4 Effective learning by design

THIS SECTION AT A GLANCE

- **we look at recognised standards for a range of aspects of learning space design: general good design practice; functional room specifications; audio/visual standards; IT standards;**
- **we discuss lessons learned from previous learning space projects which form the basis for the guidance given here.**

Expectations from reading this section

Each of the professional associations contributing to this Toolkit has a specialist interest in one or more of these subsections. We have however grouped them together to encourage readers to take an overview of the topic as a whole because of the interrelationship between the various aspects and the way in which they provide opportunities and constraints affecting the way each of the professions can support users of the space.

One of the main lessons learned from evaluation of other spaces is that some of the management and usability issues that occur can be designed out if a holistic view is taken at an early stage. Conversely, any project is likely to go through a stage of conceptualising an ideal design and then some form of *value engineering* to better match the specification to the resources available for the project. The guidance in this section will enable you to take a value engineering approach whilst having an eye on the long term sustainability and usability of the space.

In particular we suggest that:

- Heating, ventilation, cooling and noise are key to user comfort and perceptions of the space and economies in this area can lead to serious usability issues that are costly and difficult to rectify afterwards. Natural light is important for the wellbeing of staff and students, and staff in particular exhibit a preference for having some form of environmental controls that can be user regulated.
- The ability to both see and hear what is going on in any kind of formal directed learning session is fundamentally important for learners. The availability and affordability of technology to support visual display may make issues of poor sight lines an easier problem to solve than poor acoustics in cases where electronic display is used, although this is not the case where writing remains important to the teaching practice.
- As learning and teaching practice develops we should not necessarily be constrained by the assumption that all spaces used for teaching should have a defined front and we need to understand the implications of new types of collaborative learning for those supplying audio visual and other teaching facilities.

4.1 Introduction to design standards

The guidance in this section is based on three fundamental premises[64]:

- learning spaces must be usable by all those who need to work in the space;
- users of the space must be able to hear what is presented;
- learners must be able to see what is presented.

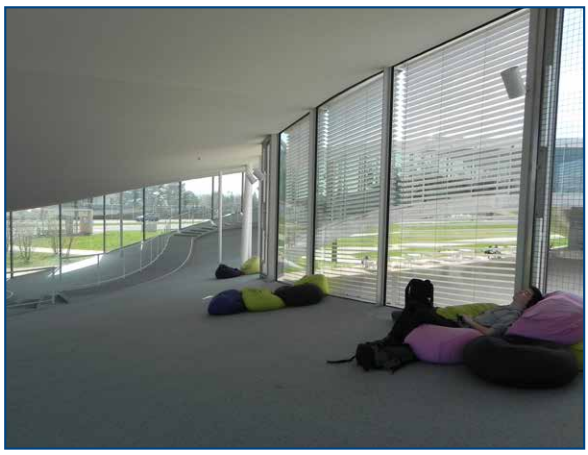

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Photo 5: The Rolex Learning Center, EPFL, Lausanne, was conceived as a rolling landscape with formal and informal study areas.

The use of the term *design standards* may give rise to a concern that all learning spaces that apply the same standards will end up looking alike; this could not be further from the truth. The requirements of a learning space amount to far more than usability, viewability and audibility. The application of different styles of pedagogy and the technologies that support this are what ultimately lead to differentiated, engaging, and inspiring learning spaces. This is why the design principles discussed in Section 1, Building a new pedagogy, are so important and why inspiring and motivating students is a core aim. We need to delight as well as be functional.

Good design in learning spaces will take account of the following characteristics of the space[65]:

- **Intended use** —thought needs to be given to the learning and teaching scenarios to be deployed and the identities of the learners and teachers.
- **Adaptability** — so that the space can be easily and quickly reconfigured for the range of different teaching and learning scenarios for which it is intended.
- **Inclusivity** — the space should be designed so that it is readily accessible and usable by all members of the student and staff population. Bearing in mind that significant numbers of people have physical disabilities, mental health issues and learning difficulties such as dyslexia, choice and control over the learning environment can make a significant difference to the usability of space[66].
- **Usability** — spaces that are easy to use will be used. User interfaces should be simple and intuitive. When designing controls, make sure that the most used items are the most visible and that controls that are likely to confuse less expert users are difficult to find accidentally. Related characteristics are **consistency** (e.g. of interfaces, software versions, layout, colour of cables, placing of user controls) and **reliability** (e.g. avoid equipment that uses batteries, can be inadvertently removed or has a high failure rate). Inevitable tensions between the degree of standardisation implied by these characteristics and a desire to innovate and experiment will have to be worked through with stakeholders.

> *"It should be obvious on entering the space how to turn equipment on and get it running without having to read a manual. The very exercise of trying to achieve this scenario should focus the minds of the designers onto the important issue of how the space and its technology are to be used to promote learning instead of creating 'eye candy'. This process would need the engagement of potential user groups at the design stage to go through scenarios of operation, but would hopefully result in a much more user friendly environment."* (Martin 2010[67])

64 *These premises presuppose that any users of the space who have special needs will be supported through appropriate facilities and assistive technologies to make full use of the space and participate fully in learning activities*

65 *A report on evaluation models and practice in technology supported learning spaces (Pearshouse et al 2009) gives a similar list of aspects of learning space design that appeared to contribute most to effective learning in the evaluations they reviewed. Pearshouse et al (2009) A Study of Effective Evaluation Models and Practices for Technology Supported Physical Learning Spaces. Report produced for Jisc: http://oro.open.ac.uk/29996/2/*

66 *Visitors to the Rolex Centre, the iconic learning resource centre at the École Polytechnique Fédérale de Lausanne in Switzerland, are often puzzled by a series of what appear to be rubber tramlines crossing otherwise minimalist open spaces. The space was conceived by its architects as a* rolling landscape *for learners to explore. This idea of self direction in the space was reinforced by minimal signage. In practice the space proved extremely difficult for visually impaired users to navigate and the* tramlines *are necessary to help such users get from one part of the building to another: http://rolexlearningcenter.epfl.ch/*

67 *Martin, P. (ed) 2010) Making space for creativity. University of Brighton: http://about.brighton.ac.uk/creativity/Library/UofB_msfc-ebook_FINAL.pdf*

- **Comfort** — heating, ventilation and cooling are common sources of complaint from building users and require careful consideration. The availability of natural light can also do much to promote learning. In the past comfort has not been a high priority when selecting furniture for student use but the provision of high quality, comfortable furniture is an important element in ensuring student time on task[68] in a particular learning space.

- **Proximity** —users must find the space convenient to access: the best space in the university may not be used as much as the nearest one. Speculative developments may be better sited in less used spaces and, where possible, close to a support team. Current trends in integrating learning and social space bring their own set of issues, not least the transmission of noise and odours from hot food from social spaces into more formal study areas, so zoning and differentiation needs to be carefully thought through.

- **Sustainability** —this relates to environmental sustainability, ongoing maintenance and the need for equipment and software upgrades. The need to conduct training and repeat this for new staff or new cohorts of students is also something that can be overlooked in terms of ongoing costs.

> *"The problem that is most easily solved is making things usable and this is where the technologists fail. You need to get user interfaces right because if people can't use it you will spend all your time supporting it."* Tessa Rogowski

> *"Spaces should work seamlessly whether the teacher wants to use technology or not, the technology should not overpower the room or force users to think it must be used."* Toni Kelly

- **Durability** — think carefully about the expected lifespan of floor coverings, furnishings and fittings. A lesson learned from many new developments is that increases in user footfall in the new spaces can greatly exceed your wildest expectations. When considering the funding needed for a build or renovation project you need to take into account routine replacement of equipment and upgrading/maintenance of decoration.

4.2 Designed to last?

The term "*Long life, loose fit, low energy*"[69], coined by RIBA president Sir Alex Gordon in 1972, sums up good design that recognises buildings need to have a degree of permanence and also be capable of adaptation to a variety of uses over their lives.

When designing a building it is often useful to think of it in terms of a series of components or layers with different lifespans. The diagram below is taken from the work of Brand (1994)[70] and shows the layering including the geographical site which is permanent, the load bearing structure which is expensive to change, an external skin that may change due to fashion or the need for maintenance and internal services and structures which have a much shorter lifespan. The concept was used in the building of a number of further education colleges that have movable internal walls so that space can be reconfigured as numbers in different subject areas vary.

