the advent of COVID emergency plans were put in place to deliver the Masters course in Environmental and Architectural Acoustics totally on-line. This was necessary as although the acoustics laboratory is large, it was deemed to be unsafe for face-to-face teaching due to a complete lack of ventilation in the anechoic and reverberation chambers. Hence, it was necessary to create an alternative. It was decided that a “lab in a box” supported by on-line demonstrations and pre-recorded films would create the best alternative experience for the students. The “lab in a box” allowing the demonstrations to be replicated at home or in the garden. The results showed that the students gained from more independence, increased flexibility in deliver achieving very similar marks. This has opened up the possibility of increasing student numbers by reusing these alternative teaching strategies.

1. **Introduction**

In June 2020 in the midst of the initial COVID outbreak emergency plans were put in place to deliver the Masters course in Environmental and Architectural Acoustics on-line. It was decided that on-line delivery was the only option. This was necessary as although the acoustics laboratory is large, it was deemed to be unsafe for face-to-face teaching due to a complete lack of ventilation in the anechoic and reverberation chambers. Hence, it was necessary to create an alternative. It was decided that a “lab in a box” supported by on-line demonstrations and pre-recorded films would create the best alternative experience for the students. The “lab in a box” allowed the students to run experiments at home or in the garden.

1. **Course Design**

The MSc course consists of both theoretical modules and practical modules [1], or in some cases theory and practice, see Table 1. The practical aspects of the course

Table 1: Design of the Masters in Environmental and Architectural Acoustics

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Research Methods | Subjective + Environmental | Measurement + Control | Acoustic Laboratory | Architectural Acoustics | Masterclass in Acoustics | Project |
| Theory | Y | Y | Y | N | Y | Y | Y |
| Practical | N | Y | Y | Y | Y | Y | Y |

The theoretical aspects of the course were easy to deliver using on-line tool, Microsoft Teams [2]. However, due to international students- and the associated time different, it was decided that half of the material be pre-recorded and put up on the virtual learning environment, Moodle [3], at least two days before the lecture. The pre-recordings used the Panopto system [3], although if the lecturer wishes to appear in the corner of the screen the materials needed to be moved two inches to the right!

1. **Practical Approach**

The practical aspects of the course consist of two main approaches: computing and laboratory based work. This was necessary as six out of the seven modules have practical components, see Table 1.

* 1. ***Computing***

The course offers access to the latest and leading commercial software. To enable the software to be used by students ICT organised a virtual system, called Cloudpaging Player with Global Protect software creating a Virtual Private Network [4]. Once the software is installed students can remotely access software and run the simulations on-line. Site licenses for CATT-Acoustics was used to teach architectural acoustics, CADNA-A for environmental acoustics, and MATLAB for coding.

* 1. ***Laboratory Work***

The laboratories issue was more difficult to solve. It was necessary to create an acoustic measurement platform that was affordable and could be shipped around the world. This formed “Lab in a Box”. As an auxiliary plan it was decided to record ever experiment on campus, so that by September 2020 twelve short films were created over a period of two days to cover the labs in the Acoustics Laboratory module. These films were recorded under strict COVID secure conditions with signed off risk assessments with a minimum number of people present. The filming and editing was undertaken by entrepreneurial students from our Film School and was completed by early October 2020. The edited films were uploaded on-line to Moodle, along with the lab sheets and all the experimental data taken at the time of the recordings. The experimental data was designed to be analysed live on MS Teams to extract the maximum possible educational value. As an aside, during all recordings and live sessions branded attire was worn to emphasis a feeling of community and quality.

1. **Lab in a Box**

Given the Acoustics Group does not have enough resources to give every Masters’ student a sound level meter, another solution had to be developed quickly. It should be noted that our Institute of Acoustics Diploma students, a UK based course, each received a Class 1 sound level meter to undertake their experiments. Under a very tight deadline it was decided that a computerised measurement system would form the basis of the “Lab in a Box”. The Acoustics Group had previously trialled the shareware software ARTA [5], a computerised measurement platform, as part of our architectural acoustics module. Hence, ARTA would form the best available platform for the “Lab in a Box”.

* 1. ***Instrumentation and Equipment***

An inexpensive solution was necessary that could be quickly bought, packaged, and shipped nationally and international to meet the start of term deadline, late September 2020. The only assumption made was that the student would have a Microsoft Windows laptop available. The main limitations were budget, £200, and the system must be portable.

ARTA is a very capable measurement platform. The software can measure impulse responses (RT, EDT, Speech Intelligibility), fast and slow time weightings, overall weighted sound levels with logging, real-time frequency analysis in octaves and 1/3 octaves, loudness (Phons/Sones), and Noise Criterion (NC, NR, PNC, RC, NCB). This met the teaching requirements of four modules: Acoustics Laboratory, Architectural Acoustics, Measurement and Control of Sound, and Subjective Acoustics.

It was then necessary to specify the hardware. It was felt that audio based equipment rather than acoustic instrumentation would be used due to budgetary restrictions. The hardware specified was a USB sound card: Behringer UHD202 along with a Behringer ECM8000 omni-directional measurement microphone [7]. This allowed 48 kHz 24-bit measurements to be taken using ARTA. A simple single driver sound source with lithium ion batteries was found Ankar Soundcore [8]. These were connected to the sound card using a balanced XLR for the microphone and Jack-to-mini-Jack cable for the speaker, giving a total measurement capability of 10m. To calibrate the systems 13 Class 2 sound calibrators by Voltcraft, SLC-100, were purchased. These calibrators included a sleeve which provided the non-standard 12.5mm microphone a snug fit. Finally, additional equipment was purchased including: a tuning fork, a music box and a digital metronome.

