



Northern Ireland
Assembly



Queen's University
Belfast



The Open
University



Ulster
University

Knowledge Exchange Seminar Series (KESS)

Acoustics for STEM and STEAM

Introduction

Acoustics is defined as *the science that deals with the production, control, transmission, reception, and effects of sound*. Many people think that acoustics is related only to music or buildings. As well as being involved in the production and recording of music, the testing and development of musical instruments and the suitability of performance spaces, acoustics is relevant to a vast array of topics, including noise control, SONAR for submarine navigation, ultrasound in medical imaging, thermoacoustic refrigeration, seismology, bioacoustics and electroacoustic communications (loudspeakers, microphones, public address, alarms). Acoustically-related activities range from cosmology, for example theories of wave propagation in the sun and in galaxies, to more down-to-earth matters such as the best way to stop noise from the house next door. Sound impinges on daily life continuously. We cannot 'shut' our ears. We expect reasonable acoustic conditions for sleeping, working, relaxing and communicating. We do not expect to suffer hearing loss at work; we do not expect to be disturbed by noise from other people or activities, yet we expect to be able to produce 'reasonable' levels of noise as part of our activities. Among other criteria, we judge the quality of many products from the way they sound. We want the benefits of technology, but we want to influence the ways in which it impacts our sense of hearing.

2018 is the 'Year of Engineering'. According to Engineering UK, Engineering contributes £456bn (27%) of UK GDP. There is an annual shortfall of 55,000 skilled workers and not enough new recruits coming through the system (<https://www.engineeringuk.com/our-programmes/tomorrows-engineers/>). To meet demand, we need to double the number of engineering apprentices and graduates entering industry. January 2018 has seen the Royal Academy of Engineering, collaborating with Engineering UK and industry partners, launch [This is Engineering](#) seeking to 'rebrand' engineering's image for young people aged 13-18 years, presenting it as dynamic, exciting and making a difference to society and how we live¹. There are predictable contributions concerning space science and robotics. But some of the associated videos concern acoustics². One introduces basic aspects of sound, speed, wavelength and frequency. One is concerned with room acoustics and another with building a sound diffuser. At a time when it is increasingly difficult to persuade school leavers to follow studies related to science and engineering, the multi-disciplinary and life-impinging aspects of acoustics make it an interesting area at all stages of education and for research and for career options. This briefing document explores what acoustics has to offer.

The fact that the study of acoustics crosses many discipline boundaries is illustrated by "Lindsey's Wheel of Acoustics" (Fig. 1) created by R. Bruce Lindsey (Journal of the Acoustical Society of America, volume 36, p. 2242 (1964)) who was an American physicist and physics professor, known for his prolific authorship of physics books. This wheel describes the scope of acoustics starting from the four broad fields of Earth Sciences, Engineering, Life Sciences, and the Arts. The

¹ Related films are available at www.thisisengineering.org.uk and [on YouTube](#).

² <https://www.youtube.com/watch?v=-S6FPeJW60s> https://www.youtube.com/watch?v=oHTmNyo_00Q
<https://www.youtube.com/watch?v=JPYt10zrcIQ>

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outer circle lists the various disciplines one may need study to prepare for a career in acoustics. The inner circle lists the fields of acoustics to which these disciplines relate.

Acoustics research at the Open University

Past and present acoustics research at the Open University relates to most of Lindsey's Wheel (Figure 1). Soon after the Open University was created, advantage was taken of the large number (4000) of students distributed throughout the UK on the original Foundation course in Technology. The Technology students were issued with low-cost sound level meters as part of a 'Home Experiment Kit' and used them to survey noise levels³. Traffic noise measurement features as one of the residential school activities for the current first level Technology course.

'Greening for noise control' 'sonic crystal noise barriers' and 'rough surface noise barriers' were the basis of a KESS talk in 2017 where I presented results of research supported by EC FP7 (www.greener-cities.eu). Fundamental research on 'acoustic-to-seismic coupling', i.e. the way in which above-ground sound sources make the ground surface vibrate, has applications in 'non-invasive soil monitoring' and 'buried landmine detection' and in improving the location and identification of acoustic and seismic sources. Following a research grant entitled 'Periodicity-Enhanced Absorbing Layers and Structures (PEALS)' and through a current EC COST network, the Open University is involved in the 'hot topics' of acoustic metamaterials and additive manufacture. The unusual properties of metamaterials can be used to create thin lightweight sound-absorbing and sound-insulating structures.

