THE IOA SCHOOLS COMPETITION ON SOUNDSCAPES: STUDENT LEARNING AND STEM ENGAGEMENT

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1 ABSTRACT

This paper presents the work of students at St Oscar Romero Catholic School who participated in the Institute of Acoustics (IoA) Schools Competition on Soundscapes 2022. The students used a smartphone to measure sound levels at locations around the school at regular intervals. These data were used to create an interactive 'heat map' showing how the soundscape changes during a typical school week. The limitations of the model are discussed, and an issue arising from the sound measurements is further investigated, namely the extreme loudness of the school bells. The impact of excessive noise levels in the learning environment is explored, with staff and students surveyed. Interventions are suggested, and a method of continuous monitoring of sound levels in key locations is devised. It is concluded that both duration of exposure and proximity to the sound source have a significant impact on wellbeing. The findings of this study have implications for the design of learning environments and the use of alert systems in workplaces. Further studies should investigate the impact of different alert sounds on wellbeing. The paper also discusses how students' learning experiences through involvement in the IoA competition impacts on future engagement in STEM-related activities in UK education.

2 INTRODUCTION

The aim of the IoA Secondary School Competition 2022 was to get students to discover the basics of sound measurement. Students were instructed to first become familiar with the hardware and software to be used (a smartphone and the Decibel X app[1,2]), and then to take measurements of various sounds – indoor/outdoor, pleasant/unpleasant etc. Participants were encouraged to investigate the factors affecting their measurements.

3 METHODOLOGY

3.1 Familiarisation

A signal generator was connected to a loudspeaker, and a smartphone positioned with microphone oriented the same way, and at a fixed height. The average sound levels over a time period of 10 s were recorded using the Decibel X app. Distance between smartphone and loudspeaker was varied between 0.10 m and 1.00 m, at 0.10 m intervals. This was repeated at three different frequencies (256 Hz, 512 Hz and 1024 Hz), keeping the same amplitude setting of 12 V on the signal generator. The experiment was also repeated using three different models of smartphone (iPhone 7, iPhone 8, Samsung Galaxy A71) and the suggested calibration settings of the Decibel X app: +2.5 dB for the iPhones, and -4 dB for the Samsung Galaxy.[3]

Distance between loudspeaker and phone (m)	Mean sound levels (dB)		
	256 Hz	512 Hz	1024 Hz
0.10	91.0	83.6	87.0
0.20	86.8	78.3	83.6
0.30	85.7	74.0	80.5
0.40	84.3	71.3	81.0
0.50	82.9	69.5	77.6
0.60	81.7	67.8	77.9
0.70	80.5	65.0	74.7
0.80	79.9	64.8	75.1
0.90	79.0	63.9	72.6
1.00	78.8	63.1	70.8

Figure 1: Sound levels measured at different distances, over a range of frequencies

There was a small variation between the measurements taken with the three different phone models, but it was considered that the differences were not significant. It was noted from the results in figure 1 that a doubling of distance led to a mean sound level decrease of between 3 dB and 7 dB, and this was the case at each frequency.

A variety of sounds were then recorded, measured and described. It was then decided that if measurements could be taken around the school at various times of day, it would make an interesting extension to the competition entry if we could map out the measurements in some way.

3.2 Measurements

Once the Decibel X app had been calibrated, it was decided that measurements were to be taken in 35 different locations, as shown in figure 2. This would be carried out at ten different times across the school day. This resulted in, across a five-day school week, 1750 measurements being taken.[4] For each measurement, the mean sound level over a 10 second time period was taken.

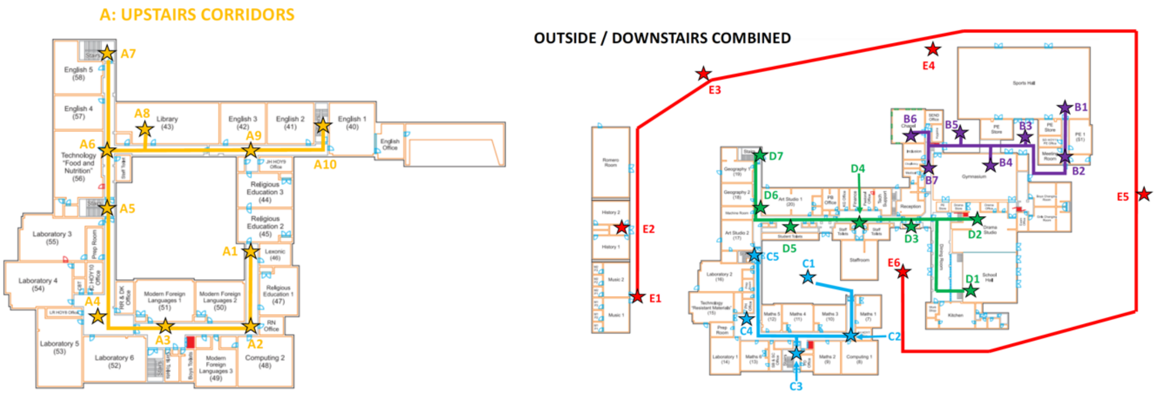

Figure 2: The 35 locations at which measurements would be taken, 10 times each day.

