SOCIO-ECONOMIC CONSEQUENCES OF BETTER AIR QUALITY IN PRIMARY SCHOOLS

SLOTSHOLM A/S
RÅDHUSSTRÆDE 6
1466 COPENHAGEN K
WWW.SLOTSHOLM.DK

IN COLLABORATION WITH THE CENTRE FOR INDOOR ENVIRONMENT AND ENERGY AT THE TECHNICAL UNIVERSITY OF DENMARK AND THE DREAM GROUP, FINANCED BY VELUX A/S
JULY 2012

SLOTSHOLM

1. Synopsis

One of the objectives of the Government Foundations of 2011 is a *public school that gives every child the opportunity to learn as much as possible and gain greater proficiency in subjects taught.* One of many measures that can be taken to reach this goal is to ensure air quality in classrooms matches that of our neighbouring countries; air quality in schools in Denmark is currently far below those levels.

Danish research has shown that improved air quality leads to better performance by schoolchildren. Adequate fresh air in a classroom leads to an estimated 10 point improvement in performance on the PISA scale, a tool used to compare pupil performance in various countries. It is believed that this ten-point improvement could be achieved if Danish requirements for amount of fresh air in classrooms were to be raised to the level currently required in Sweden.

The amount of fresh air available can be increased by mechanical ventilation or automatic opening of windows. In principle, this can also be done by manually opening windows in breaks, for example – the problem is that teachers and pupils forget to do it. In such a situation a visual indicator that indicates when CO_2 levels in the classroom are too high could be usefull.

Better air quality not only makes going to school (and teaching) more enjoyable. It also gives socio-economic benefits. International research has shown that better performance leads to better educated and more productive adults, which has a positive effect on both production and the public purse.

The financial benefits of better air quality in primary and secondary schools can be quantified with the DREAM model. DREAM estimates that the effect of Danish schoolchildren having the same air quality as those in Sweden would be an annual increase in the GDP of €173 million and an annual improvement of public finances of €37 million. The underlying reasons are that pupils will be more productive when they grow ups, that somewhat fewer would elect to stay for an extra years in primary school before going to secondary, and that sick leave among teachers would fall.

The steps needed to be taken to improve air quality in schools could probably be instigated within the budgetary frameworks of the energy-political agreements for 2012-2020. In other words, achieving these economic benefits is possible with existing budgets.

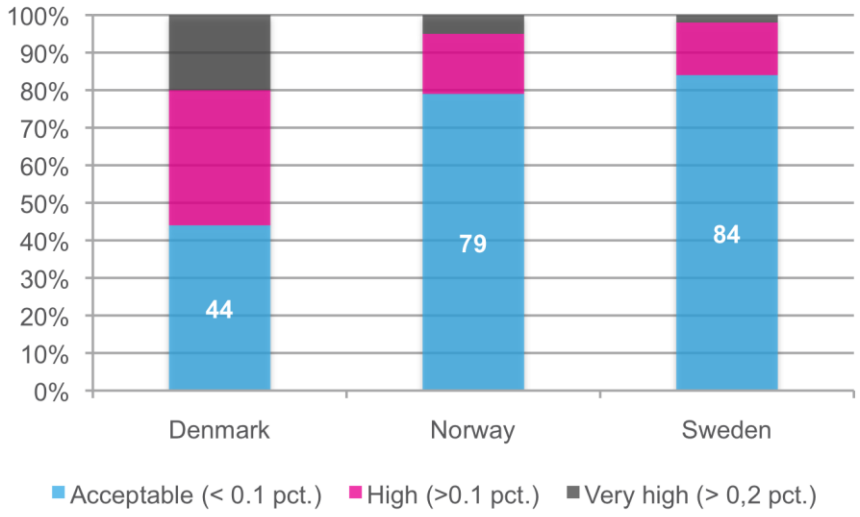
2. Air quality in schools

The air quality in many Danish classrooms falls short of current regulations. Furthermore, Danish pupils have to contend with poorer air quality than their counterparts in Norway and Sweden.

According to the Building Code, “classrooms in schools and other educational institutions” should not have a CO_2 level exceeding 0.1 per cent[i] for extended periods. The CO_2 level is a measurement of how well a room is ventilated and an indicator of air quality in general. If CO_2 levels are too high, the ability to think rationally and make decisions is affected.[ii]

Danmarks Tekniske Universitet (DTU – The Technical University of Denmark) has been involved in taking measurements in many classrooms and has concluded that the rules are generally ignored − CO_2 levels in most classrooms are too high.[iii]

Figure 1: CO_2 concentration in classrooms– Denmark, Norway and Sweden



Source: Report on Mass Experiment, DTU Source: Report on Mass Experiment, DTU 2009 and own calculations

According to DTU, CO_2 concentrations are *high* or *very high* in 56 per cent of classrooms. Air quality is also worse in these classrooms than legislation requires. 44 per cent have acceptable air quality.