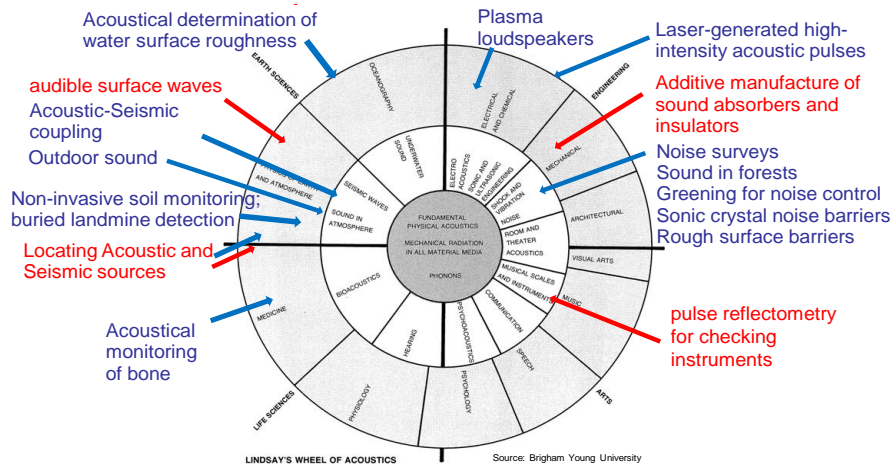


Figure 1 Lindsey's wheel of acoustics and relevant *past* and *present* research at The Open University

Research on musical instrument acoustics bridges the arts-science divide. Professor David Sharp, who heads the work on musical instrument acoustics, was included in the 'Music' submission from the Arts Faculty at the Open University in the last research assessment exercise.

Acoustics and Music Education

Although typical STEAM initiatives strive to introduce arts and design into STEM teaching, acoustics provides a way of introducing STEM learning into Arts education. The essential connection between acoustics and music seems to be ignored or taken largely for granted by education for music performance. Many professional musicians, composers and conductors in the UK complete their extensive musical training without a basic understanding of the fundamental acoustics concepts related to their work. In the UK, out of 71 institutions providing training in music (Higher Education Statistics Agency, 2015), only three Higher Education (HE) institutions provide a brief acoustics education to some students. Moreover, this instruction focuses mainly on aspects of instrument acoustics while neglecting important topics such as the acoustics of auditoria. A relevant course would cover the nature of sound, the auditory system, hearing conservation, psycho-acoustics, acoustics of performance spaces and musical acoustics. With the aim of promoting the introduction of basic acoustics into the music performance curriculum in the UK, Luis Gomez-Augustina (gomezagl@lsbu.ac.uk) at London South Bank University has conducted an online survey in which 31 institutions participated (including the most prominent in the UK) as well as interviewing 21 senior music academics. The results of his study strongly suggest that there is a potential demand for the introduction of acoustics teaching into music education.

³ S E Clark, K Attenborough and W A Utley, Background Noise Levels in the United Kingdom, *Journal of Sound and Vibration* 48(3) pp 359-375, August 1976; J R Brooks, K Attenborough and W A Utley, "Student based surveys of noise levels in and around dwellings in the U.K." *J.Sound.Vib.* 132(2) pp 317-330 (1989).

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The Control of Noise at Work Regulations (2005) are designed to prevent hearing damage from occupational noise exposure and, since 2008, they cover musicians working in the music and entertainment industries. A good education programme should include information on the resulting requirements for employer's and employee's responsibilities, typical noise exposures and the associated risk to hearing, the signs and symptoms indicative of hearing damage, the types of hearing protectors available, the advantages and disadvantages of each type and the extent to which hearing protection is an effective method for controlling noise exposure⁴.