4 RESULTS

To best represent the data collected, we wished to create a 'heat-map' to illustrate the changing sound levels for each location at the various times of measurement. We first imagined the plan of the school sitting on an imaginary grid. Each measurement location could then be positioned on this grid. Instead of a number, each dB measurement was allocated a colour on a scale (covering the range of measurements between 30 dB and 90 dB), as shown in figure 3. We imagined the measurements to be point sources of sound, so unmeasured locations between each point were filled in, to represent a reduction of measured sound from each source, plus the combination of sounds from other measured sources, as shown in figure 4.

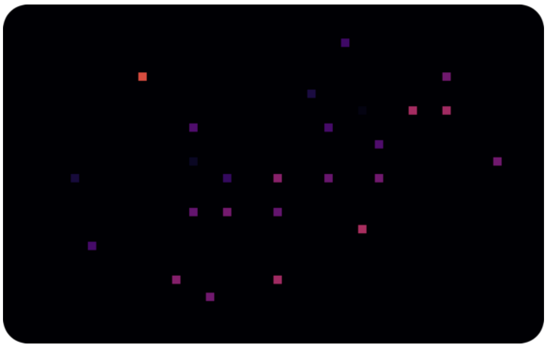

Figure 3: Measurements on imaginary grid

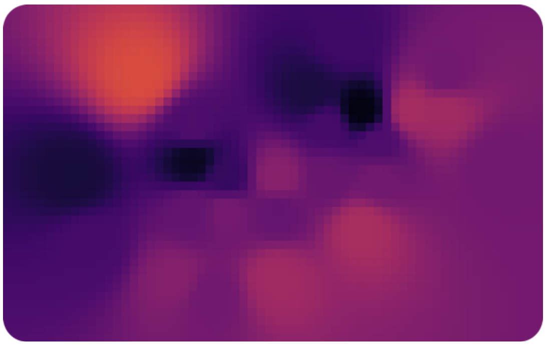

Figure 4: Filled in between measurements

Next, a blur was applied over the filled in image to create a smoother heat map (figure 5). The plan of the school was then overlaid, resulting in one image, for one time of one day (figure 6). This process was repeated for each of the other times and days, resulting in 50 images.

Figure 5: Added blur

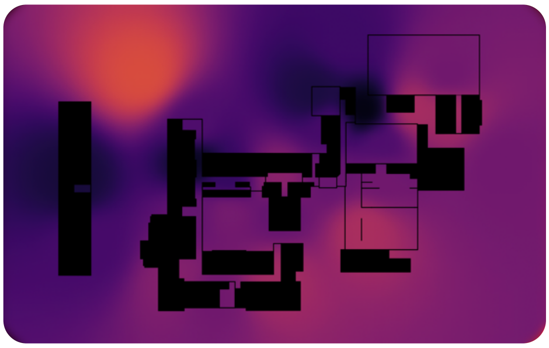

Figure 6: Overlay plan of school

Putting these together and adding a slider and dB scale gave the final interactive heatmap[5] (figure 7).

Figure 7: The interactive heat map

5 DISCUSSION

5.1.1 Limitations

This method of collecting and presenting data does have some drawbacks. Firstly, it was incorrectly assumed that the measurement at any one particular location was due to a point source of sound at that location. Rather, the measured value at each point is the combination of sounds from numerous points sources, each diminishing with increasing distance from their actual source.

Secondly, each measurement is a snapshot, taken at a single moment in time. With time intervals of up to an hour, some regular sounds at a particular location, such as the school bells, were not recorded if the measurement time did not correspond with the timing of the bells. The sound profile at each location could vary significantly between readings. Similarly, loud noises which occurred only during a 10 second measurement could falsely suggest a particularly noisy location, whereas the average sound intensity at that location across a longer duration measurement could be very different. Had data collection been repeated several times at each time of day, and across multiple weeks instead of just the one, and mean values calculated, this would have perhaps resulted in a more reliable representation.

Furthermore, in simply laying the plan of the school over the generated heat map images, we are ignoring the effects of the building itself on the propagation and reflection of sound.

However, the aim of the heat map is to visually represent the collected data and to show the changing soundscape in the school environment across a typical school week. We believe this still to be a useful representation, despite the limitations outlined above.

