AN ACTIVE LEARNING COURSEWORK FOR ENGINEERING ACoustics COURSE

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This paper describes a newly developed summative assessment for an engineering acoustics course offered to fourth year and postgraduate engineering students at the University of Auckland, New Zealand. The course teaches fundamental knowledge that Acoustics Engineers need and which underpins a variety of sub-disciplines in acoustics including fundamental physics of wave propagation, building acoustics, electro-acoustics, audio signal processing, and psychology of hearing. The coursework was developed to help students understand complex concepts through active learning processes and to provide an introduction to areas of acoustical engineering and consultancy which are typical for a practising Acoustical Engineer in New Zealand. In the assessment, students are told to assume that they are serving as a professional Acoustical Engineer being tasked by a mock “client” to measure the acoustic properties of rooms with different volumes using various metrics: i) sound level of ambient noise, ii) reverberation time (RT60), and iii) clarity (C50), and report the results back to the client. In the report, students have to discuss the measurements using knowledge covered in the lectures as well as articles from various resources. Room impulse responses are measured in the rooms using free software for acoustic measurement (Room EQ Wizard) in conjunction with a calibrated USB microphone (miniDSP UMIK-1) and a small computer loudspeaker, which are then processed using Matlab to derive the targeted metrics. Overall the new coursework successfully filled the gap between the theoretical content covered in the course and the practical tasks which an Acoustical Engineer would encounter in their day to day work. The University of Auckland is especially fortunate in having a full suite of ISO conforming acoustical chambers which are used by the students during practical laboratory classes that compliment the coursework. The success of the course has been supported by anonymous feedback from students through the formal course evaluation run by the university.

Keywords: Coursework, active learning, practical, electro-acoustics, room acoustics measurement

1. Introduction

Active learning has been receiving extensive attention as an alternative teaching strategy that has a potential to improve students’ learning performance as opposed to classical lecture style teaching [1]. A study has proven that introducing active learning components in undergraduate science, engineering and mathematics courses improves the average examination scores and decreases the likelihood of students in the course failing compared to those in a class with only traditional lecturing [2]. Although there seems to be no unique definition for active learning, in a relatively wide sense, active learning is defined as any instructional tasks that require students to engage practical activities and think about the meaning of the tasks [1, 3].
In the context of acoustics education, there have also been a few reports that introduced curriculums including some active learning components [4, 5, 6]. Forms of such active learning components vary from in-class demonstrations [4] and discussions [5] to out-of-class activities such as computer simulation based homework and group projects [6].

An engineering acoustics course, MECHENG726 “Acoustics for Engineers”, is offered to fourth year and postgraduate engineering students at the University of Auckland, New Zealand. Historically, the syllabus of this course included some active learning components through a laboratory session which took place in the acoustical test chambers of the University. In addition to the laboratory session, in 2017, another new coursework was developed and introduced to the syllabus with an intention to provide students with more active learning activities. This paper introduces the details of the new coursework and reports how it was perceived by the students enrolled the course.

2. Course syllabus

The course consists of $36 \times 50$-min lectures delivered in one semester, covering a variety of sub-disciplines in acoustics with an overall aim of teaching topics relevant to the required knowledge of a practising Acoustical Engineer. Table 1 summarises the contents covered in the lectures with approximate number of lectures spent for each topic.\(^1\)

There are a few assessments conducted to measure students’ understanding and achieving learn-

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\(^1\)The order of the contents in the table does not reflect the actual delivery of the course.
ing outcomes of the course. They include two assignments (worth 30% of the whole course grade), which are held during the semester as formative assessments [7] for aiding students’ understanding of concepts covered in the lectures; and a 3-hours examination taken place at the end of the semester (worth 70% of the course grade), as a summative evaluation [7] of students’ achievement. The first assignment is a take-home quiz consisting of a series of challenging exam-style questions. Students are expected to complete this assignment individually. The second assignment is a take-home practical assignment that students work outside the class. It was designed to provide students with an opportunity to practically experience the processes of acoustical measurement of rooms using various metrics covered in the lectures. More details of the second assignment are introduced in Section 3.

