

School assets and student outcomes

Centre for Education Statistics and Evaluation



Introduction

There has been a slow but steady increase in research into the impact of the physical school environment on student learning outcomes. Research in this area draws from a variety of fields, including education, architecture, health and design, and examines both tangible and intangible elements of the school environment.

While there is evidence that the physical school environment can affect student learning outcomes, it is difficult to isolate from other influences. Research has shown teacher quality is the greatest in-school influence on student engagement and outcomes, with other factors such as students' socio-economic status and language background also known to impact on outcomes. With this in mind, the built environment is only one of many factors that may affect student learning outcomes.

This paper reviews and summarises the literature on this topic. It begins by considering the available evidence for capital spending and investment in schools. The paper goes on to consider how physical elements of the school environment can affect student learning, and how both students and teachers respond to different learning spaces. It also identifies gaps in existing research, such as how 'vertical' schools and open plan classrooms affect student performance as well as the role educators and students can play in the design process.



Capital spending in schools

Investment in schooling has widespread and long-term benefits. Investment in education has positive public returns, such as improved employment outcomes, better health outcomes and greater social cohesion (Australian Government 2014; Institute for Social Science Research 2013). Education is also seen as a way to mitigate background disadvantage and encourage social and intergenerational mobility (Australian Government 2014; Institute for Social Science Research 2013).

A new study in the United States (Jackson, Johnson & Persico 2015) found that sustained increases in funding can have a positive impact on student outcomes. The study, conducted using data from 1967 to 2010, tracked 15,353 individuals until the age of 25. It found that increasing funding had a significant effect on student outcomes, particularly for low socio-economic students, with students exposed to greater funding being more likely to graduate and earn higher incomes in later life. The study also found strong evidence that the benefits of increased educational investment accrue over time, with students showing more positive outcomes the longer they experienced increased funding in their schooling.

There is still debate, however, as to whether there is a direct relationship between funding and student attainment. One way this relationship has been examined is by comparing spending with standardised test scores over time, to draw correlative inferences between the two. As an example, a recent report by the National Commission of Audit (Australian Government 2014) noted that Australia's comparative scores in the Programme for International Student Assessment (PISA) declined between 2000 and 2012 despite real growth in Commonwealth and State funding of over 3.8 per cent per year. Based on this, the report stated 'There is no clear, consistent correlation in the academic literature between increased funding and school outcomes.' Similar conclusions have been reached by others, with cross-country analyses of PISA scores finding that countries that spend more on school education do not always perform better (Centre for Independent Studies 2014).

The OECD Universal Basic Skills Report (Organisation for Economic Co-operation and Development 2015) suggests that there is a relationship between spending per student and learning outcomes, but only up to a point. For countries that currently invest less than USD 50,000 per student between the age of 6 and 15, the data shows a relationship between spending and outcomes. Yet once spending has reached this threshold, such a relationship no longer exists. The report concludes 'money alone gets education systems just up to a point' (2015, p. 13). So, for countries that have ensured an essential level of funding, it is not primarily about how much they spend on education, but how they spend it.

Similar conclusions have been reached by others, suggesting that it is not the amount of funding, but how this funding is spent, that is most important (Connors & McMorrow 2015; Centre for Independent Studies 2014; The Albert Shanker Institute 2012).

Capital investment

One focus of the literature in this area is the relationship between capital expenditure and student outcomes. That is, how spending on school buildings, facilities and infrastructure can affect student performance. It is agreed that certain basic conditions are essential for an adequate teaching and learning environment, including health and safety features and sanitary facilities. Many of these are already defined in state legislation¹ and assessed as part of the registration of schools. In addition to these basic conditions, there is also growing evidence to suggest that certain aspects of the physical environment – such as ventilation, lighting and temperature – can impact on student outcomes (Barrett et al. 2015).

Despite a growing interest in this area, little empirical research has examined the relationship between capital investment and student performance. The evidence that does exist tentatively suggests a positive relationship, but warns that it is difficult to isolate the impact of capital spending from the range of factors known to affect student attainment, such as teacher quality and students' socio-economic status. The Commonwealth Government's 2011 *Review of Funding for Schooling* (the Gonski Review) commented, 'Governments and the community invest a significant amount of funding into school buildings, facilities and infrastructure, yet it appears that the educational value of this investment is not well understood' (Australian Government 2011, p. 101).

Two studies in the United Kingdom (Department for Education and Skills 2000; Department of Education and Skills 2003) found a small but statistically significant positive relationship between capital investment and student attainment. The first study (Department for Education and Skills 2000) provided qualitative evidence and some quantitative evidence to support the view that a positive and significant association existed between capital investment and student performance. The second study (Department of Education and Skills 2003) built on the first, by examining different kinds of capital investment. Investment in specialist facilities, such as information and communication technology (ICT) and science blocks, was found to have the strongest and most direct impact on student performance of capital projects analysed. However, the report notes that capital investment on its own is not necessarily enough, and that student performance is impacted by a wide range of factors.

¹ See: *Education Act 1990* (NSW) and *Disability Discrimination Act* (1992).

In addition to the effects on student outcomes, the Department of Education and Skills (2003) also found that school facilities serve as a wider resource that can be used by the broader community. The report states 'it is important for any assessment of the benefits of schools' capital investment to reflect the broader benefits' (Department of Education and Skills 2003, p. 45). These benefits may include making school facilities available after hours for sporting events or adult education.

In 2013, the University of Queensland published a report examining the effect building condition has on student achievement and attendance (Institute for Social Science Research 2013). As part of this, the researchers analysed the impact of round 1 of the State Schools of Tomorrow program (2008-2012), which committed \$850 million to refurbish schools across the state. The results showed that students enrolled in the 12 State Schools of Tomorrow schools showed significantly improved NAPLAN scores in the Grammar and Punctuation and Reading domains, and significantly better attendance. The study's authors conclude that these results indicate the State Schools of Tomorrow program significantly improved student outcomes across several indicators.