* 1. ***Sound App***

In case that international shipping could not ship the “Lab in a Box”, due to a lack of international flights a back-up solution was also offered. This solution had to use what the student might already have at home. As such, an iPhone smartphone was deemed a reasonable assumption [9]. An application was identified as free and simple to use, SPLnFFT app [10] which had been previously identified as a quality iPhone app for acoustic measurements [11,12].

* 1. ***Class 1 Sound Level Meter***

The lecturer also had access at home to a Class 1 sound level meter and Class 1 sound calibrator. This was used for live demonstrations to explain the difference in the quality of the measurements compared to the ARTA measurement platform. This was achieved through side-by-side comparisons for instance difference in calibrator accuracy, or experiments under low noise conditions. In addition, vibration kit was included including calibration and isolating plate to demonstrate how a sound meter could be converted into a vibration meter.

1. **Delivery and Reporting**

The main point of contact with the students was through Moodle using a University email address. On Moodle each week a pre-recorded film was uploaded, along with links to the live section, lab sheet, lecture notes, and experimental data from the film. There were two types of module to deliver: purely practical and a mixed theory and practice module.

* 1. ***Pure Practical Module***

The delivery of the purely practical module was divided into two halves. The first half of the lecture was covered by the pre-recorded film of the experiment, approximately 15-25 minutes, in length; a full list is given in Table 2. This was followed by a discussion of the laboratory and an analysis of the experimental data with a comparison to the expected theoretical result.

Table 2: Laboratory Experiments with at Home possibilities

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Sound Calibration | Environmental Parameters | Fast+ Slow | Facade | Noise Survey | Sound Propagation | Reverberation |
| Filmed | Y | Y | Y | Y | Y | Y | Y |
| Home | Y | Y | Y | Y | Y | Y | Y |
| Equipment | Calibrator | ARTA | Metronome | Wall | Domestic Appliance | Loudspeaker + Garden | Room with Duvet |

Table 3: Laboratory Experiments not Replicated at Home

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Sound Power (Free and Diffuse Field) | Normal Incidence Absorption | Random Incidence Absorption | Sound Insulation (impact, air-borne) | Vibration (calibration, isolation) |
| Filmed  | Y | Y | Y | Y | Y |

The second half of the lecture is where the students attempted to replicate the experiment at home, see Table 2. They reported both experimental results as part of their professional report. Table 3 shows what experiments could not be replicated at home.

***5.2 Mixed Theory and Practical Modules***

The delivery of each mixed module consisted of two equal halves. The first half of the lecture covered the theory, which was pre-recorded, with a live section to cover Q&A. This had the additional advantage of providing an offset in any international time difference.

The second half of the lecture covered the experiment. This was undertaken live over Teams with the students using what was to hand. For instance, for Subjective Acoustics, see Table 4.

Table 4: Subjective and Environmental Acoustics using Lab in a Box at Home

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Noise Exposure | Loudness | Noise Criterion | Speech Intelligibility | BS4142 |
| Lab at Home | Y | Y | Y | Y | Y + Filmed |
| Additional Equipment | Sound App Nor140 | Sound App Nor140 | Sound App Nor140 | N/A | Sound App Nor140 |
| Sound Sources | Kettle, Extractor Fan, Hoover, Hairdryer | Drill, Hoover, Hairdryer, Metronome | Kitchen, Bathroom, Living Room | Living Room (windows open, cushions, curtain) | Lawnmower |

The assignment was to write a professional report based on one of the experiments. This report should detail the theory behind the experiment, what standard and guidance was used, methodology applied, results, critical analysis, uncertainty, improvements / non-compliance, and conclusions. In addition, experimental results should be compared to theory as filmed, as well as with their own experimental data. This could be followed by comparing the quality of the data collected by different measurement systems Class 1 sound level meter, ARTA measurement system, and Sound App on a smartphone.

1. **Feedback**

The student expectation was managed so that they understood that under COVID teaching would be significantly different, whilst keeping the same learning outcomes and maintaining fairness. It was also explained that the model of delivery could continue into Semester 2, which commences in Late January 2021.

The size of the student cohort was in-line with previous years, and attendance was near 100%. Student feedback was through Module Evaluation Questionnaires and through the full-time and part-time course representatives. So far, the feedback has been excellent, and assignment marks in line with previous years.

1. **Conclusions**

Under very difficult circumstances teaching was moved from face-to-face to all on-line over the period of one month. The students had the option of on-campus tutorials, but none was taken up, preferring to meet on-line. Sociality was maintained through Teams with the student left alone to discuss work/education materials over an on-line coffee.

To overcome these difficulties an approach which combined on-line teaching, pre-recorded lectures, filmed laboratories, Lab at Home experiments, desktop-based computer modelling, and live Q&A sessions was employed. The pre-recordings helped the international students overcome the implicit time differences. Student feedback was excellent.

The specification of the Lab in a Box, a fully calibratable acoustic measurement system, for under $250, helped create a better student experience under difficult conditions. The creation of the ”Lab in a Box” allowed the students to undertake the practical aspects of the course during the year.

The legacy of the COVID conditions teaching is the greater use of on-line tools, a library of filmed experiments and the rapid adoption of computer software tools. This will aid in the delivery of a new course the HNC Apprenticeship in Acoustics, where the employers wanted the students to be taught the very latest tools and techniques. Hence, this year’s Masters’ students provided a pilot study for the rollout of the new course, starting September 2021.

The final legacy is the creation of public engagement materials suitable for use by schools at the 16/18-year level [12]. The experiments can be undertaken in class using a large screen to display the results to provide an understanding of acoustics in physics lessons.

1. **Acknowledgements**

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