Apart from these assessments, the course runs a laboratory session where students are offered an opportunity to experience various acoustic environments using the acoustic chambers at the University of Auckland. Although students are not assessed with a mark for their performance in this lab session, the content covered is material that can be part of questions in the final examination. Section 4 introduces the practical activities taken place during the laboratory session.

3. Take-home practical assignment

The take-home practical assignment was designed to aid students understanding the topics covered in the lectures. The assignment specifically focused on the contents under Fundamental physics and Electro-acoustics in Table 1. In this assignment, students were told to assume that they were professional Acoustical Engineers working for an Acoustical Consulting firm. Their mock “client” asks them to investigate the acoustics of rooms in client’s buildings. The students’ task in this assignment was to investigate the acoustical properties of these rooms by measuring their room impulse responses (RIR) using available equipment and software, then report back to the client with the results of the measurements and technical discussions from the perspective of an Acoustical Engineer. Specific intended learning outcomes of this assignment were:

- To be able to read microphone specifications (type, frequency range and response, directivity, etc.) and use these to calculate sound pressure levels from measurements taken using those microphones.
- To measure sound pressure levels (A weighted and no weighting) using a sound level meter.
- To describe how SPL(A) is a representative measure of perceived noise level and what limitations this metric has.
- To measure RIR using a swept sine signal.
- To calculate reverberation time (T20, Early Decay Time) from measured RIRs and to describe how reverberation time changes in different frequency bands and locations.
- To estimate speech intelligibility from measured RIRs using C50 and describe how speech intelligibility changes with distance from the sound source.

3.1 Equipment

Students were provided with software, a microphone and a loudspeaker to carry out the required acoustical measurements tasked in this assignment. To run the software, students used their own laptop computers. Because of budget limitations, affordability of equipment also had to be taken into account in the design of the assignment.

3.1.1 Software

Since the aim of the assignment was to provide students with practical experience, learning the intricate details of the algorithm for measuring an RIR was outside the scope of this assignment. In addition, not all students in the course have a background in electronics and digital signal processing, hence the assignment had to be designed in such a way that students could measure an RIR easily
without having a strong knowledge of these disciplines. To that end, Room EQ Wizard (REW)\cite{8} was chosen for the software to measure RIRs. REW is free software which has multiple useful functionalities for acoustics measurements, including RIR measurement, sound level meter, and spectral analyser. REW measures an RIR using a swept sine signal \cite{9, 10} with a few options available for the length of the swept sine signal and multiple synchronous average \cite{10}. Figure 1 shows a screen-shot of an RIR and associated frequency response of a room measured by REW.

### 3.1.2 Microphone

For the microphone, MiniDSP UMIK-1 \cite{11} shown in Figure 2 was selected because these microphones were pre-calibrated (every microphone comes with a calibration file with the microphone’s serial number) and is compatible with REW. It is also very affordable (USD 75 each as of January 2018) despite its high quality.

### 3.1.3 Loudspeaker

Ideally a loudspeaker with a flat frequency response would be used in order to ensure accurate measurements. However, because the loudspeaker also has to be compact and light to allow students to carry it in order to measure rooms on/outside the campus, a small computer loudspeaker with amplifier was utilised.

### 3.2 Assessment

Students were instructed to work in pairs. Each group was required to submit a formal report prepared to the standard expected of a Professional Engineer, which was assessed using the following marking rubric. The overall length of the report was limited to 4000 words.

**Completeness and professional presentation (40%):** The marking criteria assigned marks to the completeness of the assignment (whether all required tasks were completed). Correct spelling, gram-
mar and professional presentation were also assigned marks. **Correctness (40%)**: Reports were assessed if the contents and discussion in the report were technically correct. **Integration (20%)**: Reports were assessed if the authors of the report have integrated all relevant knowledge covered in the lectures in their presentation and discussion. In the discussion, students may refer to knowledge covered by other parts of the course or that they find in the published literature (correctly citing the original sources of information).

