Institution: London South Bank University		
Unit of Assessment: 13 – Architecture, Built Environment and Planning		
Title of case study: A Sound Design of Schools		
Period when the underpinning research was undertaken: 2000 – 2014		
Details of staff conducting the underpinning research from the submitting unit:		
Name[s]:	**Role[s] [e.g. job title]:**	**Period[s] employed by submitting HEI:**
Bridget Shield	Professor of Acoustics	1986 – 2014
Julie Dockrell	Professor of Psychology	1998 – 2000
Stephen Dance	Professor of Acoustics	2000 – current
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

Over the past twenty years the unit has carried out research into the impact on pupils and teachers of poor acoustic conditions, including high noise levels and excessive reverberation, in schools. The research has shown that pupils of all ages and abilities in primary and secondary schools are negatively impacted in terms of their performance in class, their concentration and their academic achievements. The impact of the research is evidenced by the active and extensive participation of Professor Shield in assisting the Department of Education and the (then) Department of Communities and Local Government to draft revised legislation (contained in Building Regulations) on the acoustic design of schools, and related guidance documents, which were published in 2015. Through Professor Shield's involvement, the results of the research have informed the scope of the legislation and specific design performance standards, which must be met to comply with the Building Regulations. These have led to improved conditions for teaching and learning in new and refurbished schools in England and Wales, benefitting all pupils and teachers, and to increased work for UK acoustic consultancy firms. The research itself and the regulations have also influenced international standards and research.

2. Underpinning research (indicative maximum 500 words)

Context

In the 1990s the (then) Department for Education and Skills (DfES) was concerned about the poor acoustic design of school buildings, which led to high noise levels and reverberant classrooms, making it difficult for pupils to hear their teachers and for teachers to speak. The DfES, together with the Department for Communities and Local Government (DCLG) decided to introduce legislation as part of Building Regulations, to govern the acoustic design of new school buildings. The acoustic performance standards which were to be met to satisfy Building Regulations and the School Premises Regulations were contained in Building Bulletin 93: Acoustic Design of Schools (BB93), published by DfES in 2003. Also, in the late 1990s, the Department of Health (DoH), recognising that there was a gap in evidence for the impact of noise on children's health and general well-being, funded research in this area. In 1999 Professor Shield was awarded a DoH grant for a collaborative study with LSBU Professor of Psychology, Professor Dockrell (now at the Institute of Education), to study the effects of classroom and environmental noise in London primary schools on children's learning.

Following completion of the DoH project in 2001, Professor Shield continued to develop and lead a research programme at LSBU, in collaboration with the Institute of Education and the University of Salford, further examining the effects of acoustic design of schools on pupils and teachers in primary and secondary schools and open plan classrooms, mainly supported by EPSRC (see Section B3).

Research methodology

In all of the school acoustics projects the research consisted of:

- questionnaire surveys of pupils (completed by over 2,000 primary and 2,500 secondary school pupils) and teachers to ascertain their awareness of, and attitudes to, noise and its effects on the ability to hear the teacher and to work;
- external noise surveys around schools (142 primary; 13 secondary) and detailed internal noise surveys of empty and occupied classrooms (140 primary; 185 secondary);
- comparison of internal and external noise levels with results of national standardised tests (SATs) in primary schools;

- development of age appropriate tests of literacy and numeracy, and experimental testing of pupils (160 primary; ~1,000 secondary) using these tests in artificially generated noise conditions
- acoustic and questionnaire surveys of pupils and teachers in 42 classrooms in 12 open plan schools.

Key findings of the research

The research provided clear evidence of the extent and type of impact of noise and poor acoustics on school pupils of all ages. Key findings were as follows:

Noise in schools and pupils' perceptions

- Noise levels in schools vary significantly (by up to 20 decibels (dB) in primary schools) depending on the numbers and ages of pupils, classroom activities being undertaken etc. Levels increase with the number of pupils and tend to decrease with the age of pupils. Average levels measured in occupied classrooms were 72 dB in primary schools and 64 dB in secondary schools **[R1, R2]**.
- The most common source of noise in school classrooms is that of pupils talking **[R1]**.
- Pupils of all ages were annoyed by internal and external noise and reported it affecting the ease of hearing the teacher. Annoyance was related to noise levels **[R3, R4]**.
- The sounds perceived to be the most disturbing in both age groups were from intermittent internal and external noise sources **[R3, R4]**.