The Institute of Acoustics

The Institute of Acoustics (IOA) is the **UK's** professional body for those working in **Acoustics**, Noise and Vibration. Its membership of about 3000 individuals work in a variety of research, educational, environmental, governmental and industrial organizations. The Institute has nine specialist interest groups which organize meetings throughout the year and there are regional events hosted through a network of eleven Branches (including an Irish branch which offers an annual award for the best performance on the Institute of Acoustics Diploma in Acoustics and Noise Control by an Irish candidate). For the 2016 to 2017 Diploma presentation, the best student prize for overall performance on the course is being awarded to a student based in Northern Ireland (Jill Crawford, Fermanagh and Omagh District Council).

Working as an acoustician offers an excellent route to achieving Incorporated Engineer (IEng) or Registered Engineer (CEng) status with the Engineering Council. The requirements for registration changed in 1999 so that CEng requires a Masters degree and IEng an ordinary degree. Since the Institute of Acoustics is one of the bodies licensed by the Engineering Council, it enables suitably qualified applicants to achieve these important professional qualifications.

The profile of a recent IEng candidate who graduated in music and worked as a professional musician is shown in Figure 2. He has been helped by IOA courses and the IOA Engineering Division along a career path to acoustics consultancy.

Nick Long

"Having graduated in music back in 1999 with a BA (Hons), I worked for around 13 years as a musician, which involved teaching, performing and examination work around the UK and Ireland. During the latter part of my music career, I elected to undertake the Certificate of Competence in Environmental Noise measurement and subsequently the Diploma in Acoustics and Noise Control at Colchester Institute in 2010.

Achieving the IOA diploma enabled me to complete my career transition from music into acoustics.

During the early stages of my career in acoustics, I initially gained valuable practical experience centred around system design for HVAC, survey / design work and acoustic modelling. Alongside this experience I also developed working knowledge of legal metrology,



concerned primarily with acoustic instrumentation whilst working as a calibration engineer. It was during this time I applied to become a corporate member (MIOA) of the IoA.

Currently, I work as a consultant for Cahill Design Consultants (CDC). My day to day duties include acoustic design work for hotels, residential and acoustic modelling. Additionally, I undertake long term noise and vibration monitoring.

Gaining Incorporated Engineer (IEng) registration was a very positive move, as it enabled me to demonstrate a culmination of my experience to date in the form of a recognised qualification.

Good support from colleagues and the IoA meant that the process was relatively straightforward, with clear guidance on preparing the associated paperwork for the interview.

Once I have gained sufficient additional skills and experience, I would seek to apply for CEng in the future".

Figure 2 Profile of a successful IEng candidate with an Irish connection (from *Acoustics Bulletin* Vol.43 January/February 2018).

Schools Activities

In 2008, the IOA worked with STEMNET in the East of England to create resources that use aspects of acoustics as a learning and teaching context and presented these ideas at a STEM conference for teachers where 'acoustics' was chosen to feature alongside such popular topics as 'robotics' and 'space'. The first activity introduces the noise and the potential for hearing damage if noise levels are too high. The second involves measurements with a sound level meter and enables the opportunity to introduce graphs and statistics.

The Institute of Acoustics works with SETPOINT (<http://www.setpointherts.org.uk/>) to encourage corporate members to become 'Acoustic Ambassadors', promoting 'Acoustics' as a career choice. Acoustic Ambassadors are part of a national team of Science and Engineering Ambassadors, all of whom are promoting their passion for Science and Engineering. In this connection an exercise for school pupils and associated experimental kit have been developed by a practising

⁴ <http://www.hse.gov.uk/noise/musicound.htm>

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acoustics consultant, and Acoustics Ambassador, Richard Collman (RichardAC@acoustical.co.uk). Pupils are asked to pretend that they are in a band but need somewhere to practice. They can use a room at home as long as they ensure that they do not disturb the other occupants. The different 'bands' have to design the most effective scheme using the materials available as part of the kit subject to a major budgetary constraint and some minor constraints such as not suffocating the band. Each band is given a test rig consisting of a drum and bass simulator (airborne bass guitar and structure borne impulsive 'drum' beats), together with a framework into which they can fit a range of 'costed' materials of differing density and absorptive characteristics such as foam, sheet steel, plywood, hardboard, plastic and wadding. The test rig enables them to test partitions of single or composite construction and to see how well the different constructions cope with airborne and structure borne sound. A 'floating floor' is also available as part of the test assembly. The acoustics ambassador checks and compares the performance of the final designs, and after a final session where the pros and cons of each design are discussed a 'winner' is declared.