© City University

Photo 6: Node chairs are used for easy reconfiguration of groups at City University.

68 *Chickering, A. W. and Gamson, Z. F. (1987) Seven Principles for Good Practice in Undergraduate Education. American Association for Higher Education: www.lonestar.edu/multimedia/SevenPrinciples.pdf*

69 *See discussion of the model by Langston (2014) Measuring Good Architecture: Long life, loose fit, low energy: http://ojs.ecsdev.org/index.php/ejsd/article/viewFile/186/178*

70 *Brand, S. (1994) How Buildings Learn: What Happens After They're Built. Viking Press.*

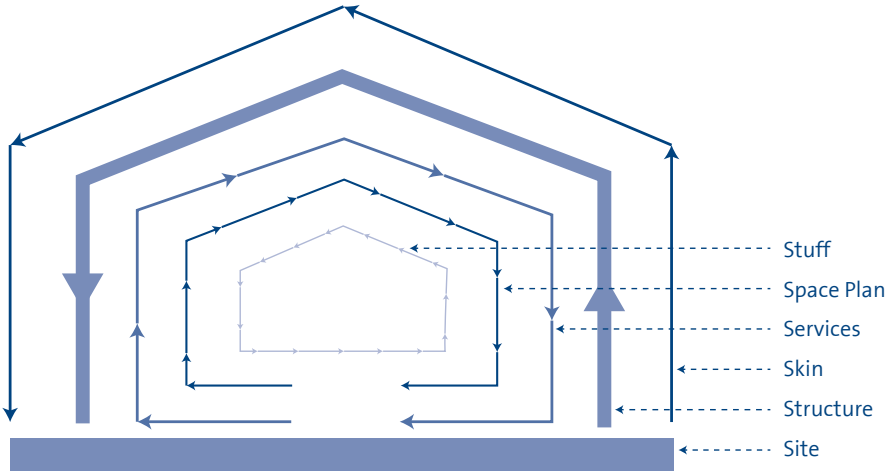

Figure 4: Brand's Six S's from How Buildings Learn

The flexibility of the building is therefore underpinned by those building elements at the lower end of the list in this diagram. The more that the elements further up the list can be kept separate from the physical envelope and servicing strategy of the overall building, the more opportunity they have to change. For example ventilation systems which depend upon the specific arrangement of internal walls (or lack of them) can sabotage the possibility of organisational change.

In designing learning spaces it pays to be realistic about how long you expect each element of the space to last. Most institutions try to design with low maintenance in mind but, even so, it is not unusual to see relatively new learning spaces showing signs of wear and tear. Floor boxes (for electrical power) with their covers snapped off, coffee stains on furnishings and floor coverings, broken writing tablets and difficult to reach architectural features that gather litter and dust are common problems. Contributors to this Toolkit have given quite different indications of how long their institution would expect a new development to last from a *shopping mall* model where internal fittings can be changed quickly and cheaply, to an expectation of no significant change for around 10 years. Whichever end of the spectrum you plan for, you need to consider whether all of the components are sufficiently durable to last this length of time.

VIEWPOINT

Matt Sherlock Assistant Director, Learning Environments, University of Birmingham has two key messages for colleagues developing learning spaces. The first is that everything in a learning space needs to be *appropriate*. It may be either innovative or low tech but it needs to be appropriate for the learning activities taking place.

The second is that universities need to think in terms of managing a *portfolio* of spaces. Not every space can be generic and the flexibility to better support a range of learning activities is best achieved through shared ownership of the institution's resources rather than thinking about designing individual spaces for maximum flexibility.

Matt is trying to achieve this by changing the vocabulary people use when booking space. He tells us that in the past people have tended to be very vague about their space requirements. They might say they want a flat floor and space for 50 students but this doesn't tell you what is actually going on in the space. Matt realises we need to ask less about the functional requirements (given that most suites have quite similar facilities) and more about the desired learning approach. This will allow the matching of activities to space in a much more intelligent way. This links back to the idea that the space needs to be appropriate. What is actually needed might be a relatively small room suitable for formal teaching with informal spaces located nearby for breakout activity. Matt notes that the person teaching often is not the person who is doing the room booking and a lot can be lost in translation but overall there is a very positive message here about collaboration and the potential for much better space utilisation if the right class is timetabled in the right room.

VIEWPOINT

Caroline Pepper, Learning and Teaching Space Manager, Loughborough University, told us that one of the main surprises from Loughborough's extensive consultation with students about learning spaces was quite simply the diversity of student views. This has led Loughborough to define its learning space strategy as being about *diversity in design*. Many students still want tiered lecture theatres whilst others are demanding more collaborative space. Caroline told us that node chairs[71] are one of the best examples of an innovation that has polarised views. *"They are a bit like Marmite: students and staff either love them or hate them"*. The chairs are available in a range of colours which makes it easy to form groups by saying, for example, students in orange chairs get together and form a group, but some students don't cope well with this type of activity. Caroline also feels that the chairs work well in small groups but once you get to over 30 the room starts to look messy and uncontrolled and some students do not like this. Cultural factors come into play here and, in particular, some groups of international students exhibit a strong preference for being taught in tiered lecture theatres because this most closely mirrors their previous educational experience.

VIEWPOINT

Tessa Rogowski, Client Services Manager, University of Essex, strongly promotes the principles outlined in this Toolkit of ensuring (with appropriate adjustments for particular user needs when necessary) audibility, visibility and usability in learning spaces. Tessa takes this view based on considerable experience of inheriting, and having to put right, badly designed learning spaces. She told us "*All of my pain is in here. I have inherited all of these mistakes and learned from every one*".

Throughout her career Tessa has seen many examples of poor learning spaces across the sector. She believes that if the principles outlined in the Toolkit had been applied at the design stage, many institutions would have realised that that some of those areas could never be teaching spaces.

Elsewhere in this Toolkit we look at making investment decisions and suggest that upgrading ten rooms with minor problems might be cheaper and more worthwhile than the investment required to adapt a space with significant design issues.

4.3 Functional room standards

For every separate *room* or zone within a learning space you will need to understand the activities that will be going on in the space in order to determine the functional specifications to be met. The overall shape and configuration of the space may be a major factor in determining what is possible e.g. if there are columns to support the ceiling or if the shape of the space is awkward. This section assumes you have reached the point where you are specifying the detail of a room that is generally adequate for the intended activities.

© University of Derby

Photo 7: Plectrum shaped tables are particularly conducive to group work. University of Derby.

Sometimes all it takes is a little bit of ingenuity to turn an unsatisfactory space into a highly functional one. Paul Burt, Learning Spaces Service Owner, University College London (UCL), told us "*If you have a room that is already long and narrow the chances are the end wall will have the door in it and you will also need to find a place for the teacher to stand. The answer is to flip it - the 90° flipped classroom*".

71 *Node chairs have swivel seats and adjustable work surfaces. They are easy to reconfigure as they are on castors.*

In the case of large spaces you may need to break the area down into a series of individual zones with different requirements. At an early stage in the planning process you should capture the basic requirements for each space. The headings you will need to consider include:

- activities to be carried out;
- general design criteria;
- specific technology or equipment requirements;
- services to be provided in the space.

We have already said that usability is a key design principle for all learning spaces and we must keep that in mind at all times. In the majority of rooms users should generally be able to do what they want to do without having to undergo training or read a lot of instructions. Matt Sherlock told us *"Everything has to be **appropriate** and this is a keyword that should feature in the Toolkit. It can also be innovative but being appropriate is key"*. It is possible to design rooms that are intuitively usable.

Technology can be used to provide such information and support as may be needed, for example, at the University of Birmingham QR codes[72] in every teaching room link you to all of the information about that room including the timetable and instructions for using the equipment. The learning spaces team would like to extend this to provide a very easy means of fault reporting. Matt Sherlock says *"It is frustrating to hear somebody say 'something isn't working and it wasn't working last week either' i.e. they didn't report it"*.

A number of contributors to this Toolkit talked about norms in terms of the amount of space per student for different types of activity. Some said their institution had a clear focus on trying to increase the amount of space per student whereas others thought there was a risk of space norms going *out of the window* if over recruitment occurs due to the lifting of the student numbers cap. Financial imperatives to reduce the amount of space per student may be at odds with the educational principles we have outlined to better support active learning. As one of our Toolkit contributors put it: *"Don't crowd students out - they won't turn up to classes"*.