Effects of noise on pupils performance and attainments

- In primary schools, the scores of Year 3 (age 8) pupils in spelling, reading and arithmetic tests were adversely affected by classroom babble at 65 dB, as was their speed of processing **[R5]**.
- The performance of children with special needs was much more severely affected than that of other pupils **[R5]**.
- In secondary schools classroom babble at 70 dB affected the performance of students aged 11 – 16 in reading tests; the older pupils were also affected at 64 dB **[R6]**.
- Noise affects academic attainments (SATs) of primary schools, particularly at Key Stage 2: an increase in average background classroom noise of 5 dB corresponded to a drop of 13% in school SATs scores **[R7]**.

Acoustic design of classrooms

- Noise levels during lessons are related to the acoustic design of the classroom: the higher the unoccupied noise level and reverberation time, the higher the noise levels during lessons **[R2]**.
- The BB93 design criterion of 35 dB maximum background noise level in an unoccupied classroom corresponds to a level of 64 dB in an occupied classroom during lessons **[R2]**.
- Absorptive ceilings are more effective than carpet in reducing noise levels and reverberation **[R2, R8]**.
- In order for open plan classrooms to be used successfully certain design criteria must be achieved, for example: no more than three class groups sharing a space, low reverberation times and specific speech criteria to provide good speech intelligibility (R8).

The number of teaching spaces meeting BB93 criteria doubled when the acoustic requirements became mandatory under the Building Regulations in 2003 **[R2]**.

3. References to the research (indicative maximum of six references)

The research has been published in rigorously peer-reviewed journals in the Acoustics and Education fields. The Journal of the Acoustical Society of America is regarded as the most prestigious journal in acoustics, and the British Educational Research Journal is the major journal for the publication of educational research.

[R1] Shield, B, Dockrell, J. E., (2004). External and internal noise surveys of London primary schools. The Journal of the Acoustical Society of America. 115, 730; https://doi.org/10.1121/1.1635837

[R2] Shield, B., Conetta, R., Dockrell, J., Connolly, D., Cox, T, and Mydlarz, C. (2015). A survey of acoustic conditions and noise levels in secondary school classrooms in England The Journal of the Acoustical Society of America 137, 177; https://doi.org/10.1121/1.4904528

[R3] J E Dockrell and B Shield. (2004). Children's perceptions of their acoustic environment at school and at home. The Journal of the Acoustical Society of America 115, 2964 (2004); https://doi.org/10.1121/1.1652610

[R4] Connolly DM, Dockrell JE, Shield BM, Conetta R, Cox TJ. (2013) Adolescents' perceptions of their school's acoustic environment: The development of an evidence based questionnaire. Noise Health;15:269-80; https://doi.org/10.4103/1463-1741.113525
[R5] Dockrell, J. E.; Shield, B. (2006) Acoustical Barriers in Classrooms: The Impact of Noise on Performance in the Classroom. British Educational Research Journal, 32, 3, 509-525; https://doi.org/10.1080/01411920600635494
[R6] Connolly, D., Dockrell, J., Shield, B., Conetta, R., Mydlarz, C., and Cox, T (2019). The effects of classroom noise on the reading comprehension of adolescents. The Journal of the Acoustical Society of America. 145, 372; https://doi.org/10.1121/1.5087126
[R7] Shield, B, Dockrell, J. E., (2008). The effects of environmental and classroom noise on the academic attainments of primary school children. The Journal of the Acoustical Society of America. 123, 133 (2008); https://doi.org/10.1121/1.2812596
[R8] Greenland, E. E., Shield, B. (2011). A survey of acoustic conditions in semi-open plan classrooms in the United Kingdom. The Journal of the Acoustical Society of America. 130, 1399; https://doi.org/10.1121/1.3613932

Quality of the research

The quality of the research has been demonstrated by the succession of research grants awarded to Professor Shield and colleagues to continue and extend the research.