Many other acoustics-related teaching and learning resources are available to teachers. Some result from an EPSRC-supported project 'Sound Matters' which was carried out jointly by Salford and Southampton Universities, the only UK Universities who offer undergraduate degree courses in acoustics (http://www.acoustics.salford.ac.uk/acoustics_info/sound_matters/ and <https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=APEN>).

Teachers and others can learn about ways of involving school pupils in science and engineering at the increasing number of science fairs including 'big-bang' events <http://www.nsew.org.uk/>.

Earlier this month, the Open University was involved for the fourth time in the Northern Ireland Science Festival. Among the six contributions on February 15th to 18th this year was a shouting competition at the Foyle Shopping Centre in Derry/Londonderry organised by Dr. Shahram Taherzadeh (<http://www.nisciencefestival.com/event.php?e=184>).

An Acoustics Engineering Technician Standard

An amendment to the Technical and Further Education Act (May 2017), proposed by the former education secretary Lord Baker and known, therefore, as the Baker clause, came into force on 2nd January 2018. It requires all local authority-maintained schools and academies to give education and training providers the opportunity to talk to pupils in years 8 to 13 about approved technical qualifications and apprenticeships.

A timely initiative by Richard Grove (of the Building Design Partnership richard.grove@bdp.com) aims to create an Acoustics Engineering Technician Apprenticeship Standard through the Government Trailblazers system. There are many companies and authorities involved in acoustics, but they tend to be relatively small. They include consulting firms that specialise in the built environment; planning consultants; construction companies; health and safety practitioners; entertainment and performing arts venues; a variety of engineering disciplines and national and local government.

An Acoustics Engineering Technician would be part of a wider project team, focussing solely on the acoustic aspects of a project, alongside fellow specialists. Specific job titles would include:

- Architectural and Environmental acoustics technician
- Acoustics laboratory technician
- Acoustics calibration engineering technician
- Junior environmental health officer for noise
- Acoustics design technician
- Digital Signal Processing (DSP) technician

A problem encountered during the development of the standard was the need to persuade the Institute for Apprenticeships panel that an Acoustics Engineering Technician standard would be sufficiently distinct from existing Technician standards such as for Building Services, Construction and Highway Engineering. Nevertheless, an application for a Level 4 Acoustics Technician standard has been accepted by the Government's Trailblazer group. It appears under 'Construction' in the Occupational Maps document currently out for consultation (https://consult.education.gov.uk/apprenticeships/institute-for-apprenticeships-occupational-maps/supporting_documents/Draft%20occupation%20maps.pdf).

The next steps require devising a course content, obtaining approval of an assessment plan and selection of provider(s).

IOA Certificate and Diploma courses

The syllabus for the Acoustics Engineering Technician will draw on the content of existing IOA courses. These include five short (week long) certificate courses and a one-year Diploma in Acoustics and Noise Control. The certificate courses relate to workplace noise (CCWPNRA), environmental noise measurement (CCENVM), building acoustics measurements (CCBAM), hand-arm vibration (CCMOEHAV) and anti-social behaviour (Scotland). They are delivered through accredited centres and involve written and practical examinations devised by certificate examiners management

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committees under the auspices of the IOA. CCENM and CCWPNRA have been offered since 1990. CCMOEHAV has been running since 2003. To date more than 2000 students have satisfactorily completed the courses. CCBAM was introduced in 2012 but, to date, is delivered at only one Centre.

The Institute of Acoustics Diploma in Acoustics and Noise Control is intended to provide sufficient specialist academic training to satisfy the educational requirements for Membership of the Institute of Acoustics. The Diploma has been presented since 1975 and is well known for providing a high-level training in acoustics and noise control. It is widely recognised as the educational qualification of choice for the professional practitioner in acoustics. Four Universities (Derby, Leeds Beckett, London South Bank and Southampton Solent) recognise the Diploma as providing partial exemption from their requirements for the award of MSc degrees.