3. Better learning with better air quality in classrooms

A lower CO_2 concentration, and thereby better air quality, can be achieved with better ventilation – which is why the Building Code includes regulations about airing out. Several factors are involved but they approximately correspond to a demand for 6 litres of fresh air per second per person. This is considerably lower than in Sweden, for example, where the figure is 8.4 litres. DTU has studied the effect of ventilation, and therefore better air

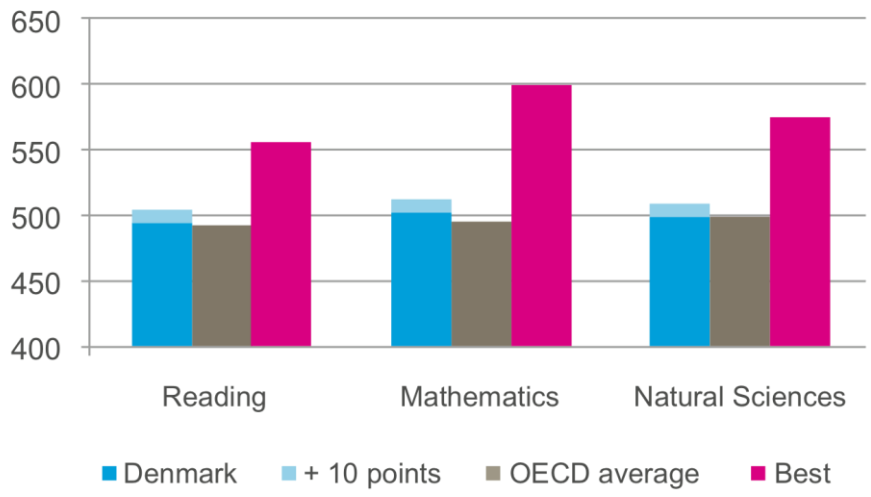
quality, on pupil performance; the conclusion is that pupils' test results improved.

The study was conducted as a controlled experiment in six school classes where the students completed a series of tests in Danish and maths under two different sets of conditions – good and bad air quality. The experiment was blind – that is, the students involved knew nothing of the different conditions. The experiment was also corrected for learning effect – that is, that better performance may be due to academic improvement between the first and second test. This correction was achieved by swapping classrooms, with three classes taking the first test under poor air quality conditions and the second under good air quality conditions, and the conditions being reversed for the other three classes.[iv]

DTU's conclusions correspond with international research results – that better indoor air quality improves learning ability.[v]

Based on DTU's data for performance under good and bad air quality, DTU and the consulting firm Slotsholm estimated that more ventilation in all primary and senior schools for children in ages 7-15 years (corresponding to Danish ventilation levels being raised to Swedish levels) would improve pupils' test results (reading, comprehension, maths, nature studies, sciences etc.) by ten points in OECD's PISA study.[vi] Such an improvement, in PISA terms, is moderate[vii]. Denmark would certainly rise to an above-average position in OECD but there would still be a very long way from the top. Despite the fact that the effect is moderate, an improvement of ten points would have significant long-term financial consequences in the form of a better educated and more productive labour force.

Figure 2: PISA score with increased ventilation in Danish classrooms



Source: OECD and own calculations

An improvement in PISA results would not only result in better educated adults – it is also highly probable that it would result in a slight reduction in the group of pupils who need to go through the danish Tenth Class because of educational difficulties.[viii] An improvement of 10 PISA points approximately corresponds to 2 per cent more pupils in a school year (about one pupil in two classes) achieving a mark of 2 (the lowest current mark). The inference is that an improved PISA result will reduce the group electing to take Tenth Class from 55 per cent to 53 per cent.

Apart from better pupil performance, research shows that sick leave among employees falls when ventilation is increased. After a study of the literature on sick leave and ventilation in office buildings[ix], DTU estimates that teacher sick leave can be reduced by 4 per cent by raising Danish levels of ventilation to those in Sweden. This roughly corresponds to a reduction in sick leave of about half a day a year, or 0.2 per cent of the working year.

The lower incidence of sick leave also applies to pupils, who are absent for one to two days fewer every year.[x] The effect of the reduced absenteeism on learning is not included in the calculations. Another aspect that is not included is that fewer sick days for the youngest children means fewer days off work for the parents who have to look after them. Furthermore, better test results may well reduce the need for special tuition. This effect is not included in the calculations either. The exclusion of these three factors is due to the fact that there is no valid research basis for their quantification; it also means that overall assessment of the effect of better air quality must be regarded as a conservative estimate.