### 3.3 Tasks

In total, four tasks were given to students as requirements from the client, the details of which are summarised in the rest of this section.

**3.3.1 Requirement 1: Specifications of the microphone used for the measurement**

The first task was set to make students aware of the specifications of the equipment they used. Students were required to search and collect following information about the specification of the microphone (MiniDSP provides detailed specifications of this microphone on their web page):

- Microphone type
- Directivity type
- Frequency range
- Frequency response
- Sampling rate
- Bit rate

Students were asked to describe the format and function of the calibration file which contained data defining a fine resolution frequency response curve for the microphone from $10$ Hz to $20$ kHz.

**3.3.2 Requirement 2: Noise level in the measured rooms**

The second task was to measure the noise level using the sound level meter provided by REW. Students were required to have the measurement both in dB(A) and dB(Z) (not weighted), then explain why the discrepancy occurs between the two values by referring to the definitions of dB(A) and dB(Z).

For this and following tasks (i.e. Requirement 2 to 4), students were asked to investigate the acoustics of two different rooms. To that end, students were instructed to find two rooms that they thought were reasonably quiet. One room was to be smaller (Room A; $<100 \text{ m}^3$) than the other room (Room B; $>100 \text{ m}^3$). These rooms could be lecture theatres or meeting rooms on the University campus or anywhere outside the campus such as a room within students’ home. If the sound level measurement acquired for Requirement 2 exceeded $40$ dB(A), which indicates that the selected room would be too noisy for further measurement, students had to find another room or remove the cause of noise in the room. Students also had to take photographs of each room and show them in their report.

**3.3.3 Requirement 3: Reverberation time of the measured rooms**

The third task was to measure the reverberation time ($T_{60}$) of the rooms. The task required students to include the following values for the rooms measured in the report:

- Early decay curve (EDC) [12] for every 1/3-octave band frequency between $250$ Hz and $4\text{kHz}$ measured at two different positions in the room (i.e. Position A and Position B). Both of the positions should be at the same height and 2 metres away from the sound source (i.e. loudspeaker) but one of them should be closer to the walls of the room than the other position.
- Following values estimated from the EDCs measured at every position specified above (i.e. two positions in each room): Early decay time (EDT), $\text{T}_{20}$ [12]. For each position (i.e. Positions A and B), these values should be plotted on the same graph the horizontal and vertical axes of
which are frequency and estimated reverberation time, respectively. It was also expected that a
summary of how the values were calculated from the EDCs was included in the report.

- A sketch of the room plan which includes the dimensions of the room, the position of the
  loudspeaker and microphone used for the measurement.
- Discussion/explanation about the differences of the measured values between the rooms and
  positions in the same room.

3.3.4 Requirement 4: Speech intelligibility at different positions in the measured rooms

The final task was to evaluate the speech intelligibility at different positions in the measured rooms
using Clarity ($C_{50}$) [12] as an evaluation metric. The positions to be measured were: 0.5, 1.0, 2.0, and
3.0 metres away from the sound source placed at an arbitrary position in the room. The report had to
include following items:

- A plot of clarity ($C_{50}$) against distance from the sound source.
- Discussion about how the speech intelligibility varied depending on the room and the distance
  from the sound source. Students were allowed to refer to their observations provided by going
  through tasks in the previous Requirements.

3.4 Examples of measurements

Figures 3 and 4 show examples of room acoustics measurements conducted by a group of stu-
dents. Although the reverberation time is somewhat “bumpy”, which might have been caused by
measurement errors, the results still provide sufficient information to discuss the trend in the acousti-
cal property of the rooms. Common points students discussed in their reports were:

- $T_{60}$ was typically longer at low frequency than high frequency because of different amounts of
  sound absorption within the room at those frequencies.
- $T_{60}$ measured by EDT was typically shorter than that measured by T20 because of the effect of
  noise in the measured RIR.
- Speech intelligibility ($C_{50}$) was reduced with increasing distance from the sound source.