A study examining the effects of a school construction project in the United States reached similar conclusions (Institute for the Study of Labor 2011). The study examined the effects the 15-year, \$1.4 billion project had on student test scores, enrolment numbers and house prices. The changes made to schools varied but the project targeted certain areas for improvement, including heating and air conditioning, science facilities, classroom technology and play areas. The authors found strong evidence that the program led to sustained gains in reading scores for elementary and middle school students but found weak evidence of a corresponding increase in math scores. Based on their data, the authors were unable to draw any conclusions as to why capital spending may improve test scores or whether any specific building features are particularly important.

The cost of establishing and maintaining physical school assets can vary depending on the characteristics, needs and priorities of the school community. As an example, schools in rural and remote locations have different costs and cost drivers from those in metropolitan areas, just as schools with boarding facilities and schools for specific purposes also have unique needs (Australian Government 2011). The age of school buildings can also impact on maintenance costs, with the upkeep for older buildings generally being more expensive than for newer buildings (Australian Government 2011).

The United States and other industrialised countries provide detailed reports and statistics on the age and condition of school buildings, yet only limited information is available for Australian school facilities (Institute for Social Science Research 2013). A report by the Victorian Auditor-General (2013) found that although 67 per cent of the state's school buildings were in good or excellent condition, 7.5 per cent of buildings, across 505 schools, were at a serious point of decay or were no longer operational (Victorian Auditor-General 2013). No such assessment is available for New South Wales schools,² nor is there a national standard against which the adequacy of school facilities can be assessed. The Gonski Review acknowledged that this lack of data makes it difficult to make a comprehensive assessment of the adequacy of school facilities. However, the review concluded 'it is clear that many government schools, and some poorly resourced non-government schools, are suffering in terms of their facilities' (Australian Government 2011, p. 97).

2 In NSW, the Educational Facilities Standards and Guidelines set out minimum standards and design criteria for all new Department of Education projects. However, these standards are not intended as a benchmark by which current school facilities can be assessed.

The effect of building condition on student performance

The condition of a school environment is generally determined by examining a number of separate physical elements, including lighting, temperature and indoor air quality. Much of the research examines these elements in isolation and, as a result, recommendations regarding some elements conflict with recommendations regarding others (e.g. findings on heating and noise). While separating these elements can be useful, it is also important to consider them together to get a holistic understanding of the school environment.

A number of international studies have identified a link between building condition and student attainment (Barrett et al. 2015; Tanner 2009; Cash 1993). These studies have generally employed a similar approach; rating the overall condition of school buildings and then comparing this against standardised student test scores. A common finding across these studies is that inadequate environmental conditions, such as poor indoor air quality or excessive noise, have a detrimental impact. However, it remains unclear whether improving these elements beyond a reasonable standard has any additional benefits (The Design Council 2005; Woolner et al. 2007; Earthman 2004; Education Endowment Foundation, n.d.). Further, much of this research has been conducted overseas, in the United Kingdom and the United States, so findings may be influenced by the geographical and environmental characteristics of these countries.

Barrett et al. (2015), in a recent study in the United Kingdom (the HEAD project), found the physical characteristics of primary schools can affect students' learning across reading, writing and mathematics. The researchers collected data on 153 classrooms from 27 primary schools, located across three local authority areas that represent a mix of socio-economic levels. They then separated the classroom environment into three categories: naturalness, including light and air quality; stimulation, such as colour; and individualisation, including the flexibility of the space. The classroom environment was then compared to anonymised performance data for 3,766 students from across the schools. The authors found differences in the physical characteristics of classrooms explained 16 per cent of the variation in learning progress over a year. Naturalness was found to account for about half of the effect, with stimulation and individualisation accounting for about a quarter each.

A study commissioned by the New Zealand Ministry of Education (New Zealand Ministry of Education 2004) aimed to gain an understanding of what key stakeholders consider to be elements of 'good' classroom and school design³. Although the sample size was relatively small, and therefore cannot be assumed

to be representative, participants consistently identified four physical factors they felt affected student learning. These were: temperature control, proper lighting, adequate space and appropriate equipment and furnishings.

Although some studies have found a negative link between older facilities and student outcomes (National Clearinghouse for Educational Facilities 2002; Earthman 2004), it is not clear whether this is due to the age of the building or its condition. As Tanner (2009) notes, even new school buildings may have structural problems such as inadequate natural light. Some have suggested that, if nothing else, new school buildings can improve student and teacher attitudes. In a desktop review, the Victorian Department of Education and Early Childhood Development (DEECD 2011) found newer school buildings can have a positive effect on student morale as well as the perception of the school in the local community.

A number of studies have identified improvements in student performance following the renovation of school buildings (Berry 2002; The Council of Educational Facility Planners International 1999). In a case study of a primary school in Washington D.C. Berry (2002) found student attendance, morale and attainment all improved after the school was renovated. The renovation involved replacing the carpet and upgrading heating, cooling and exhaust systems, while teaching staff, curriculum and technology were unchanged (Berry 2002). However, there does not appear to be any evidence to indicate whether the student performance improvements are ongoing or whether they subside in the years following a renovation.

Temperature and ventilation

Evidence suggests there is a positive correlation between student achievement and 'comfortable' temperatures and ventilation. In a review of the existing literature, Earthman (2004) rated temperature, heating and air quality as the most important individual elements for student achievement. Similarly, Woolner et al. (2007) cite a range of research to suggest air quality can improve student morale, behaviour and attendance.

In the New Zealand Ministry of Education study (2004), almost 90 per cent of participating students agreed having a classroom that is 'not too hot or cold' is vital or very important and 70 per cent of teachers rated having a 'well ventilated classroom' as vital. Teachers interviewed felt that good ventilation helped ensure students stayed awake and attentive during class.

³ The study was carried out in two stages: a preliminary qualitative phase, consisting of in-depth face-to-face interviews with teachers, principals and students (20 in total), and then a semi-quantitative survey with school users and design consultants (433 in total).