A number of years ago, the University of Birmingham created an "overspill" facility to accommodate fifty medical students that could not be accommodated in the largest lecture theatre available. A great deal of effort was made to make the students using this space feel they were getting the same experience as if they were actually in the lecture theatre but, within three weeks, the facility was unused and the students squeezed themselves into every available space in the lecture theatre, on stairs and on the floor at the front of the room. The response was to build a new, larger lecture theatre.

Consideration of the above will allow you to start defining the specification more precisely.

The main areas you are likely to look at are:

Area	Specifications to be covered
Finishes	Floors; walls; ceilings; windows; doors; acoustic treatment; decoration
Mechanical and electrical	Electrical (including any machinery with specialist power requirements); data; heating; lighting; ventilation; plumbing
Fixtures and fittings	Furniture; equipment; audiovisual equipment; security requirements; storage requirements

Ultimately you will require some form of space data sheet for every individual space that goes into precise detail on all requirements, down to the level of number and position of power sockets and the need for small equipment such as waste and recycling bins, clocks etc.

There are no universal standards as regards access control and attendance monitoring in learning spaces but you should consider local policy and likely future requirements at the design stage.

These are some of the things the Toolkit contributors told us about functional room standards:

72 *https://en.wikipedia.org/wiki/QR_code*

- Doors onto learning spaces should, where possible, contain glazed vision panels so people can see if there is a teaching session in progress and to minimise the risk of accidents. Students also like to retain a connection with the *outside world* and there are considerations of safety, security and the university's duty of care for students working alone in a room.

- All teaching spaces should have a working clock visible to the tutor. A traditional clock face is more readily interpreted than a digital numeric display.

- For genuinely flexible spaces, staff and students need to be able to move furniture easily e.g. put tables together to create different shapes and layouts. Lightweight and stackable furniture may be most practical, which may run counter to usual purchasing policy of selecting furniture that is more robust, but less easy for staff and students to move.

- Bigger is not necessarily better when it comes to table space for group work. The University of Edinburgh tested some six seater tables (shaped a bit like an ironing board) for group work by creating models in four different widths and testing them in the library. It might have been expected that students would prefer the widest tables but it was found that the bigger desks resulted in problems with noise levels as people talking across the large tables were louder.

- Plectrum shaped tables have been found to be particularly effective for group work.

4.4 Heating, ventilation and cooling (HVAC)

> *"Environmental factors are absolutely fundamental. When you ask students about learning spaces, being too hot or too cold and having uncomfortable seats is always the first thing they talk about. The key thing is that students want to feel relaxed and they don't feel relaxed in many of our learning spaces. This inhibits their ability to learn."* Toolkit contributor

Heating, ventilation and cooling (HVAC) tend to be linked, although in building systems terms they can equally be provided independently. They are fundamental to user comfort and hence the perception of the usability of particular space. Physical and psychological responses to one can be affected by another (air movement affects the sensation of air temperature on the skin and provision of adequate fresh air is critical to mental alertness and concentration). Furthermore, there is considerable difficulty in providing air temperatures which are acceptable to everyone, as different individuals respond differently (it is acknowledged that women are generally more sensitive to cold than men). This can make it difficult to be precise as to what is required and what is being experienced, and may lead to confusion and sometimes mistrust (of those who operate, designed or installed the system).

A study on the management of open plan learning spaces (Watson *et al* 2007[73]) found that HVAC represented the top issue for managers of such spaces. Issues included the perceived inadequacy of most systems and frustration at lack of local control. This was often articulated as a tension between the managers of the space and the estates or facilities department that managed the system and highlights the importance of achieving a common understanding between all departments involved in making such spaces work. The study also found that complaints to do with HVAC most often came where changes had been made to the internal partitioning of large spaces that were originally designed as open plan.

Open plan areas work on the principle, generally, of there being uniform temperatures across the total space. Temperatures at the perimeter of a large space (where there is going to be the greatest heat loss and heat gain and sudden changes in outside temperature) will be more variable and might not be able to be fully compensated for by a uniform HVAC system.

Ideally HVAC systems should be designed with considerable variability in mind (by providing zones which can cater for locally changing conditions). This does however make them more expensive, and sophistication in air conditioning is often first to be trimmed from the cost plan. However a space is originally designed, the fact that internal changes will inevitably occur should therefore be taken as fact and as an essential requirement for flexibility within a building.

Full air conditioning implies modification of the quality of the air in terms of fresh air content, temperature and humidity. Often however what is called air conditioning involves little more than *comfort cooling* i.e. recirculating and

73 *Watson, L, Anderson, H. and Strachan, K. (2007) The Design and Management of Open Plan Technology Rich Learning and Teaching Spaces in Further and Higher Education in the UK. Report produced for Jisc: www.webarchive.org.uk/wayback/archive/20080925103236/http://www.jisc.ac.uk/whatwedo/themes/elearning/tele/managinglearningspaces.aspx*

cooling the internal air. This is sometimes provided in the theoretical belief that it will be combined with openable windows, which will provide the fresh air component. In practice however the external windows prove difficult physically or managerially to open, resulting in a dearth of fresh air. Such environments feel stuffy and result in a loss of concentration.

> *"Economies to the air conditioning design would appear almost always to prove to be false economies, resulting in the greatest reason for user dissatisfaction."* (Watson *et al* 2007[74])

The difficulty of meeting the requirement of responsiveness to individual preferences can result in a *Catch-22* situation: frustrated building occupants tamper with controls thereby upsetting the system's balance and this in turn can result in the deliberate removal of local control, further aggravating user frustration.

It is significant to note that an important factor in the analysis of *Sick Building Syndrome* was found to be lack of personal control. As a result of this the reintroduction of openable windows and thermostatic radiators has become a more familiar feature of modern buildings, being considered preferable to the centralised control and uniform provision of full air conditioning. Reasons this may not be practical include a noisy or polluted external environment or security risk.

The concept of passive heating and cooling systems has featured heavily in the design of many new buildings, not least because such systems are believed to fit with the sustainability agenda. This often involves air movement across open plan floors and up through an open atrium. Again changes in the configuration of the building such as closing off some areas can have a detrimental effect on the working of the system. Watson *et al*[75] issued caution in the use of such systems and noted *"...noise, smells, variations in temperature, and the inability to adapt the building were starting to render the building unusable and were clearly an unacceptable price to pay in the name of sustainability"*. They went on to say: *"So limiting was the operation of some of the buildings visited, that it was concluded that sustainable design should be treated with extreme caution at the early stages of any project"*. They suggested that mixed mode or blended systems where the feeder air routes could be adapted or modified through the use of mechanical fans or with certain spaces dealt with by localised artificial systems offered for greater flexibility and were found to be far more successful than solutions that emphasise sustainability above all else.

- In spaces where it is practical it should be possible to open windows for natural ventilation.
- Space designers need to acknowledge that individuals respond differently to environmental factors and provide, if possible, a degree of local control over them.
- The implications of passive heating and cooling systems need to be carefully thought through particularly in terms of the potential for future changes to building layout and use.
- Controls for air conditioning are notoriously complex for end users and clear instructions should be produced and positioned alongside the controls.

4.5 Lighting

The provision of adequate and glare free artificial lighting is relatively simple, but maximising natural lighting and providing good lighting that meets the needs of all users and enhances the ambiance of a particular learning space is less easy.

Where possible learning spaces should permit controlled admission of daylight. The psychological benefit of natural light is widely accepted[76]. In terms of management however it can pose difficulties. It can be too bright, causing glare which makes it inappropriate for computer screens or even conventional text reading. Natural light therefore needs to be regulated in combination with blinds or (preferably) external fixed or movable louvres where the shading provides the additional benefit of minimising heat gain. External systems are more expensive however, more difficult to maintain and difficult or inappropriate to retrofit to an existing building. Very often therefore best use has to

74 *Watson, L, Anderson, H. and Strachan, K. (2007) The Design and Management of Open Plan Technology Rich Learning and Teaching Spaces in Further and Higher Education in the UK. Report produced for Jisc: www.webarchive.org.uk/wayback/archive/20080925103236/http://www.jisc.ac.uk/whatwedo/themes/elearning/tele/managinglearningspaces.aspx*

75 *Watson, L, Anderson, H. and Strachan, K. (2007) The Design and Management of Open Plan Technology Rich Learning and Teaching Spaces in Further and Higher Education in the UK. Report produced for Jisc: www.webarchive.org.uk/wayback/archive/20080925103236/http://www.jisc.ac.uk/whatwedo/themes/elearning/tele/managinglearningspaces.aspx*

76 *See for example: https://stevemaslin.wordpress.com/2015/04/29/clear-as-daylight/*

be made of internal blinds. Another option is *encapsulated* blinds between the primary and secondary glazing which are particularly suitable for non-opening windows.