Key grants

1. 1999-2001. The effects of noise on the attainments and cognitive performance of primary school children. Department of Health £96,000. PI: Professor Shield.
2. 2002-2005. Acoustic design guidelines and teacher strategies for optimising learning conditions in classrooms for hearing and hearing impaired children EPSRC (GR/R26634/01) £159,000. PI: Professor Shield.
3. 2003-2007. Acoustics of open plan classrooms EPSRC Doctoral Training Account £50,000 Supervisor: Professor Shield.
4. 2009-2012. Identifying a sound environment for secondary schools. EPSRC (EP/G009767/1) £380,000 PI: Professor Shield.
5. 2011-2018. Voice problems among teachers. Part time PhD studentship sponsored by Sharps Redmore Partnership. Supervisors Professor Shield and Dr Dance.

Grants 2 and 4 were for collaborative projects carried out with Professor Dockrell (Institute of Education, UCL) (grants 2 and 4) and Professor Cox (University of Salford) (grant 4) who were each awarded EPSRC funding for the projects. The total funding awarded to the collaborating institutions was £502,000, in addition to the LSBU funding.

The impact and quality of the research has been recognised by academic bodies nationally and internationally through the award to Professor Shield by the UK Institute of Acoustics in 2011 of the R W B Stephens medal, citing the influence of the research on regulations and improving the design quality of schools; and by her election in 2014 as a Fellow of the Acoustical Society of America *'for research, teaching, and leadership to standardize classroom acoustics'.*

4. Details of the impact (indicative maximum 750 words)

The research has had a direct influence on government policy and regulations concerning the acoustic design of schools.

Pathway to impact

In 2001 Professor Shield was invited by the DfES to chair the drafting committee of Building Bulletin 93 (BB93), and was subsequently appointed as editor of the document, which was published in 2003. Evidence from the research on noise levels in schools and the detrimental effects of noise on pupils' performance and ability to hear the teacher informed discussion on the mandatory performance standards in BB93, such as maximum allowable noise levels and reverberation times in schools.

In 2008 concern was mounting within the acoustics profession and the Department of Education that schools continued to be built without adhering to the regulations, by applying (often incorrectly) permitted exemptions. There was also concern that the regulations did not apply to alterations or refurbishments of school buildings. At the same time many architects and building contractors argued that the regulations were too onerous and imposed too great a financial burden on school building works. On 16th October 2009 the (Labour) Minister for Schools and Learners, Vernon Coaker, made a statement in the House of Commons announcing a review of BB93, to be carried out in 2010 **[S1]**. However, following the 2010

general election the new (Conservative) government decided to revoke all legislation and Building Bulletins relating to school building, following a review of the capital costs of school building **[S2].**

In 2011, as President-elect of the Institute of Acoustics (IOA), Professor Shield led a joint IOA/Association of Noise Consultants (ANC) campaign to lobby the government on the importance of maintaining the regulations. Activities included:

• producing a briefing note for MPs outlining the economic cost of poor acoustics in schools and including results of research by Shield and Dockrell

• visiting Lord Hill, the Parliamentary Under-Secretary for Education, to present the research results, in particular the decrease in schools' SATs results with increased noise levels, and the greater impact of noise upon pupils with special needs.

Following the lobby, in 2012, the Secretaries of State for Education and for Housing, Communities and Local Government agreed to retain BB93 and the regulations on school acoustics in a revised form **[S2]**.

Impact on policy

Following the policy decision to revise the Building Regulations on the acoustic design of schools, a panel of experts was established by the Department for Education (DfE) to debate changes to the performance standards in BB93. Professor Shield's extensive research and knowledge meant she was asked by the DfE to chair the panel in its early days and subsequently played a leading role in discussions and in drafting the revised legislation and guidance **[S2, S3]**, several aspects of which were directly influenced by her research (see below). The panel met at regular intervals from 2012 to 2015, and also organised, with the DfE, conferences and consultations on the proposed revisions

In 2014 the DfE and Education Funding Agency (EFA) carried out an Impact Assessment and cost benefit analysis of proposed changes to the regulations **[S4]**. Research by Shield and Dockrell was repeatedly cited as evidence that the introduction of regulations in 2003 had improved the acoustic performance of new school buildings and of the impact of poor acoustics on pupil attainment (S2, S4). Ministerial approval for the changes was granted in late 2014 **[S2]**.

The revised Building Bulletin 93 was published in February 2015 **[S5]**.

Guidance on the new regulations was published by the IOA and ANC in November 2015 (S6). Professor Shield took a lead role in editing the document, which has become an essential document for all those involved in the design of school buildings **[S3b, S3c]** and also contains several references to the research by Shield *et al* **[S6]**.