This is supported by research which has found students perform better in rooms kept at moderate temperatures and humidity levels (National Clearinghouse for Educational Facilities 2002; Wargoocki & Wyon 2007). In an experimental study at a Danish school, Wargoocki and Wyon (2007) found that room temperature and ventilation can improve the speed at which students complete both numerical and language based tasks. In two separate experiments, the authors manipulated air quality and temperature, finding an increase in outdoor air supply and a reduction in temperatures (from 25°C to 20°C) led to an improvement in the speed with which students completed the tasks and had a negligible effect on their accuracy.

Earthman (2004) suggests that good quality central air-conditioning and ventilation can also reduce the incidence of illnesses caused or aggravated by poor air quality, such as asthma. This, in turn, can reduce absenteeism, which often results in poor academic achievement. The Design Council (2005) cites a study that found a link between air quality and attendance at a nursery school (Rosen and Richardson 1999, cited by The Design Council 2005). The National Clearinghouse for Educational Facilities (2002) also refer to a number of studies that have found links between poor indoor air quality, student health and absenteeism.

However, Shield and Dockrell (2004) found air conditioning, ventilation and heating systems may have unintended negative consequences as they can contribute to classroom noise. Further, it is important to keep in mind that, as the National Clearinghouse for Educational Facilities (2002) points out, people often have personal responses to temperature and it is not always possible to maintain the optimum temperature or humidity levels for all students in a classroom.

Classroom lighting

There is a considerable amount of literature relating to lighting in the classroom, including the effects of different types of lighting on both student performance and health. Research shows classroom lighting can affect students' mood, concentration and attitude, which in turn can influence student attainment (National Clearinghouse for Educational Facilities 2002; Earthman 2004; Woolner et al. 2007). There is also evidence to suggest inadequate lighting can exacerbate health issues, such as headaches, eyestrain and fatigue (Woolner et al. 2007).

In the Ministry of Education study, teachers identified the quality of lighting as one of the top three most important factors in classroom design (New Zealand Ministry of Education 2004). Both teachers and students involved in the study expressed a general preference for natural lighting but acknowledged that it was important to be able to control

the level of light (such as through blinds). This is supported by research, which has found a positive relationship between natural light and improved student achievement (Heschong Mahone Group 1999; Tanner 2009; Barrett et al. 2015).

The Heschong Mahone Group (1999) examined the effect of daylight on students' academic performance. The researchers obtained information on a variety of student and institutional variables at schools across three American school districts, each with different curricula, teaching styles and climates. Through a multivariate regression analysis, the researchers identified a statistically significant correlation between the presence of daylight and student performance, even when controlling for variables such as students' socio-economic status and ethnic background. The authors suggest the consistency across the three districts supports the proposition that there is a 'valid and predictable' effect of daylight on student test scores (Heschong Mahone Group 1999, p. 7). However, they note that the study does not indicate whether daylight affects students uniformly.

Importantly, relying solely on natural light is not always practical and it seems that a combination of natural and artificial lighting is ideal (New Zealand Ministry of Education 2004; Benya 2011 cited by The Design Council 2005; Barrett et al. 2015). Barrett et al. (2015) conclude natural daylight should be the main source of lighting in schools but it should be supplemented by artificial lighting where necessary.

Noise and acoustics

It is generally accepted that noise has a detrimental effect on student learning (Shield & Dockrell 2004; National Clearinghouse for Educational Facilities 2002; Woolner & Hall 2010). Noise can come from inside the classroom, such as the sound generated by heating systems and children talking, as well as outside the classroom, such as traffic and noise from other parts of the school. This can be exacerbated by physical aspects of the space, including poor sound insulation between rooms, inadequate window glazing and the presence of hard, noise-reflecting surfaces (Woolner & Hall 2010).

In a review of existing literature, the National Clearinghouse for Educational Facilities (2002) cites a number of studies that suggest classroom noise can have negative effects on students' reading comprehension, morale, concentration and health. The Clearinghouse comments that, overall, the research is 'consistent and convincing: good acoustics are fundamental to good academic performance' (2002, p. 6). Woolner and Hall (2010) also refer to research suggesting excessive noise can be stressful for teachers and often forces them to pause or raise their voice. However, there is also evidence to suggest that although noise can affect student learning, it is not as significant as the other environmental factors described above (Barrett et al. 2015).

Research into the effect of noisy learning environments was initially driven by concerns about exposure to chronic external noise, such as that from aircraft or road traffic. Exposure to external noise has been found to affect sleep, cognitive development and even blood pressure, although some of these findings have been inconsistent (The Design Council 2005). Hygge (2003) found that recordings of air and road traffic negatively affected students' memory and recognition. Similarly, the RANCH Project (Clark et al. 2006) found aircraft noise exposure at school was linearly associated with impaired reading comprehension, even when controlling for socio-economic variables. However, unlike other research, the study found no significant effect of road traffic noise exposure.

Shield and Dockrell (2008) carried out a study to examine the impact of both environmental and classroom noise on student performance. The impact of noise was examined in two ways: by investigating the link between internal and external noise levels and students' performance in standardised tests, and by experimental testing of children in different classroom noise conditions. Findings from the two investigations were consistent, showing that both environmental and classroom noise have detrimental effects upon children's academic performance. This was particularly evident among children with special educational needs.

Barrett et al. (2015) suggest designers and teachers can do a number of things to reduce classroom noise, including: adding sound absorbing materials, such as rugs; and configuring the classroom so students are seated close to the teacher. Shield and Dockrell (2007) recommend improving insulation and investing in quieter models of heating and other classroom equipment. However, attempts to reduce noise can be problematic as they often have detrimental impacts on other physical elements, such as indoor air quality (Woolner & Hall, 2010). As an example, carpets or ceiling hangings may collect dust, while open windows may improve indoor air quality but enhance external noise levels.