Adequate lighting which permits easy reading of text and computer screens but which is otherwise uniform can dull the atmosphere of a learning space. Good lighting should provide variety in support of different types of activity. Differences in personal requirement with respect to lighting can be relatively easily dealt with at the level of *task lighting*.

A particular facilities management issue arises with respect to lighting in the need to have easy access to light fittings to be able to change light bulbs. This can be a problem specifically with feature lighting where it is often combined with double height or atrium spaces. The implications of certain designs are not always appreciated in advance.

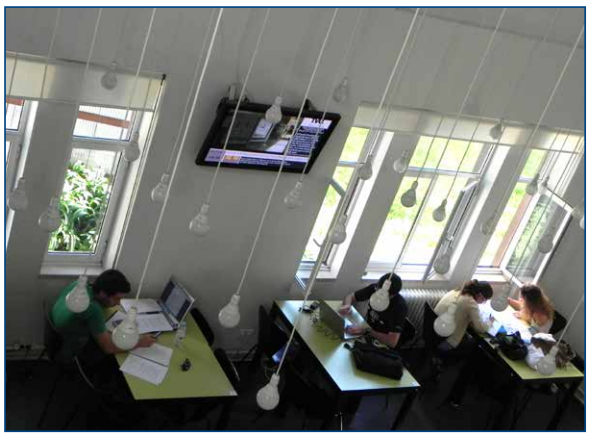

Photo 8: At different times of day this is a quiet study space, a busy cafeteria or a venue for events: fixed and projected lighting change the ambience. The University of Porto's e-learning café.

Where sustainability is not already being met by maximising the use of natural light, there is a need to ensure use of low energy fittings. These can have the added benefit of being long life thereby reducing the problem of access.

These tips and detailed specifications for lighting (in space that is used for formal teaching sessions) are adapted from University College London Learning Space Guidelines[77]:

- There are recognised specifications giving minimum lux levels for different types of activity and these should be followed.
- Lighting design in learning spaces should enable presenters and students to see (sufficiently for note taking) and be seen. Placement of lights in relation to projection and/or writing surfaces requires care: a common mistake is the positioning of a light directly above the projection surface which results in uneven image contrast.
- Low energy lamps that require more than ten seconds to reach maximum brightness are not suitable in learning spaces due to the frequent need to change between different lighting states within a taught session.
- Lights specified for new or refurbished learning spaces should give high frequency (no flicker) light output. General area lighting should have a colour resembling daylight whereas breakout or small group learning spaces may benefit from a directional pendant that focuses warmer light on the centre of the discussion area.
- Lighting controls should be available close to the entrance in all learning spaces unless occupancy sensing is used. For larger spaces secondary controls in proximity to the teaching facilities are required so that the lighting can be optimised by the lecturer for different sections of the session.
- Ideally a range of lighting levels and disbursement patterns should be selectable by the user of the space. Lighting controls should be clearly labelled, ideally with illustrative lighting pattern diagrams.
- Controls and switching should permit separate control of the lighting above projection and writing surfaces in relation to the other lighting zones in the space.
- With the increasing use of lecture capture technologies it is important to understand the lighting requirements in relation to all the visual resources that will be used a particular session.
- If occupancy sensing is used to avoid energy wastage it is important that the sensor technology is capable of detecting static occupancy as well as movement because a lecture audience or students taking an exam may move very little.
- Care should be taken in the choice of fluorescent lights as learners using tablet computers can experience harsh reflections due to the horizontal angle at which tablets are used.

77 *University College London Learning Space Guidelines v.1.1.2, Information Services Division (2014): www.ucl.ac.uk/isd/services/learning-teaching/spaces/documents/ucl-learning-space-guidelines.pdf*

Resources

- The Jisc learning spaces guide (2013) has some examples of lighting solutions in a range of learning environments[78].

4.6 Considerations for particular types of learning space

Functional room standards vary according to the particular types of learning activity to be carried out in a space. Here we take a broad look at the major considerations for some common types of formal teaching space. We have not included libraries or specialist spaces such as laboratories and spaces dedicated to performance art, but you can find some examples of good practice in specialist spaces amongst our resources.

A set of guidelines based on published space norms by AUDE[79], RIBA and sector leading universities identify the need to provide sufficient space per person depending on the activity planned. Apart from meeting pedagogic requirements this also takes into account health and safety regulations for fire safety evacuation:

Lecture theatre = 1.1-1.25 sq.m per person

Interactive lecture theatre = 1.7-2.0 sq.m per person

Seminar room = 2.2-2.50 sq.m per person

IT cluster rooms = 2.75 sq.m per person

4.6.1 Interactive lecture theatres

Despite the trend noted in Section 1, Building a new pedagogy, towards learning becoming more social, active and collaborative, a significant amount of university teaching still takes place in the traditional setting of the lecture theatre. What has changed however is that advances in technology and space design offer increased opportunities to make lectures a more interactive learning experience.

Rows of fixed seating are being replaced by sofa type seating that position students in small groups, or swivel seating so that students can turn and work with others. Where this swivel seating is used, attention needs to be given to the relative positioning of the seats. Positioning both front and rear seats on a particular tier in direct alignment will obscure the view of the rear seat occupant. There is also a need to ensure that there is sufficient space between the two rows on the same tier to avoid students being uncomfortably close when in discussion mode.

© City University.

Photo 9: Swivel seating is used in the interactive lecture theatres at City University.

Even in lecture theatres where seating is laid out in conventional rows, consideration should be given to improving sight lines by staggering the seat positions between rows. Lecture theatre seating should be of high quality and be comfortable for extended occupancy periods and upholstery should be chosen for durability and longevity. Each student seat should be provided with a horizontal surface that is sufficiently large to permit the use of a paper pad or laptop for taking notes.

Technologies such as personal response systems (also known as electronic voting systems (EVSs) or clickers[80]) permit students to interact with the lecturer. For more on this topic, see Section 5, Learning technologies.

78 Jisc Learning spaces guide (2013) www.jisc.ac.uk/guides/learning-spaces/lighting
79 AUDE (2010) Space Assessment Models and Space Profiles: www.aude.ac.uk/documents/samuserguide/
80 Electronic voting systems (EVSs), also known as personal response systems (PRSs) or clickers, are a classroom based technology which can be used to support learning, teaching and assessment by allowing students to select a response to multiple choice questions.

With more and more students using digital technologies during class there is an increasing demand for power supplies in lecture theatres. Universities are taking different approaches to meeting this demand: some are building new lecture theatres with power to every seat, whereas others, predicting a future decrease in demand as battery performance continues to improve, are choosing to provide a more limited amount of power sockets. University College London has taken the approach of only providing power to the first two rows in a lecture theatre to encourage students to move to the front.

4.6.2 Active learning classrooms

We are using the term classroom to describe rooms used for a range of formal, directed learning activities that may include approaches such as:

- Inquiry based learning;
- Problem based learning;
- Discussion based learning;
- Student led interactive learning;
- Simulation based learning[81].

> *"The cultural change required in thinking of space in a new way should not be underestimated. We need to ask such basic questions as 'Should rooms have a front and a back?' Spaces should center on learning, not experts".* (Van Note Chism 2006[81])

Applying a socio-constructivist philosophy challenges the notion that a classroom should have a clearly defined *front* or what Van Note Chism (2006) describes as a privileged space. Many innovative classroom spaces are effectively decentred. Most classrooms do nonetheless have a primary focus direction where it makes sense to concentrate the teaching facilities and displays, often referred to as the *teaching wall*.