Examples of influence of research on standards in revised edition of BB93 (2015)

- The 2003 edition of BB93 specified 35 dB as the design criterion for background noise in empty classrooms. At the time of the revision there was pressure on the DfE from architects, consultants and building contractors to relax this to 40 dB. The research by Shield and colleagues showing the detrimental impact of noise on pupils was influential in leading the panel to maintain the original standard of 35 dB **[S2]**.
- The original version of BB93 did not apply to refurbishment of school buildings. This meant that many older schools, even if they had been refurbished, still had a poor acoustic environment. A major change in the revision is that refurbishments are now included, with performance standards being specified for refurbished spaces **[S2, S5]**.
- More extensive standards and guidance are included on open plan classrooms, based on the LSBU research **[R6] [S2]**. The performance standard for reverberation time (RT) for open plan classrooms was reduced from 0.8 to 0.5 seconds, and additional criteria were provided for speech intelligibility **[S5]**.
- The regulations have been made more inclusive by referring to pupils with multiple special needs, rather than just hearing impaired pupils as previously, as evidence now exists to show that such pupils are more affected by noise than others **[R3]**. Moreover, the RT requirements for rooms for teaching hearing impaired pupils are more stringent than previously **[S5]**.

Social impact

There are approximately 9,000,000 pupils in primary and secondary education in around 24,000 schools, according to DfE 2019/20 figures **[S7]**. All pupils could potentially benefit from improved acoustic conditions in schools as a result of the research **[S3a]**. Both new and existing school buildings will now have an acoustic environment which supports teaching and learning. The research has shown that pupils will be better able to hear and understand their teachers; teachers

will be able to speak more easily; and the academic performance of pupils will not be adversely affected by high levels of noise. This has been a consistent impact for all new and refurbished schools from 2015-20. Furthermore, pupils with hearing impairment or other special needs, who are taught in mainstream schools, are provided with more appropriate conditions for learning, hence reducing the need for such pupils to attend special schools, with the additional cost implications.

Economic impact

In the 5 years from 2015 to 2020, GBP7,400,000,000 (£7.4bn) was allocated by the government for school building works, including new school buildings and improvements to existing buildings **[S3c]**. All this building work will have to comply with the revision of BB93, and hence acoustic consultants will be involved with the projects **[S3]**. The value of this work to acoustic consultancy firms is calculated to be up to GBP3,500,000 (£3.5m) per annum **[S3c]**. BB93 **[S5]** and the associated guidance **[S6]** are also used for almost any type of learning environment, "*such as higher education, training facilities, and corporate meeting rooms*", where good conditions for listening and speaking are required **[S3c]**.

International impact

The research by Professor Shield, both directly and through BB93, has had a wide international reach **[S2, S3b, S8, S9, S10, S11]**. Countries where classroom acoustics research has been influenced by the LSBU research include Italy **[S8]**, New Zealand **[S9]**, and the US **[S10]**. The 2015 revision of BB93 has influenced recently introduced standards in countries including Italy (2020) **[S8]**, New Zealand (2020) **[S9]** and Hungary **[S11]**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] Hansard for 16 October 2009
[S2] Testimonial from the Design Team, Department of Education – PDF
[S3] Testimonials from Acoustic Consultant Directors – PDF
[S3a] Global Head of Acoustics, Cundall
[S3b] Director of Acoustics at Ramboll
[S3c] Director of Apex Acoustics Ltd. & Chair of Association of Noise Consultants, 2016-18
[S4] Validation Stage Impact Assessment - Revision of Building Bulleting 93: "Acoustic Design of Schools" - DfE guidance in support of Requirement 4 of the Building Regulations
[S5] Acoustic design of schools: performance standards. Building Bulletin 93 (Feb 2015)
[S6] Acoustics of Schools: a design guide – Institute of Acoustics & Association of Noise Consultants (Nov 2015)
[S7] Government School and Pupil Figures
[S8] Testimonial from Associate Professor, Politecnico di Torino and published Conference paper: The new Italian standard UNI 11532 on acoustics for schools – PDF
[S9] Testimonial from Marshall Day Acoustics Consultant with associated New Zealand Ministry of Education Guidance – PDF
[S10] https://acousticalsociety.org/fellows-of-the-society/
[S11] New Hungarian room acoustics standards – the MSZ 2080 series (Huszty, 2018)