Demountable classrooms

The term demountable, also referred to as portable, relocatable or prefabricated classrooms (University of Melbourne 2010), refers to a movable classroom structure. These are usually constructed off-site and transported to schools to be used as additional classrooms. Demountables are widely used across Australia, and account for approximately 12 per cent of classrooms in New South Wales government schools. Demountables can be moved to follow demand, meaning they are useful in responding to changing school enrolment levels or to cope with damage caused by natural disasters (University of Melbourne 2010).

Anecdotally, demountables are thought to be inferior learning environments, yet research into the effect of demountables on student performance is limited and there do not appear to be any studies that specifically compare the difference in performance between students in demountable and permanent classrooms.

Slee et al. (2014) cite two American studies that identified a number of problems with demountable classrooms in California, including air quality, acoustics and temperature control. Importantly, the studies found many of these issues also existed in permanent classrooms, suggesting that it is the quality of the space, not its permanence, that matters most. Similar issues were reflected in the anecdotal comments reported in a Melbourne University-ARC linkage project, in which educators were asked about their experiences with demountables (University of Melbourne 2010). However, it remains unclear whether environmental issues, such as poor indoor air quality, are more common in demountables than in permanent classrooms.

Slee et al. (2014) comment that demountable classrooms may impact more on community perceptions than student learning. This is consistent with feedback in the Future Proofing Schools project (University of Melbourne 2010), with participants suggesting that there is stigma attached to the use of demountables and that this can affect both teacher and student attitudes. One teacher commented 'They are seen as second rate. The kids know this and are less respectful of the space' while an infrastructure manager said 'We can't deny the stigma that is attached to portables' (University of Melbourne 2010, p. 18).

The effect of building condition on teacher attitudes

A number of studies have also examined the impact of the learning environment on teachers' attitudes. In an American study, the National Clearinghouse for Educational Facilities (2003) asked teachers to rate their working conditions and how they perceived these conditions affected their job performance. The study involved surveying 688 teachers in Chicago and 1,273 teachers in Washington D.C. on a range of factors, such as the degree of overcrowding, the availability and adequacy of school facilities and physical elements, such as indoor air quality and classroom lighting. The author concluded that poor conditions make it more difficult for teachers to deliver an adequate education to their students and also adversely affect teachers' health and retention.

Berry (2002), in his case study of Charles Young Elementary School, observed an improvement in teacher attitudes following the school's renovation. In addition to improvements in student performance, Berry also found improvements to the school environment led to better staff retention rates and more optimistic and proactive attitudes amongst teaching staff.

In the United Kingdom, the Building Schools for the Future (BSF) program, which involved the refurbishment of secondary schools, was found to have a positive impact on school engagement with local communities. Eighty four per cent of head teachers from schools within the program indicated that the new or refurbished buildings led to an improvement in relationships with parents. Many also expected that the new buildings would lead to more positive engagement with the wider community (Department for Children, Schools and Families 2010).

School facilities and amenities

Specialised facilities: libraries and science laboratories

Both Australian and international research has identified a link between the quality of school libraries and student outcomes (Francis, Lance & Lietzau 2010; Softlink 2014; Australian School Library Association 2003). In a desktop review, the Australian School Library Association (2003) identified a range of evidence to suggest a strong library program that is adequately staffed, resourced and funded can lead to higher student achievement even after controlling for socio-economic factors.

A Commonwealth Government inquiry into the role, adequacy and resourcing of school libraries found 'Whilst research demonstrates a clear correlation between a good school library and teacher librarian and student achievement, the link is not always appreciated, acknowledged or made best use of' (House Standing Committee on Education & Employment 2011). The inquiry, *School libraries and teacher librarians in 21st century Australia*, acknowledged the capacity of school libraries and teacher librarians to improve student literacy as well as their understandings of ICT.

There is also some evidence linking the quality of science laboratories and equipment with student performance. Earthman (2004) rates improving science laboratories as the fourth most important priority, after ensuring schools have adequate lighting, acoustics and temperature. He refers to a study conducted by Hines (1996), which investigated the relationship between the condition of school buildings and student achievement. In the study, principals were asked to rate the condition and age of their school's science equipment. Hines then compared this rating against students' performance in science. He found students in schools with more highly rated equipment, achieved better science results. This is consistent with findings in another American study, which also found a link between the quality of science laboratories and higher student attainment in science subjects (Cash 1993).

Recreational and outdoor spaces

There appears to be limited research into specific links between the design of outdoor and recreational spaces in schools and student learning outcomes. There is, however, substantial evidence to suggest students who regularly engage in play and physical activity tend to have better grades, school attendance and classroom behaviour (DEECD 2011; National Center for Chronic Disease Prevention and Health Promotion n.d.).

Much of the literature in this area focusses on the benefits of play, including its effect on physical, social and emotional development. It appears that the capacity to gain such benefits depends on the quality of the play environment, as well as how such environments are used and supervised (DEECD 2011).

The DEECD literature review identified a number of considerations for outdoor design, including student safety and security, the access and needs of students with a disability and the need for quality, well supervised environments that encourage free play. Thian (2006) suggests that 'good' school playgrounds support developmentally appropriate activities, provide diverse spaces and are interesting to the user. She notes, 'If a type of space or equipment is not liked by the children – irrespective of whether it has been well-designed – it will not be used' (Thian 2006).

There is also a growing body of research into the role of school spaces in encouraging physical activity and, in turn, improving health outcomes amongst students. The United Kingdom Department of Education and Skills (2003), in their study into the relationship of capital spending and student performance, found spending on school sports grounds/gymnasiums had health benefits for students. These benefits were particularly apparent in lower socio-economic areas, where children had little access to other facilities. New or improved facilities in schools were found to encourage students who did not previously participate in sport to do so while also reducing the risk of injury for those who already participated.

In a recent Australian study, Hyndman et al. (2014) evaluated the impact of a simple school playground intervention on students' physical activity. The researchers placed a range of materials, including milk crates, buckets and bicycle tyres, in the playground at one school and then compared the play of students at this school against those at a control school. They measured the activities of children at the schools through the use of pedometers and direct observation and found children at the intervention school were more likely to participate in, and enjoy, physical activity.