Adaptability is vital in these spaces so that a group of learners can easily move from listening to one speaker to working in groups or working independently. The flow of activities needs to be seamless so it makes sense to have tables and chairs capable of quick reconfiguration to support different kinds of activity. Guidance illustrations of exemplar layouts with the furniture supplied should be available in the space and on the room bookings website. Layout can have an impact on group dynamics e.g. the traditional layout of rows of chairs allows certain students to hide at the back and avoid participation in class activities.

Researchers have explored the psychological and educational effects of classroom density, both spatial (the size of the room) and social (the number of students). Graetz (2006)[82] suggests a good social density benchmark for classrooms is three to five groups, of six to twelve students each. Designers should also pay attention to the risk of overcrowding in classrooms. Research suggests that students can be expected to work together effectively at distances of 0.6-1.2 m between individuals and 1.2-2.1 m between tables, without feeling crowded. Both students and instructors should have enough room to move easily from group to group.

Comfortable furniture has often been seen as a luxury for students but furniture design, and hence, bodily comfort, can impact on learning. Chairs need to be comfortable, moveable and allow students to turn in different directions, flex their backs and move. Consideration needs to be given to catering for a range of body sizes and accessibility (for example, whether left handed students have appropriate facilities for note taking and laptop use). It has also been suggested that a waterfall front seat edge is better than a right angle for circulation and comfort. James Rutherford, University of Birmingham, in studying for a related master's degree found there was little research into table design but what there is suggests that non-rectangular tables promote collaboration and reduce confrontation.

In spite of the value of digital devices to support learning, they also provide many distractions in the classroom e.g. common instances of students checking social media or playing online games during lessons. Graetz (2006)[83] suggests that attempting to prohibit the use of devices in class through edict or infrastructure (for example, installing an internet kill switch) is costly and does little to address the underlying problem. Space design is of relevance here and a better approach may be to ensure that laptop screens should be easily visible to tutors as they walk around the room. Tutors must be able to engage students in the learning process during class time, and learning spaces must be

81 *Van Note Chism, N. (2006) Challenging traditional assumptions and rethinking learning spaces in Oblinger, D.G. (ed) Learning Spaces. Washington DC: EDUCAUSE: www.educause.edu/research-and-publications/books/learning-spaces*
82 *Graetz, K. A., 'The Psychology of Learning Environments', Oblinger, D.G. (ed) Learning Spaces. Washington DC: EDUCAUSE: www.educause.edu/research-and-publications/books/learning-spaces*
83 *Graetz, K. A., 'The Psychology of Learning Environments', Oblinger, D.G. (ed) Learning Spaces. Washington DC: EDUCAUSE: www.educause.edu/research-and-publications/books/learning-spaces*

designed to facilitate that engagement: it is difficult for students to attend to other activities when they are talking to a tutor, working on a group activity, or using their devices for academic purposes.

Given that adaptability is key to the use of these spaces it should be facilitated temporally as well as spatially i.e. the scheduling of room bookings must allow sufficient time for a change of room configuration between classes. The provision of ubiquitous wifi, the prevalence of user owned portable devices and the high degree of mobility of modern furniture makes this a much easier problem to solve than it was only a few years ago e.g. the use of node chairs[84] as commonly used at City University. The issue nowadays is as much about staff development and encouraging academic staff to make full use of all of the opportunities available to use a variety of collaborative learning and teaching practices.

The Singapore Management University is trialling a new *Active Learning Classroom* that has no formal or prescribed layout. The tutor arrives, creates whatever layout they need that session and at the end they, and the students, move the furniture to the side of the room so that the next tutor can come in and decide what they need. This challenges the situation where tutors just accept the layout they are faced with[85].

4.6.3 Computer rooms

By computer rooms we mean rooms with desktop computers that support some or all of the following functions:

- taught sessions that include a significant element of IT usage by students;
- providing computer and associated facilities for self directed use by students to support their learning;
- electronic individual examinations (e-assessment) which are usually taken under invigilation.

Some computer rooms perform all these functions at different times whereas some may be open access facilities that are not bookable for teaching purposes.

Audio reinforcement and assistive listening technology may be necessary in rooms used for teaching due to the additional ambient noise created by computer fans and the additional heating, ventilation and air conditioning (HVAC) required in rooms with many computers.

Many existing computer rooms are densely packed which provides little opportunity for collaborative learning and makes circulation around other users in the space difficult. Accommodating the maximum number of workstations in a space is often a priority but the assumption that the density achieved with straight rows is much greater than any other layout should be questioned and alternative layouts investigated. Sightlines and security may be significant issues especially if the room is to be used for examinations.

The choice of computer type should be considered in relation to security, the aesthetics of the space and the possible impact of base units on students needing to work collaboratively at a single computer. All in one units may provide the best solution provided they can be adequately secured.

Each computer workstation should be set up so the user is in the correct ergonomic posture. Design and dimensions of computer workstations in offices are legislated through the European Display Screen Equipment Directive (90/270/EEC) and dimensions for workstations should comply with British Standard EN 527-1:2011. Computer monitors (or the whole computer if an all in one unit) should be mounted in such a way to facilitate easy tilt and height adjustment of the display by the user and chairs should be standard rotatable, castor mounted and adjustable.

Resources

- The Learning Space Toolkit[86] (produced by North Carolina State University (NCU) Libraries and its Distance Education and Learning Technology Applications (DELTA) in partnership with brightspot and AECOM) has an Integration Blueprint[87] which can be used to compile information about activities, spaces, technology and services to aid the design process. A worked example is also available[88].

84 *Node chair animation: www.youtube.com/watch?v=5Q9uMb0CG7o*
85 *http://blog.nus.edu.sg/citations/tag/active-learning-classroom/*
86 *http://learningspacetoolkit.org*
87 *https://docs.google.com/document/d/19Ov6jcJ1ZpQJB_yvaEFDGixFeLQj1TbgdgD50oambg0/edit?pli=1*
88 *http://learningspacetoolkit.org/wp-content/uploads/Integration-Blueprint-Example.pdf*

- This space data sheet template is based on a model created for a newbuild at Edinburgh's Telford College and makes a distinction between equipment to be transferred from the old building and purchase requirements[89].

4.7 Audio standards

This section is founded on the premise that all users of the space must be able to hear what is being presented and be able to hear and participate in group discussions.

Different learning spaces require different treatments e.g.:

- a lecture theatre will require sound reinforcement to enable all learners to hear;
- an open plan group working space will require sound to be deadened to contain the need of learners to speak up over the background noise;
- a library must be insulated from external noise;
- areas adjacent to a learning space emanating noise (e.g. a music room) must be protected from that noise.

You will need to be clear about the sources of sound before you start to design the space. As well as noise generated by building users and their activities, you may also have to protect against noise produced by heating ventilation and cooling systems.

The layout of the space and the choice of materials used will impact how sound travels in space. As a beginner's guide to noise there are two aspects that you need to think about:

Insulation

Insulation against noise stops transmission from one space to another. It is difficult to make a lightweight material insulate against sound. Good acoustic insulation is provided by mass, so one centimetre of concrete will provide better acoustic insulation than one centimetre of plasterboard.

The downside of this is that dense materials may stop noise well but, if noise is made by impacting the material, then the dense material will also transmit noise very effectively. For example if there is impact on a concrete floor and this surface is contiguous then the noise will transmit along the surface and transmit effectively to spaces that share the floor.

Only a full height wall will provide full acoustic separation and, where this is necessary, the process has to be followed through completely: walls should be sufficiently solid; walls should penetrate both the ceiling void and the floor void and wall penetrations, like ventilation ductwork, should be fitted with sound attenuators. Costs can mount and benefits have to be clearly articulated in order to be justified.

Absorption / diffusion

Noise can be absorbed or reflected so that reverberation can be reduced. Absorption of sound occurs when sound hits the surface and is not reflected but enters the material and goes no further. Diffusion surfaces may be required for particular acoustic performance. Examples of surfaces that are good at absorption are carpets and fabrics in the form of pin boards and furniture.

Ceiling finish has been found to have the greatest impact on the acoustic properties of a space. An *industrial look* (with hard ceilings and exposed ventilation ducts) is currently very fashionable but very bad acoustically in a learning space. Suspended ceilings with ceiling tiles have much better acoustic properties.