5.1.2 Response

Due to the time intervals of the measurements for the main heatmap being up to an hour apart, it was decided that a method of taking more frequent samples was needed. A raspberry pi (RPi Zero2) was used with sound intensity sensors / microphones. In addition, temperature and humidity sensors were added. The raspberry pi was placed in the main school hall, a location that experiences a wide range of sound intensities throughout the day. The raspberry pi was subsequently programmed to collect sound level (dB), temperature and humidity measurements every 3 seconds, and to transmit this data to the competition entry website[6], providing a means of collecting virtually continuous live data (see figure 8). Had it not been for limited availability of raspberry pi modules at the time, additional locations could also have been monitored in this way.

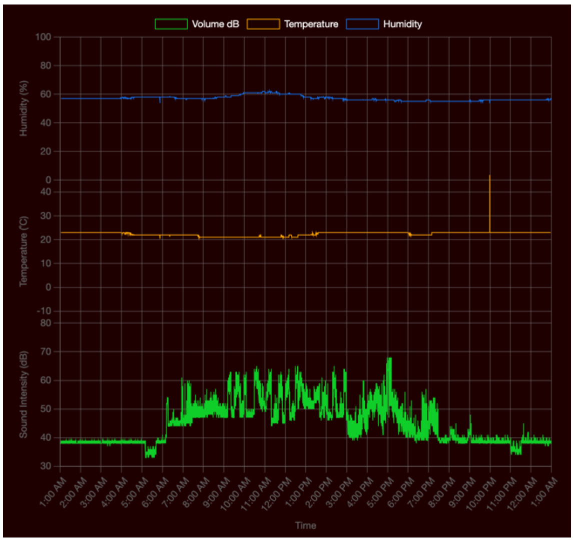

Figure 8: Live data fed to the website

6 FURTHER INVESTIGATIONS

6.1 Issue arising

Whilst carrying out measurements for the IoA competition entry, it became apparent that there was an issue with the loudness of the school bells. Measured from a distance of 1 metre from any one of the bells, the sound levels register at 115 dB. Some bells are located above classroom doors, where teachers would be standing to meet and greet the students. Standing beneath a school bell when it rings at such a volume can be extremely unpleasant[7] and, it is suggested, harmful not only to hearing but also to personal wellbeing. Students[8] and staff[9] were subsequently surveyed and their feelings about the school bells were quite revealing.

6.2 Interventions

6.2.1 Modelling lower amplitude bells

We mapped out the location of all the school bells, and drawing on our work with the heat map we assumed that each of the bells acted as a single sound source of 115 dB. On this basis, the heat map for the current situation is shown in figure 9.

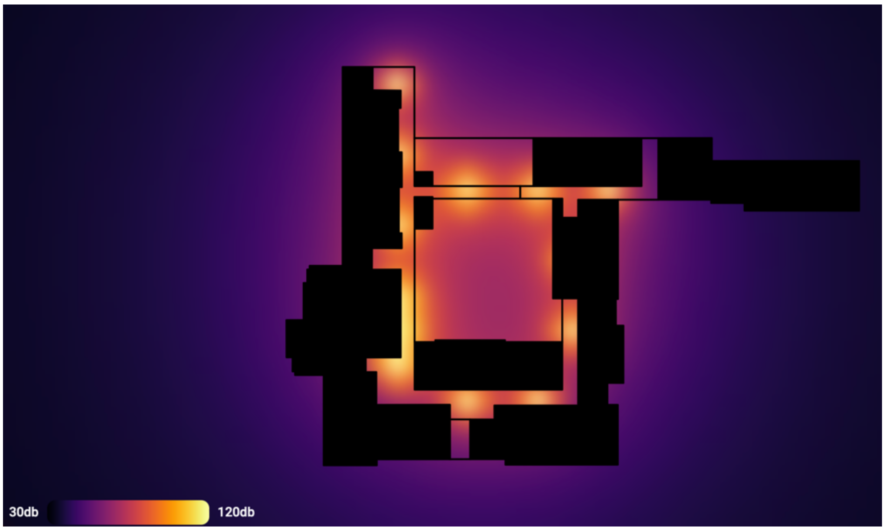

Figure 9: Current setup, 115 dB bells

It is understood that the bells need to be heard at all locations around the school, so there needs to be sufficient coverage of the whole building. However, as previously mentioned, being in close proximity to any of the bells when they sound is particularly undesirable. It is suggested that adequate coverage could still be provided with quieter bells. In figure 10 the heat map models a setup with 70 dB bells which shows minimal impact on the overall picture, but a significantly reduced loud noise experience for anyone close to any one bell. It is further proposed that a greater number of quieter more closely spaced bells would be an ideal solution.