There is also some evidence to suggest school garden and kitchen programs can have a range of benefits for students and the wider school community (Centre for Health Service Development 2013; Pascoe & Wyatt-Smith 2013). A common aim of school gardens is to improve students' intake of fruit and vegetables, however there is also some evidence that these initiatives can have positive impacts on student learning (Pascoe & Wyatt-Smith 2013). In Australia, an evaluation of the Stephanie Alexander Kitchen Garden National Program⁴, found parents and teachers identified improvements in students' behaviour and teamwork following the commencement of the program (Centre for Health Service Development 2013). Ninety-seven per cent of teachers involved in the evaluation felt the program supported classroom learning and had positive benefits across subject areas. However, the evaluation found no evidence to suggest the program had any effect, positive or negative, on NAPLAN scores.

⁴ The Stephanie Alexander Kitchen Garden National Program teaches students in Years 3 – 6 how to grow, harvest and prepare fresh food. To date, the program has been implemented in 837 schools across Australia.

School size and crowding

School size

There is some disagreement in the existing literature regarding the benefits or drawbacks of different school sizes. There are few studies with rigorous methodologies (Slate & Jones 2005), and much of the literature on the subject is characterised by ideological argument, rather than a careful analysis of the evidence (Scheerens, Hendriks & Luyten 2014). Many of the existing studies also fail to take into account potentially confounding factors, such as prior achievement, socio-economic status or remoteness (EPPI-Centre 2004).

Much of the research in this area has been conducted in the United States, where schools are considerably larger than schools in Australia. In these studies, a 'small' school is sometimes defined as schools with up to 1,000 students (Cotton 1996), and so a study may end up comparing the performance of what would be, in the Australian context, moderately-sized or large schools to very large schools.

To date, evidence of the effects of school size has been mixed or inconclusive. Hendriks (2014 cited by Luyten 2014), in a review of 46 studies of the effects of school size on achievement, found that 62 per cent of reported effects were not statistically significant. Of the remaining studies, 18 per cent showed negative effects (smaller schools do better) while 9 per cent showed positive effects (larger schools do better). There is some research to suggest that the 'optimal' school size is somewhere in the middle. That is, students in very small or very large schools tend to do worse than students in moderately-sized schools. Garret et al. (EPPI-Centre 2004), in their systematic analysis, predicted optimal sizes of between 900 and 1500 students.

A literature review by the Organisation for Economic Co-operation and Development (OECD) (2014) identified both pros and cons for students at large and small schools. The paper notes that school size may affect students' learning through the quality and variety of subjects offered, the availability of special needs support and the possibility to implement ability streaming (i.e. gifted and talented programs). The paper also cites research to suggest that although smaller schools can facilitate more personal teacher-student relationships, they can also create professional isolation amongst teachers and reduced social networks for students. Ultimately the OECD paper concludes that there is no 'one-size-fits-all' solution to school size as factors such as location and cost play an important role.

To address concerns over school size, some high schools in the United States have moved towards a 'school-within-a-school' model. This model may be employed in different ways, but generally involves dividing a school into smaller, autonomous units or 'home-bases'. Students often complete their core

subjects, such as maths, English and science, at their home-base and then work with other bases for specialist elective subjects. Facilities such as gymnasiums and play spaces may also be shared between the bases (Human Scale Education 2009).

No robust studies have been conducted on the impact of the school-within-a-school model on student outcomes, but proponents suggest that the model provides the community atmosphere of a small school, while still providing students with access to facilities and resources that are often not available in small schools (Human Scale Education 2009a). Advocates suggest that creating smaller schools within larger school communities will mean teachers get to know their students better, which allows them to more effectively monitor their students' progress (Human Scale Education 2009a). However, Lippman (2010) notes that although the goal of breaking up large schools is to create units with separate identities, these units tend to maintain the mentality of a large school. Lippman suggests that the sharing of sports facilities or lunch areas, as an example, sustains the 'big-school mentality' and prevents the units from developing their own cultures.

Crowding

Overcrowding is often anecdotally linked to poor student learning outcomes but there is limited empirical research on this issue, particularly in Australia. Of the research that does exist, the majority has been conducted in specific school districts in the United States, where overcrowding has been an ongoing issue. Generally, a school is deemed overcrowded when it enrolls more students than it was designed to accommodate. This may negatively affect teacher-student relationships, noise, student concentration levels and teacher stress (Earthman 2004).

In a study of schools in Los Angeles, Welsh et al. (2012) identified achievement gains amongst students who moved from overcrowded schools to new, less crowded facilities. The researchers tracked almost 20,000 primary and secondary students who moved to new schools from 2002 – 2008. The degree of overcrowding in the students' previous school was a strong predictor of achievement gains, with those from severely overcrowded schools experiencing the largest improvements. They also found students who stayed at their school benefited from their peers moving to the new facilities, as this reduced crowding at their own school. They found no relationship between the per-student construction cost and the magnitude of achievement gains, meaning that the improvement by students moving to less-expensive new schools was no different, on average, from those moving to more expensive new facilities.

Rivera-Batiz and Marti (1995) conducted a study to examine the impact of overcrowding on student test scores as well as student and teacher attitudes. The first part of the study used data from the New York City Board of Education, including information on a number of student and school-level variables, for all public schools in New York City. Using a multiple regression statistical analysis, the authors found that overcrowding has a strong negative impact on student achievement in schools with a high proportion of students from low socioeconomic backgrounds, but not in schools with a high proportion of students from high socioeconomic backgrounds. The second part involved surveying 599 students and 213 teachers from four randomly selected, overcrowded schools in New York. Of the students surveyed, 62.6 per cent felt that their school had too many students, while more than 75 per cent of teachers surveyed felt that overcrowding affected classroom activities, instructional techniques and student achievement.