Given the importance of how sound is controlled and managed to the usability of your learning space you might want to consider employing an acoustician to help model the noise within the space you are planning and to advise on floor, ceiling and wall finishes. Acoustic insulation is often something that is compromised when budgets begin to escalate and savings need to be made but this can be a false economy as mistakes can be costly to rectify afterwards. Good professional advice at an early stage should help avoid these types of mistakes.

89 http://bit.ly/sps-example

Assistive listening systems

There are three types of assistive listening systems; they all require a microphone of sufficient quality to relay a signal to the systems.

Induction loop systems – under floor installation is advised wherever possible to ensure standard compliance. Whilst there can be issues around cut tape when replacing flooring they can be proactively managed by writing a damages clause in to the flooring contractors' contract. Ceiling level installations are considered undesirable and should only be considered as a last resort as:

- they are usually further from head height therefore more power is required;
- metal losses are usually higher within a ceiling therefore more power is required;
- installation of array systems is much more difficult at ceiling level.

The presence of an induction loop should be signalled by the use of the international symbol:

Infrared systems – involve a transmitter (there must be line of sight from the transmitter to the receiver) which is worn round the neck. They work well where there are high ceilings but clearly identify someone as hearing impaired. If you use this system then the university should issue hearing impaired learners with their own receiver and make the receivers available to visitors. Some institutions issue these from the main reception desk.

Frequency modulation systems – require licenced FM bands, are expensive, identify the user as hearing impaired and require thorough hygiene routines. For these reasons this is not a recommended approach.

Hints and tips:

- Do not place multi directional microphones near noise sources such as projectors or HVAC systems.
- Do not attempt to rectify poor acoustic performance without considering a potentially lower cost of moving the location.
- Physical routing of lighting and audio cables and locations of fittings should be considered, and as far as possible separated, to avoid problems such as light dimming causing interference with audio. Parallel routings of cables should be avoided. Power sources for audio and environmental services, such as lighting and HVAC, should ideally be phase separated and ground connections for audio dedicated (i.e. not shared with anything else in the building).
- The scraping of chairs across floors has been identified as a major source of noise in a number of buildings and the most straightforward way of dealing with this is to fix rubber stoppers to the bottom of chair legs.

Resources

- Acoustic performance standards set by the Department for Education[90].
- The InfoComm Audio Coverage Uniformity standard is a widely recognised commercial standard and copies can be purchased[91].

90 www.gov.uk/government/uploads/system/uploads/attachment_data/file/400784/BB93_February_2015.pdf
91 www.infocomm.org/cps/rde/xchg/infocomm/hs.xsl/32930.htm

4.8 Visual standards

This section is founded on the premise that users of the space should be able to see what is being presented.

Ensuring the visibility of resources used for learning and teaching has long been a significant issue as the layout of many university buildings, whether a historic campus or a 1960s building with concrete pillars, is often not conducive to good sightlines. The increasing flexibility and affordability of technology does however make these problems easier to solve, for example:

- Structural columns are often the cause of poor visibility of presentations. Repeater screens mounted on the pillar can resolve this.
- Where you have long spaces with low ceilings, the head of the person in front will obstruct the view. Turning the space 90° and using dual projection can help. You might also be able to use repeater screens for the back rows (due to the height restrictions it may be necessary to set these into the ceiling void if one exists).

The legibility of material on vertical writing surfaces is constrained by the size that someone can write with natural fluidity. Technology can provide solutions to this issue in the following ways:

- use of visualiser[92] as a horizontal writing surface;
- use of touch sensitive fixed display monitor (for example a Smart Sympodium[93]);
- use of an interactive whiteboard with its display duplicated onto a larger projection surface;
- use of a portable tablet device with its display mirrored onto a larger projection surface (possibly via the fixed teaching station PC).

Visual design guidelines

- The dimensions of the projected image in learning spaces should be proportional to the viewing distance. The maximum acceptable viewing distance (or conversely the minimum image size) is however dependent on the type of material being shown. A demonstration of how to use a software application such as Excel will require students to be able to see much finer detail than a few bullet points on a PowerPoint slide.
- Older rules of thumb such as *"No learner should sit further away than six times the diagonal measurement of the screen"* need to be revised as the arrival of HD displays and the emergence of the newer 4K resolution displays means higher resolution where computer interfaces tend to display smaller. Similarly the 4:6:8 rule (whereby the minimum image height should equal the maximum viewing distance divided by a factor of 4 for Excel, 6 for PowerPoint or 8 for videos) is problematic unless the room is only used by a single tutor who presents a single type of material. No learner should have to turn their head to an extreme angle. In general a cone of viewing giving less than 45° angle to the centre of the screen gives a good viewing experience whereas a viewing angle within 45° of the near edge of the screen gives an acceptable viewing experience.
- No learner should have to look upward to the top of the screen more than 35° or 15° to the screen centre (in order to avoid neck strain).
- The base of the displayed image should be 1200mm from the floor for standard throw projectors but the height should be reduced to 1000mm from the floor if the display is to be interactive i.e. when an ultra-short throw projector with interactive functionality or a specific interactive whiteboard is used. The rationale for the different floor to screen heights is that 1200mm above finished floor level would usually allow most of a seated audience in a flat floored space to see the base of the image. However this height is typically too high for use as an interactive writing surface as the upper portions of the screen will not be reachable by most teachers. If ultra-short throw projectors are installed is should be noted that these could be retrospectively fitted with interactive capabilities and thus thought given to the optimum mounting height.
- Do not place a teaching point in front of the projector, it risks causing glare to the lecturer and obscures the students' view of the presentation.

92 Visualisers may be described as digital overhead projectors (OHPs). See Section 5, Learning technologies, for a more in-depth description.
93 http://home.smarttech.com/

- Ensure that there is line of sight for the learners in the back row.
- Ensure that the lights above a projected surface can be turned off or are dimmable independently from the rest of the space. Ensure that learners can work whilst the teaching wall is still visible.

Hints and tips:

- The provision of confidence monitors at the front of the room, facing the tutor (but not obstructing the student's view) will enable the tutor to see what is being presented without the need to turn their back on the audience.
- North facing teaching walls will not be troubled by sun, others may well require blinds.
- Use security measures such as an anti-tamper alarm or anti-theft bolt fixings to protect equipment such as projectors.
- Ensure that the stability of the image from a ceiling mounted projector will not be affected by footfall in the room above or by its proximity to other services such as heating, ventilation and cooling. Similarly with wall mounted projectors the image can be affected by closing doors etc.
- Ultra Short Throw (UST) type projectors are useful in smaller learning spaces. Whilst limited in terms of maximum image size, they have the benefit of not suffering from a *hot spot* reflecting back to users and the instructor will not obstruct the projector beam if standing in front of the board nor be dazzled by it.
- In certain situations large LCD or LED flat panel displays may be more suitable as the primary display or used in conjunction with the data and video projector to provide secondary displays for those seating positions that cannot easily view the main display. Ideally the aspect ratio and display resolution of flat panel displays should match the aspect ratio of the computer monitor and projector image.
- A challenge in larger spaces is facilitating a method for the instructor to write or illustrate and those markings to be clearly seen by the students. Conventional whiteboards have a workable height range between 1000mm and 2000mm depending on the height of the lecturer. Column track mounted boards enable the lecturer expand this workable height as the lecturer can easily raise a board to make it more visible to students whilst continuing to write on the second board below. Use of a visualiser may also help in some cases.
- If you use the same surface for projection as writing then there is a trade off to be made. Boards that clean are reflective, boards that do not reflect cannot be cleaned with dry wipe, so are unsuitable for writing.
- Display panels with a soft screen surface should be avoided because of the risk of accidental or intentional damage.

Resources

- University College London Learning Space Guidelines[94] gives general guidance on the design of rooms used for teaching and contains comprehensive discussion of the types of audio visual facilities suitable for different types of space.
- InfoComm is the trade association representing the professional audio visual and information communications industries worldwide and it provides industry standards for audio visual systems including AV/IT Infrastructure Guidelines for Higher Education - the Display Image Size for 2D content (this standard was in development, as a working draft, at time of writing)[95].
- The Association for Audio Visual and Education Technology Management (AETM), Australia has useful and well researched guidelines on integrating AV systems into learning spaces[96].