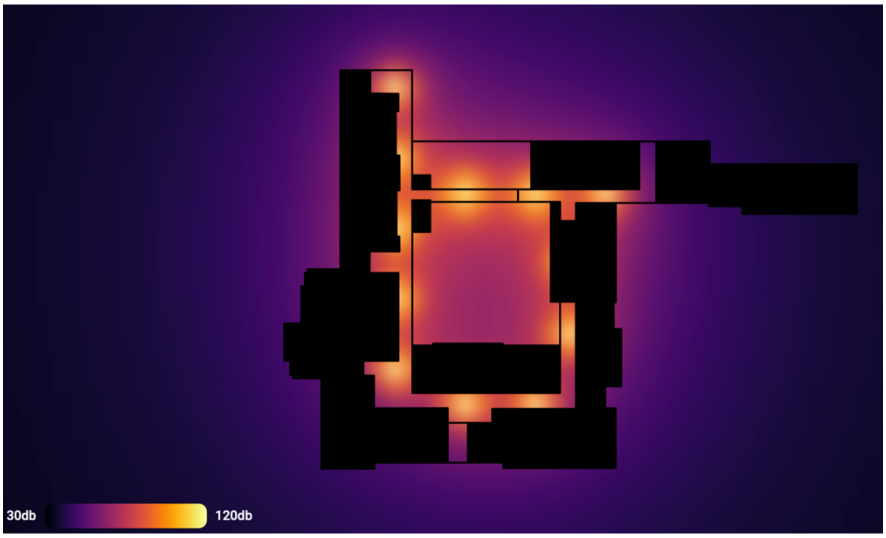

Figure 10: Proposed 70 dB setup

6.2.2 Other proposals

Instead of costly re-wiring and installation of a new bell system, something could be done about the existing bells. In fact, it is incumbent on employers to protect employees from loud noises and to take steps to reduce any risk.[10] Currently the bells ring between lessons for approximately 4 seconds. Reducing this duration would reduce exposure, but standing close to a bell when it rings, even for a shorter duration, would still be unpleasant. It is suggested that, in preference, the bells could be dampened. This could be achieved by covering the bells with an absorbent material, reducing the transmission of the sound produced by the bell. Further studies could investigate the effectiveness of different materials for reducing dB levels. In preference, a reduction of the sound produced in the first place could be achieved by placing a dampening material over the clapper. Initial testing involved placing a small rubber sleeve over the clapper. This resulted in a reduction of the sound level, measured at a distance of 1 m from the bell, from 115 dB to 105 dB – a halving of the perceived loudness. This method is encouraging and is currently being implemented across the school, one bell at a time. In schools the lesson changeover bell may also act as an alert. In our case, the lesson changeover bell rings continuously for 30 seconds to indicate a lock down situation. There is a trade-off to be made – balancing the need for an alert system to be loud enough to be heard when needed, but not so loud as to cause harm to hearing. Smoke alarms, for example, have a minimum sound level of 85 dB, measured from a distance of 3 metres.[11] Another option is to consider the type of sound used for alerts. A recent Australian study[12] found that certain alarm noises can decrease morning grogginess, causing participants to wake up faster and feel more alert. Could the type of sound used for an alert system similarly have an impact on wellbeing? Future studies could explore this.

7 CONCLUSIONS

The IoA secondary school competitions[13,14,15] have aimed to introduce students to the world of acoustics, an area otherwise unknown to many. A knock-on effect of these competitions has been increased engagement with STEM activities generally. Each competition brief, whilst giving some instruction and identifying certain tasks which should be carried out by students, has remained fairly open-ended. This has enabled students to be inquisitive, to see where the tasks take them and allow them the freedom to ask questions and to extend their investigation further. Following the success of our school in the competition, students here have subsequently had a number of learning opportunities opened up to them. IoA STEM ambassadors have visited and worked with students in a number of year groups with the You're Banned activity. A whole year group went on to visit the anechoic chamber at the ISVR in Southampton University. We have now established links with the University of Sussex Acoustics department, welcoming visiting speakers to the school. The department now hosts some of our Y10 students for work experience each year. As a direct result of the IOA competition 2022, we are currently working with the Acoustics Group of the Institute for Environmental Design and Engineering at the Bartlett, University College London, exploring the role of positive sounds within the school environment on the well-being of staff and students. Beyond this, engagement in the IoA competitions has inspired students to consider careers in the STEM subjects, and to pursue college courses in the sciences. There has also been increased uptake to other STEM competitions and activities within the school. With the IoA supporting schools and engaging with teachers, the next generation of scientists can experience further opportunities beyond the classroom, seeing the relevance of their studies in the real world. In this way, students are being inspired not only into the area of acoustics, but generally into STEM fields.

8 REFERENCES

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