Vertical schools

In response to overcrowding in some schools, particularly in urban areas, there has been a move towards designing multi-storey, so-called 'vertical' school buildings. These have been built to make effective use of small urban sites and reduce the need for children to commute long distances (Silverwood 2010). There are now many vertical schools in the United

States, Asia and Europe (Johnson 2015). Although there are some architectural case studies on these schools, there does not currently appear to be any empirical research into the effect of these environments on student outcomes.

To date, the literature on vertical schools has focussed on the challenges associated with integrating outdoor play spaces and sports facilities as well as concerns about supervision and safety (Silverwood 2010). In response to some of these challenges, Roy Strickland, director of the urban design programme at the University of Michigan, developed the City of Learning strategy (Strickland 2003). The strategy advocates using the urban environment as an extended classroom by utilising the resources available in the local area, including museums, libraries and playing fields.

In the United States, there has been some debate about appropriate sizes for school sites. McDonald (2010) notes that the preference for large school sites is shifting, particularly in urban areas. In 2004, the Council of Educational Facility Planners International (CEFPI) removed the minimum acreage standard in their school planning guidelines and many US states have also eliminated legislative acreage requirements over the past decade (McDonald 2010). Under the new CEFPI guidelines, school districts are encouraged to base the size of school sites on educational program needs.

Classroom design

The layout and aesthetics of classrooms have been shown to have an effect on student learning. Findings from the HEAD project in the United Kingdom found that the design of individual classrooms was more important than whole-school factors such as size, navigation routes and play facilities (Barrett et al. 2015). Further, The Design Council (2005) suggests the classroom environment can influence behaviour, and cites a number of studies that observed a correlation between the aesthetics of a room and student participation and attitudes.

A consistent theme across the literature is that learning spaces need to be flexible, both pedagogically and physically, to accommodate different needs and activities and allow for the effective integration of ICT (DEECD 2011; The Design Council 2005). Flexibility may be measured by assessing how easily furniture and equipment can be adjusted and moved as well as the presence of breakout spaces or zones for different activities (Barrett et al. 2015).

Innovative learning environments

There has been increasing discussion across the literature about so-called innovative learning environments (ILE). There is no clear definition for this term but it is generally used as a catch-all phrase to refer to environments that are different from 'traditional' classrooms, in terms of both the physical characteristics of the space and the pedagogical practices used within it. Chapman et al. (2014) comment that these spaces are distinct from traditional classrooms 'not only for their architectural designs and agile furniture, but also for their team teaching environments and an increased autonomy of students' (Chapman et al. 2014, p. 40).

Terminology varies across the literature, with innovative learning environments also referred to as non-traditional classrooms, flexible learning spaces, agile classrooms or open plan classrooms. The layout of such spaces may differ, but they are generally designed to be multi-purpose with large open spaces to accommodate different activities, groups and

technologies. These spaces tend to include movable furniture and dividers that may be adjusted to group a number of classes together for all or parts of the day. The adoption of such spaces has been contentious, yet there does not appear to be any robust empirical research investigating the link between these spaces and student performance.

The term open classroom gained currency during the 1960s and 1970s, although experimentation with open learning spaces can be traced back to the beginning of the twentieth century (Alterator & Deed 2013). Open plan classrooms are praised for being more social and less authoritarian than 'traditional' classrooms (Mealings 2015; Forbes 2011). They are also thought to benefit teachers by promoting the sharing of skills and allowing for collaborative teaching (Mealings 2015; Forbes 2011). However, open plan classrooms have also been criticised for being noisy (Mealings 2015; Mealings et al. 2014), difficult to manage and inappropriate for some students, particularly those with special needs (Hickey 2011).

Supporters of open plan or agile learning spaces suggest that they are better suited to preparing students for the demands of the 21st century. In an opinion piece in the Sydney Morning Herald, UK based academic Stephen Heppell (2015) comments 'In preparing our children for that uncertain future, we inevitably need schools unlike the ones that prepared their parents.' While Heppell acknowledges that instructional learning may be appropriate in some circumstances, he suggests that learning spaces should not just be designed around this learning model. It is important to bear in mind, however, that long-standing evidence shows students who experience explicit or instructional teaching practices⁵ perform better than students who do not (Centre for Education Statistics and Evaluation 2015).

Chapman et al. (2014) identified both pros and cons for students in 'non-traditional' classrooms in Australia. The researchers observed teaching and learning activities in three primary schools over a three-day period and conducted semi-structured interviews with teachers and principals. They found students in these classrooms often exhibited a considerable degree of autonomy, but this created problems for students who found it difficult to manage their own behaviour. They also found that while non-traditional classrooms allowed students to form more fluid relationships with their peers and teachers, it had the potential to prevent them from forming strong bonds (Chapman et al. 2014).

Research has also found the noise in open plan environments can be distracting and disruptive for both students and teachers (Mealings 2015). Mealings et al. (2014) examined the acoustics of an open plan Kindergarten classroom containing

91 students, compared to an enclosed classroom of 25 students. The results revealed much higher intrusive noise levels in the open plan classroom, resulting in signal-to-noise ratios and speech transmission index scores well below those recommended in classrooms with students of Kindergarten age (Mealings et al. 2014). In another study, Mealings et al. (2014a) randomly selected 22 students to participate in a speech perception task while their peers completed both quiet and noisy activities. They found participants' accuracy, including their speed, was lower when their peers were engaged in noisy activities. The authors concluded that the results suggest open-plan classrooms are not appropriate learning environments for children in early primary school (Mealings et al. 2014a).

Much of the literature on this topic suggests that the move towards open learning environments must be accompanied by changes in teaching practices. In an article evaluating the pros and cons of open plan learning environments, Forbes (2011) notes that 'without appropriate preparing and planning, the environment can become dysfunctional and chaotic, students' learning fragmented and teachers' working lives stressful.'

Open plan classrooms have been implemented in many Catholic schools in the Parramatta Diocese in Western Sydney. There is currently no published quantitative data linking these redesigns to student outcomes.