4. Laboratory practical session in acoustic chambers

The laboratory practical session complements the set assignment by focussing on techniques and
assessments to do with noise control. In particular the practical session takes advantage of the asso-
ciated facilities of the Acoustics Research Centre comprising 3 reverberation chambers and 1 large anechoic chamber all complying with relevant ISO standards for the measurement of sound level, absorption, transmission loss and impact insulation. The first component in the session is what we have termed the Acoustics Experience, which begins with small groups going into the anechoic chamber. For most students this is the first occasion they have experienced a reflection-free environment and an environment which has a background noise level significantly lower than their hearing threshold. After a brief acclimatisation we begin with a period in the complete darkness to focus our senses on hearing alone. This quite naturally prompts discussion of issues and experiences relevant to acoustics and acoustical practice including:

1. the contribution that reflected sound makes to the feel of spaces and to a listener’s emotions,
2. the functioning and performance of hearing e.g. the incidence of tinnitus (an increasing proportion of students comment on hearing loud tinnitus, c.f. only a very small minority 25 years ago),
3. the operation of the hearing system and its protection mechanism (responsible for the feeling of pressure experienced by persons new to anechoic surroundings), and
4. the opportunity to experience the results of simple diffraction, reflection and directivity experiments.

We then move to the large reverberation chambers and experience:

1. the potential for reverberation to disrupt intelligibility although making sounds appear louder, plus - as time permits - carrying out real word intelligibility (revealing the extent of the differences between first language, bilingual and second language listeners), and
2. how standard measurements for insulation and absorption are carried out.

Next, students are provided with stand-alone or virtual (VI) sound level meters and required to go out to measure typical sound spectra (e.g. traffic noise, fan noise) and become familiar with the Sound Pressure Level scale and A-weighted values. Using these they calculate sone loudness values to compare with their own impressions of the relative loudness of the different sources. The practical session is completed by a “self-training” session in our Listening Room (a standard room meeting the requirement of IEC Standard 681 for listening rooms) where recordings in different types of rooms (from domestic to concert halls) can be replayed with different reverberation times and at different sound levels. Students listen to the various sounds in different reverberation times and at different levels to become familiar with the various effects then follow that with a “test” session where they can compare their own judgments against objectively measured values. Finally the students have a hearing screening test plus a complete audiogram for those who fail the screening test. The value of including this experience in the acoustical chambers (i.e. environments at the extremes of the acoustical spectrum) cannot be overstated for engaging the interest and enthusiasm of students.

5. Student feedback

At the University of Auckland, each course may be formally evaluated by students through an online system. Most of the anonymous comments responding to the question “What was most helpful for your learning?” stated that the assignments were most helpful for students’ learning. Some of the comments are summarised below:

*In-class examples and assignment.*
*Practical assignments.*
*The very experimental and practical nature of this course. Being able to see demonstrations in class was useful.*
*Assignments which increase my understanding towards the subject and also prepare me for my exam. Assignment, using the microphone and speakers to find the SPL in rooms, calculating reverberation time, etc.*

Overall, the coursework was perceived by the students as being helpful for achieving the intended
learning outcomes of the course and most students appreciated their experience gained through the new coursework as well as other existing active learning components.

6. Conclusion

This paper has reported an active learning coursework that was recently developed for an Engineering Acoustics course offered at the University of Auckland. The coursework was designed with an aim to help students understand concepts covered in the lectures through a virtual experience of acoustical measurement processes that professional Acoustic Engineers have to know. The coursework is aided by a laboratory practical session held in our acoustics chambers which provides students with an opportunity to experience environments with different acoustical properties. Students’ feedback suggests the coursework has successfully helped students learning materials covered in the lectures. The effect of introducing the active learning coursework has to be measured in our future study.

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REFERENCES