94 University College London Learning Space guidelines v.1.1.2, Information Services Division (2014): http://www.ucl.ac.uk/isd/services/learning-teaching/spaces/documents/ucl-learning-space-guidelines.pdf
95 www.infocomm.org/cps/rde/xchg/infocomm/hs.xsl/35973.htm
96 www.aetm.org/av-design-guidelines

4.9 IT standards

This section focuses on the IT considerations that have most impact on learning space users. Technical infrastructure requirements do of course amount to a lot more than this. Most institutions will already have detailed infrastructure guidelines and these should be followed as, in this sense, there is nothing different about learning spaces. There are also certain standards that need to be met in relation to building regulations. Most of these relate to protection against fire and the thermal integrity of the space. A common problem is leaving holes between different fire containment areas when putting cables through. There is a need to make sure that all holes are sealed up and that no smoke cabling is used: LSZH (Low Smoke Zero Halogen) is the building regulations requirement for plenum environments. Your specialist advisers should be well aware of these issues. The IT elements that impact specifically on learning include:

Wireless (wifi)

We have placed wifi at the head of this section because its provision is one of the factors that has the greatest impact on building users. Wifi network connectivity should be viewed as a basic requirement of any learning space regardless of whatever other technology is in the room.

> *"Good planning is important before a wireless network is deployed. It is important to know how many users will need support, where they will be given access, how they might move around, and their anticipated bandwidth requirement. The network will also need to be designed around the physical properties of the building as the fabric of the building, such as steel columns or foil-backed plasterboard, will affect the range and coverage of the network."* UCISA (2015)[97]

Guaranteed 100% coverage is now probably the minimum requirement in formal learning spaces. In the past, this may simply have meant ensuring that a satisfactory signal strength was available throughout the space but we must also ensure that the system is designed to accommodate a very high density of users. Assuming one wireless device is no longer adequate, as many students may bring with them a smartphone, a tablet and a laptop and in future years it is likely that more types of device (e.g. cameras, watches) will seek wifi connections.

University College London Learning Space Guidelines suggest that the number of concurrent connections provided for should be five times the maximum number of people expected to occupy the space at any one time. It could be argued that five times is perhaps overkill, in particular in large lecture theatres (for a 400 seat lecture theatre, do we really need to make provision for 2000 devices?), but it is clear that in an IT enabled environment, the number of devices is likely to be well in excess of the number of participants. The shared nature of wireless means the additional bandwidth is not wasted and provides a better service for those in learning spaces not utilised to capacity.

The nature of wireless use in teaching spaces is also changing. Whereas previously a lecturer may have projected a video clip in the room, they may now suggest that each participant should access that same material from YouTube on their mobile device.

Providing pervasive wireless coverage in large lecture theatres and densely occupied teaching spaces provides particular challenges, often requiring specialist design skill to deploy larger numbers of lower powered access points or specialist antennae to ensure uniform coverage without introducing additional interference. One model that has been successfully deployed, especially in green field sites, is having an array of *picocells*[98] located underneath seats.

> *"IT demand – especially for wireless - is constantly increasing as it is predominantly consumer-driven, and thought needs to be given to the introduction of newer client technologies, for example, the anticipated growth of 802.11ac*[99] *client devices."* Bruce Rodger

In all but the simplest spaces, it is essential to do some form of wifi mapping before developing a new learning space to ensure there is sufficient coverage, and minimal interference from adjacent spaces. The design needs to take into account provision in surrounding areas, bearing in mind the *stickiness* of wireless clients, which may attempt to remain associated with an access point even though the student has moved to an adjacent room. You also need to think about outside spaces as well in relation to wifi as students like the opportunity to work outside whenever

97 *UCISA (2015) Secure Network Management: www.ucisa.ac.uk/securenetworkmanagement*
98 *A picocell is a small base station used to extend phone or wifi coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with dense usage.*
99 *The IEEE 802 Standard comprises of a family of networking standards that cover the physical layer specifications of technologies from ethernet to wireless https://en.wikipedia.org/wiki/IEEE_802.11ac*

possible. Capacity and coverage are not the only elements to be considered: the architecture and configuration also need to be thought through as continually handing connections between different access points can adversely impact users' devices and battery life. You also need to consider the importance of both university network and mobile phone network coverage. Both of these has an impact on the overall user experience but students may not differentiate between the two, and may blame the university for problems with their mobile phone service provision.

It is important to manage user expectations when deploying any network solution in a densely populated teaching space, especially if using a medium such as wireless which has no service guarantees and is prone to interference from external sources. We design systems using the best available technologies, but we need to remember that any component in the chain – IT or AV – can fail, and teaching styles must be flexible enough to accommodate unforeseen events.

Management of radio frequency (RF) spectrum

Even considering infrastructure wifi alone, management of the very limited wifi spectrum is a considerable challenge when designing a pervasive and performant network infrastructure.

Many other services involved in delivering a teaching space will want to deploy devices which use this crowded spectrum (especially the 2.4GHz range). Wireless controllers for AV systems, cable free links to projectors and screens, lighting, heating and ventilation controllers, CCTV, access control and alarms - even some radio microphones - can also make claims on this spectrum, and installers often see wireless as the simplest and easiest installation option. It is essential that these competing requirements are all identified at a very early stage and one team is given design authority to address these competing requirements.

Ultimately the student wireless experience is generally the most important factor, and it is often necessary to say "no" to some of the other facilities, insisting on a wired, non-RF solution.

It is important to work with your IT service teams to identify areas of wireless expertise; this may be in house or bought in through specialist consultants and design authorities. Experiences in this area are often discussed on the UCISA Networking Group's[100] Jiscmail discussion list[101] and the WIRELESS-ADMIN Jiscmail list[102].

> *"Wireless technology can be incredibly convenient, but we need to critically enquire whether it is really necessary for every service? Sometimes the complexity, or the potential for interference, outweighs the benefits. A top of the range radio microphone or wireless link to a projector can cost many hundreds or even thousands of pounds, and if it is carefully installed, it can give a performance which can be almost as good as a £5 bit of wire..."*
> Toolkit contributor

This design authority should sit with the IT networking team, who should have the tools and skills to identify and manage RF sources in this spectrum. One university has created an institution-wide policy which states that wifi has been provided mainly for teaching and learning. This means, for example, that if the Estates department wishes to put doors in that are linked to wifi, there has to be a discussion about it first. The critical factor here is that it is essential that conversations take place in the early design phase between the IT, AV and Estates teams to identify any potential conflicts and to ensure that any potential conflicting requirements can be resolved at an early stage, rather than being a surprise during final commissioning.

Bring Your Own Device (BYOD)

Along with the premise that learning is a social process, we also take the view that learning should not be constrained by time or place, hence mobile devices are an increasingly important way to access learning resources. We have even encountered some institutions questioning whether a fixed PC should be provided in every teaching space or whether a BYOD approach, whereby lecturers bring along their own laptop would get round issues of familiarisation with the equipment. Some institutions have however reported difficulties with connecting a range of devices to projection equipment over eduroam wifi.

BYOD is an important trend, even if the students bringing their own device do not understand the acronym. When providing documentation, advice and guidance, it is important to note that the term BYOD may mean nothing to the intended audience. BYOD is also a different prospect on different types of campus. Students in inner city areas appear less keen to carry laptops around with them than those whose halls of residence are in close proximity to where they taught. Battery life remains an issue for those who do bring devices and many institutions are providing lockers where

100 UCISA Networking Group: www.ucisa.ac.uk/groups/ng
101 UCISA Networking Group mailing list: www.jiscmail.ac.uk/cgi-bin/webadmin?A0=ucisa-ng
102 www.jiscmail.ac.uk/cgi-bin/webadmin?A0=WIRELESS-ADMIN

students can charge their laptops[103]. Overall, however, we have yet to find any institution that says BYOD is allowing them to reduce the amount of fixed PCs available on campus. In some cases institutional provision is increasing e.g. the institution is providing a greater amount of borrowable laptops to ensure they are not creating any kind of digital divide between students who own their own devices and those who do not.

When considering BYOD, it may seem intuitive to increase flood wiring provision, delivering high numbers of wired network outlets throughout learning spaces – in floor boxes, or even at every student seat. Experience has shown that this is, in general, not a practical option: BYOD these days inevitably means wireless connections. Many modern laptops, and virtually every tablet device, will not have a wired connection as standard and many wired network connections in large learning spaces, other than in specific teaching positions and specific support locations at the rear of the auditorium, remain largely unused.