Incorporation of information and communication technology

The advent of ICT has significantly influenced thinking about classroom design. In schools, design has moved away from enclosed, separate computer labs to computer pods integrated into classroom layouts (DEECD 2011). More recently, the mobility afforded by laptops, tablets and wireless internet has meant students have been able to (and in some places, required to) bring their own devices to school.

A consistent theme in the literature is that the integration of ICT into learning spaces requires the support of both the physical infrastructure of a school and its organisational arrangements, including pedagogies, policies and rules (Moyle 2010). Moulds and Harper (2009) note: 'On their own, providing a new building or introducing an ICT program will not necessarily make learning more effective' (p. 10). However, as Richards (2006) suggests, the integration of new technologies into traditional classrooms is often an afterthought and is not necessarily accompanied by changing pedagogical models.

⁵ Explicit teaching practices involve teachers clearly showing students what to do and how to do it, rather than having students discover or construct information for themselves.

Central to the integration of technologies is the IT infrastructure of a school, including hardware, software and internet connectivity (Moyle 2010). At a classroom level, there are a number of practical design elements that may hinder or enhance technology use. These include the number and location of power and telecommunication points and the positioning of computers and interactive whiteboards at appropriate heights and away from glare (New Zealand Ministry of Education 2004). The introduction of technology into the classroom is also thought to heighten the need for adequate lighting, temperature control and ventilation (The University of Melbourne 2010).

Many have suggested that classrooms need to be flexible and adaptable to ensure they can accommodate current and future technologies (The University of Melbourne 2011; Moyle 2010). This includes incorporating furniture that can be easily rearranged to accommodate different activities. Moyle (2010) recommends both classrooms and staffrooms have furniture that is adjustable, attractive and comfortable to encourage the uptake of technology amongst both students and teachers.

Byers and Imms (2014) examined the relationship between classroom layout and how students and teachers perceive the usage and effectiveness of one-to-one technology. They compared a traditional classroom, with desks and chairs in rows in a fixed instructional setting, with a new adaptable learning space, which featured flexible furniture and integrated digital and visual technologies. Results from quantitative analyses over a one-year period indicated that a more flexible, collaborative classroom layout had a measurable effect on how students and teachers perceived the usage, relevance and value of one-to-one technology. The study did not examine student outcomes.

The integration of ICT has also led to the advent of 'virtual learning spaces.' These may be provided through online learning management systems such as Moodle and Blackboard, and can include forums, blogs and interactive activities. These 'virtual learning spaces' can serve as an extension of the classroom, or in some cases may replace the physical classroom altogether. As a result, many have suggested that the school environment should no longer be thought of as merely physical (Moyle 2010; Organisation for Economic Co-operation and Development 2010; DEECD 2011; Moyle 2012). Moyle suggests that virtual learning environments allow schools to 'support students and staff to learn in ways previously not possible, and to practise different sorts of interpersonal relationships in various environments' (Moyle 2012, p. 3). In spite of this, the literature has paid little attention to the relationship between these virtual learning spaces and the built environment (DEECD 2011).

Aurora College is a virtual, partially selective secondary school⁶ run by the NSW Department of Education. The school currently has an enrolment of 160 students, and this will increase over time. The school allows students in rural and remote areas to remain in their local school and community while studying specialist subjects, that their 'home' school cannot offer. Students 'attend' classes by logging onto the school's online conferencing system and also attend a residential camp twice a year, which provides an opportunity to complete practical work (i.e. science experiments). Where possible, lessons are recorded so that students can access these at other times. The school opened in 2015, so there is not yet any evidence as to its impact on student outcomes.

Colour and complexity

A number of studies have also examined how the visual complexity of a space affects student learning (Barrett et al. 2015; Fisher, Godwin & Seltman 2014). Findings in this area, particularly in regards to colour, are often inconsistent and it appears that responses to aesthetic elements of the classroom are largely subjective.

The case is frequently made that display of children's work is beneficial, yet evidence on this is mixed. The display of students' work has been found to make the school environment more welcoming (Maxwell 2000, cited by Woolner et al. 2007) but there are disagreements about how much should be displayed and where. Fisher, Godwin and Seltman (2014) found that kindergarten students performed better in a sparse classroom than one that was heavily decorated. In the study, 24 kindergarten students were placed in a laboratory classroom for six introductory science lessons. The room was decorated for three lessons and bare for three lessons. The results showed that while children learned in both classroom types, they learned more when the room was not decorated. Specifically, the students' accuracy on the test questions was higher in the sparse classroom than in the decorated classroom (55 per cent correct compared to 42 per cent).

Findings from the HEAD project (Barrett et al. 2015; University of Salford, Manchester 2015) suggest the effect of visual complexity is curvilinear, with high or low levels of complexity producing poorer learning conditions. The authors conclude an intermediate level of visual complexity is optimal and spaces should be designed to create 'reasonable level of visual interest – not boring, but not too dramatic' (University of Salford, Manchester 2015, p. 35). They suggest students' work should be displayed but that 20 – 50 per cent of the available wall space should be kept clear.

⁶ Entry to a Selective High School is based on academic merit. Generally, academic merit is determined mainly by the combination of the results of the Selective High School Placement Test in reading, writing, mathematics and general ability, together with the primary school assessments of student performance in English and mathematics.

Colour is seen as a significant element of classroom design (Woolner et al. 2007). Yet, as The Design Council (2005) notes, research regarding the use of colour in classrooms is often conflicting, with some suggesting bright colours are best while others warn against the use of intense primary colours. Students involved in the New Zealand Ministry of Education study (New Zealand Ministry of Education 2004) indicated a preference for bright, colourful and stimulating internal surroundings. However, participating design consultants felt that colour was subjective, with some advocating the use of bright colours and others suggesting more neutral tones.

Classroom furniture and layout

Both the style and arrangement of classroom furniture has been found to impact on students, although evidence gaps remain. The HEAD project (Barrett et al. 2015) identified furniture as an important element of effective classroom design. The authors note the importance of comfortable chairs and desks, which are both visually interesting and ergonomic⁷ to the students' ages and sizes. The authors also recommend rubber feet on chairs as a way of reducing classroom noise (Barrett et al. 2015). Similarly, the Future Proofing Schools report (University of Melbourne 2010) noted that furniture choice and layout play a critical role in supporting different types of learning.