Although the normal entry requirement is a relevant degree, the IOA aims for the Diploma to be as open access as possible and accepts some entrants with little more than GCSE-equivalent Mathematics and Physics as long as they have relevant professional experience. In this regard, it offers greater flexibility in entrance requirements than the MSc courses at Salford and Southampton.

Careers in Acoustics

Many acoustical activities relate to engineering. As part of another recent promotion of engineering and careers in engineering, a website 'tomorrows engineers' has been created - <https://www.engineeringuk.com/our-programmes/tomorrows-engineers/>. A visitor can click on options of interest and, in response, links to video introductions to relevant careers are listed. Not surprisingly introductions for careers associated with music recording significantly outnumber those associated for example with architectural acoustics. The list generated by the choices 'music', 'environment', 'construction', and 'transport' result in six links to videos about sound recording and only one about building acoustics. We find that many current applicants for the IOA Diploma arrive with qualifications in media technology or music, having gained an interest in acoustics along the way. On realising that there are many more job opportunities in acoustics and noise control than, for example, in sound recording or as a performing musician, they apply for the IOA Diploma⁵.

Acoustics teaching and research in Northern Ireland

The only undergraduate acoustics teaching in Northern Ireland is in the University of Ulster where The BSc Environmental Health degree course ranges across Food Safety, Microbiology, **Acoustics and Noise Control**, Statutory Nuisance, Housing, Regulatory Frameworks, and general Environmental Health. Teaching and learning about Acoustics and Noise Control teaching is found also in courses including Construction, Design and Management, Building Surveying, and Civil Engineering. Although UU delivered the IOA Diploma and Certificates before the retirement of Dr. Oliver Hetherington, it has been able to do so in recent years since the number of applicants has not been sufficient.

While there has been past research in the Mechanical Engineering Department at Queens University Belfast related to the acoustical design of (power) generator sets (<http://www.qub.ac.uk/sites/drone/>), there is no current research of this kind. On the other hand, as well as the research from Queens being presented today, the Sonic Arts Research Centre (SARC) is a globally recognised institute for music-based practice and research. Associated with this Centre, Dr Maarten van Walstijn (m.vanwalstijn@qub.ac.uk), of the School of Electronics, Electrical Engineering and Computer Science, carries out work on musical instrument acoustics. Maarten is part of a UK wide Musical Acoustics Network in which Prof. David Sharp of the Open University is involved also.

A broader UK Acoustics Network (UKAN) is a new initiative funded by EPSRC and was launched at an event on 27 November 2017. It aims to bring together researchers working in different areas of acoustics, to enhance communication between groups, provide focus for collaboration and innovation and to maximise the future impact of acoustics related research in the UK. It is open to anyone with an interest in acoustics and who cares about the future of acoustics-related research and innovation (<https://acoustics.ac.uk>).

Concluding remarks

Acoustics offers a rich and rewarding set of opportunities for teaching and learning at all stages of education and for research. But acoustics rarely features in school teaching or in university physics and engineering curricula. Sound can

⁵ Useful career websites

<http://www.eclips-online.co.uk/leaflet.php?id=Q05> Music recording
<http://www.eclips-online.co.uk/leaflet.php?id=PA10> Radio
<http://www.eclips-online.co.uk/leaflet.php?id=PA13> Film and TV Technical jobs
<http://www.ioa.org.uk/careers>

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be used to exemplify aspects of waves in the GCSE physics syllabus and noise can be part of environmental studies. Acoustically-related research topics at the Open University include outdoor sound prediction, soil science, early diagnosis of osteoporosis and musical instrument technology. These and other example applications offer ways of motivating acoustically-related teaching and learning in school and university STEM curricula. Musical acoustics offers a basis for introducing Arts into STEM curricula and for introducing a STEM flavour into music education. There is clear scope for increasing acoustically-related teaching and research in Northern Ireland. UKAN and the IOA should be able to contribute to any efforts in this regard.