Computers in lecterns?

There are mixed views on whether institutions should install fixed computers at every teaching position.

There are a number of benefits of doing so:

- The lecturer knows there is always a computer available, with network connectivity, so does not have to bring a laptop;
- The software environment is consistent across multiple teaching spaces;
- The computer can have customised features to accommodate specialist facilities in the room (e.g. audience response systems and smartboards);
- The lecturer does not have to worry about interfacing their laptop to the display system.

Installing fixed computing equipment also raises some challenges and support issues:

- The software environment on the centrally provided desktops may not include the specific applications that the lecturer requires;
- Providing and supporting perhaps several hundred additional computers, distributed across the whole institution, is an additional support and financial overhead;
- Authentication for guest and visiting users may present challenges.

The important take away message is to ensure a consistent, well articulated strategy across the entire teaching estate, instead of a hybrid of the above scenarios which will create confusion and mixed expectations.

Authentication

Every institution will have a high level policy on authentication, authorisation and access to IT systems; this may be based on the UCISA Model Regulations[104].

These policies will of course apply to their teaching environments. Careful consideration must be given to authentication methods for non-university members, especially if the venue is being used for non-university events. In these circumstances, how does the lecturer log in to the lectern PC while still maintaining an appropriate level of security and audit trail? Stickers on lecterns with login details are not acceptable!

Standardisation versus innovation

We have heard some tensions expressed around the theme of standardisation versus innovation. In the main however institutions appear to be trying to standardise IT (and AV) facilities for ease of use for users who may teach and learn in a variety of different spaces. A simple way to address this is to work to establish minimum standards that raise the bar and provide a common specification but still allow for innovation.

103 The University of Manchester is an example of an institution where laptop charging lockers are in use: www.library.manchester.ac.uk/services-and-support/students/services/charging-stations/

104 UCISA (2014) Model Regulations for the use of institutional IT facilities and systems: www.ucisa.ac.uk/modelregs

Another effective approach is the use of virtual desktop technology which means that staff and student users have access to their personal and shared drives and the same set of software on any device whether this is on campus, at home or on a mobile device.

Network issues

As more and more facilities go digital there are increasing demands on the network. Digital signage is increasingly used to help students navigate the campus, help students to see where seats in learning spaces are available in different areas and to broadcast real time information. These screens need access to the network so you need to ensure there are enough network access points.

Within a typical AV cabinet, there is frequently a requirement for perhaps six to ten individual network connections – much of the control communication between devices that was previously handled by RS232[105] or proprietary signalling is now commonly delivered over IP (internet protocol). Provisioning these services over IP also presents significant operational benefits, allowing remote monitoring, support and diagnostics.

It is not uncommon to deliver services of this type by deploying a small network switch within the AV cabinet, with a single uplink. A typical model may also involve deployment of an AV VLAN[106] to logically isolate this type of traffic from the general building traffic. Adopting this model requires close collaboration and a clear division of responsibility between the network and AV teams. Typically, the AV team might have responsibility for the deployment of the equipment, with networking colleagues overseeing the configuration.

Institutions may want to think about implementing channel bonding. Channel bonding[107] is a computer networking arrangement, in which two or more network interfaces on a host computer are combined for redundancy or increased throughput. Channel bonding is different from load balancing in that load balancing divides traffic between network interfaces on per network socket basis, while channel bonding implies a division of traffic between physical interfaces at a lower level, either per packet or on a data link basis.

There also needs to be close collaboration between the AV and networking teams and any third party installation contractor to ensure that the installation is deployed in accordance with the requirements of the wider network.

Conversely the degree of convergence between IT and audio visual technologies can cause confusion for non specialists. We heard of a number of examples where mechanical and engineering consultants have looked at the need for a ceiling projector and seen that, whereas previously there were separate AV cables, this data is now digitally encoded and run along category cable. They therefore specified a network point next to the projector and standard network cable running back to the nearest switch room. (AV is however using a point to point standard from the AV equipment at the front of the room. Although it happens to use similar cabling it is nothing to do with the network, and so a network point is not required).

Telephones

An often overlooked aspect is the provision of telephony in teaching rooms. A telephony service, either conventional handsets or a communications tool built into the IT system, allows remote support services to be accessed should the lecturer encounter difficulties with technology, or to summon security or first aid should there be an incident.

Some universities programme their phones so calls from lecture halls and other learning spaces go straight to second line support, rather than being triaged. You can set hot dial keys (security, AV/ IT support, the departmental office) to make it easier for staff.

Knowledge is power?

The provision of power is one of the topics that can polarise the views of stakeholders in learning space projects. We know that students always seem to want more power supplies but the attitude of those who are responsible for student support can sometimes be at odds with that of those stakeholders who are responsible for the university's carbon footprint or indeed for paying the electricity bill.

105 https://en.wikipedia.org/wiki/RS-232
106 https://en.wikipedia.org/wiki/Virtual_LAN
107 https://en.wikipedia.org/wiki/Channel_bonding

We have encountered very different approaches to the provision of power in large lecture theatres including: providing power to every seat; providing power to a percentage of seats; and only providing power to the first two rows to encourage students to sit near the front.

One thing all of the Toolkit contributors seem to agree on is that floor boxes are seldom a good idea and certainly not for high footfall areas. Perimeter power, on the other hand, will inevitably have students flocking to the sides of a room. Power furniture that integrates power supplies into seating and desks remains expensive and limits the flexibility of the space.

Similar issues arise in spaces that are used for meetings, events and conferences where delegates are at least as power hungry as students.

> *"An issue that has cropped up a lot especially during assessment time in the library is 'socket rage'. Students usually have about three devices each and we often aren't doing enough to support their use. If learning resources are really virtual then we ought to be looking at access everywhere."* Toolkit contributor

> *"Power is the thing we never get right as we always think technology is going to overtake us and sort it out."* Tessa Rogowski

The provision of powered USB sockets integrated into desks or furniture, in addition to or instead of 13A mains outlets, is becoming more common. Wireless charging of smartphones via furniture[108] is also fast becoming a reality with areas such as airports and restaurant chains installing such facilities, but there are currently competing and incompatible standards[109].

Resources

- The Oxford Brookes University approach to planning, purchasing and installing IT and AV equipment for the new John Henry Brookes teaching and learning building was an entrant for the 2014 UCISA Award for Excellence[110].
- Imperial College has some standards on cabling. These are campus wide standards rather than specific requirements for learning spaces, but we present this as an example of standards being available to colleagues across the whole institution and suppliers[111].
- Loughborough University has a useful case study on deploying external wifi on a campus based network[112].

On the horizon

We have not covered the ways in which technology may be employed to create smart buildings (for instance to manage energy consumption) but there are aspects of such developments that may impact on learning and teaching. One example, currently little used in UK higher education, is beacon technology. Beacons (often known as iBeacons after the Apple brand device) are small sensors that react to devices and apps in their vicinity. They are used in retailing to detect the location of customer smartphones in a store and push relevant advertising to the customer. However, they can have application in the delivery of learning content and are also of relevance in the field of learning analytics[113], where attendance[114] and use of institutional facilities are seen to be potential indicators of student achievement. They may also be of use in the evaluation of learning space usage patterns.

108 BBC News, Ikea unveils phone-charging furniture at MWC (2015): http://www.bbc.co.uk/news/technology-31693088
109 www.makeuseof.com/tag/what-you-need-to-know-about-wireless-charging/
110 www.ucisa.ac.uk/~/media/Files/members/awards/excellence/2014/OxfordBrookes.ashx
111 www.imperial.ac.uk/admin-services/ict/self-service/connect-communicate/wifi-and-networks/network-infrastructure/. See Appendix F - UTP cabling: www.imperial.ac.uk/media/imperial-college/administration-and-support-services/ict/public/V1.3-appendix-F-UTP-cabling.pdf
112 https://community.jisc.ac.uk/library/advisory-services/deploying-external-wi-fi-campus-based-network
113 http://www.laceproject.eu/faqs/learning-analytics/
114 The University of Bradford use iBeacons. The project Bradford undertook to implement iBeacons was commended in the 2015 Amber Miro Memorial Award: www.ucisa.ac.uk/bestpractice/awards/amma/2015. A short video showcases the project: www.youtube.com/watch?v=H2YMpGqfqzs&feature=youtu.be