The arrangement of classroom furniture has been found to affect student behaviour, particularly amongst less-attentive students (Rosenfield, Lambert & Black 1985). However, optimal seating arrangements appear to vary depending on the activity in which students are engaged. In a review of the existing literature, Wannarka and Ruhl (2008) suggest seating students in rows, facing the front, can improve on-task behaviour but that arranging desks in clusters or semi-circles is more conducive to group work.

Although ergonomics has been well researched in the workplace, its role in classroom settings has received comparatively little attention. Commonly cited considerations for classroom furniture include durability, size, cost and flexibility (New Zealand Ministry of Education 2004; Barrett et al. 2015). Student comfort is also a consideration, and there is some evidence that ergonomically designed furniture can improve on-task behaviour and students' sitting positions (Knight & Noyes 1999, cited by The Design Council 2005). In the Ministry of Education study, teachers acknowledged the impact of uncomfortable seating on student learning, although this was mentioned less than factors such as lighting, acoustics or room layout. Participating students mentioned seating more frequently, with comfortable chairs being a significant issue, particularly for secondary students (New Zealand Ministry of Education 2004).

A consistent suggestion across the literature is that classroom furniture should be adjustable to accommodate different students and activities (Barrett et al. 2015; Jermolajew & Newhouse 2003; Moyle 2010). In an Australian study, Jermolajew and Newhouse (2003) examined ergonomics and the use of computer facilities in a Western Australian secondary school. Among the sample of 52 Year 8 students, participants' weight ranged from 28kg to 78kg and their height ranged from 116cm to 183cm. The authors conclude that these variations highlight the importance of adjustable workstation furniture as well as the need to teach students about ergonomic principles.

Two studies in the United States have examined the effect of standing desks in the classroom. The first (Benden et al. 2014) examined the effect of these desks on energy expenditure, finding children in seated desk classrooms had significantly lower energy expenditure and steps than children using standing desks. The second study (Dornhecker et al. 2015) was designed to specifically examine how standing desks impact on student engagement. Of the study's 282 primary school participants, 158 were assigned to standing desks and 124 were assigned to traditional desks. Both groups showed general increases in their academic engagement over time, but the average total engagement score was slightly higher for the group using standing desks. The authors conclude that the use of standing desks would allow schools to increase students' energy expenditure without negatively impacting on their academic engagement.

⁷ Ergonomics is concerned with the design of objects to match the physical characteristics and constraints of the human bodies that are to use them.

The design and transition process

Much of the existing research in this area focusses on the physical elements of spaces, without considering how students and teachers actually adapt to and use new spaces. The DEECD (2011) review found the majority of the literature focuses on 'the quality of conditions, perceptions or tangibles rather than educational practices or intangibles in terms of how a space is perceived, used, and with what effect'.

An emerging idea is the importance of the design and transition processes. Based on their evaluation of existing research, The Design Council (2005) concludes 'the nature of the improvements made in schools may have less to do with the specific element chosen for change than with how the process of change is managed.' That is, the design and transition processes may have more of an effect than the physical change itself.

Learning spaces have traditionally been designed by architects and interior designers. However, there has been a trend towards participatory decision making in which teachers and students are involved in the design process (DEECD 2011; Flutter 2006). The rationale for user participation varies, and recent initiatives have involved students and teachers for different reasons (Flutter & Rudduck 2005). Flutter and Rudduck (2005) reviewed how and why student voice has been used by examining a number of recent initiatives in the United Kingdom, including *School Works* and the *Joinedupdesignforschools Project*, as well as smaller projects in Australia and the United States. They found common objectives have been to: engage students' interest in design

and the built environment; gain valuable feedback from end-users; and provide opportunities for democratic, inclusive decision making (Flutter & Rudduck 2005).

There is a view that participatory design processes will improve teacher practices and, ultimately, benefit students' learning experiences. The input of teachers in this process is thought to improve staff morale as well as encourage positive attitudes towards the new space (The Design Council 2005). Similarly, Fisher (2007) suggests that involving educators in the design process means that once a space is complete, they will have a clear idea of how the space can best be used. Woolner (2009) also identifies benefits to involving students in the process as, aside from their day-to-day experience of the school environment, students tend to be more imaginative and less conservative than adults. However, Flutter (2006) warns that effective student participation requires more than short-term or one-off strategies to ensure students feel their views are being taken seriously.

Despite the theoretical support for participatory design, there is, as yet, little empirical evidence that this leads to better student outcomes. Further, although allowing current students and teachers to participate in the design process may give them ownership over the space, it is not clear what effect this has for future teachers or cohorts of students.

Conclusion

Overall, the research suggests that basic physical elements of the school environment, notably lighting, noise, temperature and ventilation, can affect student learning. An ongoing question is whether, once these elements are at an adequate standard, further improvements positively affect student outcomes. There is little or mixed evidence for school size, open classrooms or vertical schools in terms of their impact on student outcomes.

An encouraging finding is that many of the basic elements of learning environments are quick and inexpensive to change. These include altering the layout of a classroom, providing a range of different sized furniture or changing the way students' work is displayed. Yet the evidence also suggests

it is important to consider how the physical elements of a classroom interact, particularly where changing one element may be detrimental to another.

A common conclusion in the existing literature is that changes to the school environment should be informed by the pedagogy, culture, practices and characteristics of the particular school. In line with this, an emerging theme in the literature is the benefits of including school users in the design process. However, while there is increasing anecdotal support for this approach, there is not yet empirical evidence as to whether this actually improves student learning outcomes, particularly long-term.


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Centre for Education Statistics and Evaluation
GPO Box 33
Sydney NSW 2001
Australia

 02 9561 1211

 cese@det.nsw.edu.au

 www.cese.nsw.gov.au

NSW Department of Education