4. Better learning means better economy

To calculate the effect of better air quality, we used the economic model DREAM, which is public financed and used for economic calculations by many organisations – including the Danish treasury. Whilst the above-mentioned secondary effects are not included, the following three effects are: a) better PISA results lead to higher productivity and income later in life; b) better PISA-results reduce the number of pupils electing to take Tenth Class; c) better ventilation reduces teacher sick leave.

The calculation of the economic consequences of better ventilation are summarised in Table 1.

Table 1: macro-economic effects of better ventilation by annual effect and trend		
	Average annual effect	Trend of effect
Public primary balance - total	€37 million	Rising
of which – a) increased productivity	€16 million	Rising
– b) fewer pupils in Tenth Class	€15 million	Rising
– c) lower teacher sick leave	€6 million	Constant
GDP total	€173 million	Rising
of which – a) increased productivity	€106 million.	Rising
– b) fewer pupils in Tenth Class	€67 million	Rising
– c) lower teacher sick leave	None	-

Note: Fixed 2011 prices. Trends for year of study to 2050. Figures are rounded and do not sum exactly.
Source: DREAM Group's calculations.

Closer examination of three effects.

a) better PISA results mean higher productivity: an OECD study from 2010 shows that countries with better test results in school see higher growth rates.[xi] Because of the higher productivity and earnings in a better-educated population, an improvement of 10 points in PISA results corresponds to a growth increase of 0.17 per cent.[xii]

Although the OECD study estimates a constant growth effect of higher test results, the DREAM calculations limits that effect to twenty years. The supposition is conservative. The explanation lies in the fact that long-term estimates are fraught with a high degree of uncertainty of what 'going to school' may mean in the future. The effect will be gradually phased in over a ten-year period from 2014 at the same rate that pupils experience better air quality from more of their school time.

Despite these very conservative hypotheses, the increased productivity has an important effect − GDP will grow by an average of €106 million per year, measured in 2011 prices. At the same time, public balance will see a steady increase of an average of DKK €16 million per year, measured in the price level of 2011. The effect will be least in the short term and greater in the long term as former pupils arrive on the labour market.

b) better PISA results reduce the number of pupils electing to take Tenth Class: as mentioned, it is estimated that 2 percent points fewer will choose to take Tenth Class. Instead, pupils will choose a course by the same pattern as those who, today, go on directly to further education after Ninth Class. This effect, as with productivity, is expected to appear gradually over a ten-year period from 2014.

With slightly fewer electing to take Tenth Class, slightly more will receive further education or an extra productive year on the labour market. The

consequence will be an average growth in GDP of €67 million per year, measured in 2011 prices. At the same time, public finances will be boosted by a steady €15 million per year on average, again measured in 2011 prices. The effect will be least in the short term and greater in the long term.

c) better ventilation reduces teacher sick leave: a reduction of teacher sick leave corresponding to about 0.2 per cent of teaching hours will also have an effect. With total salary costs in state schools amounting to some €3.6 billion, that means an annual saving of about €6 million in supply teacher expenses[xiii], but no change to GDP. Unlike the other effects, this will be seen immediately and be permanent.

Unchanged energy consumption

According to DTU, better ventilation will not necessarily lead to increased energy consumption; at the worst any increase will be modest and, in many cases, there will be a saving in consumption. All that is required is suitable forms of ventilation and parallel energy renovation of unsuitable facade elements.[xiv]

Notes

[i] Bygningsreglementet (Building Code), 6.3.1.3. stk. 2. The same limitation follows from Arbejdstilsynets (Danish Working Environment Agency's) guideline A.1.2. (2008), which states,"If the people in the room are the greatest source of pollution, its carbon dioxide (CO_2),content must be measured and must not be greater than 0.1%."

[ii] Jørn Toftum, Pawel Wargocki and Geo Clausen, Center for Indeklima og Energi, Institut for Byggeri og Anlæg, Danmarks Tekniske Universitet, *(International Centre for Indoor Environment and Energy, Institute for Building and Works,Technical University of Denmark)* "Indeklima i skoler – status og konsekvenser" (*Indoor Environment in Schools – Status and Implications*), FOA, 2011.

[iii] DTU has conducted two studies of CO_2 concentration. In the first, concentrations were measured in 88 schools in 14 days in November 2009. In the second, 743 classrooms in 320 schools around the five regions were measured in September/October 2009 in the so-called Mass Experiment, part of the *Dansk Naturvidenskabsfestival* described in the DTU report by Andersen, Clausen, Larsen and Menå "Elever undersøger indeklima i klasselokaler - rapport om resultater fra Masseeksperiment 2009". *(report about mass experiment)*

[iv] Wargocki, P. and Wyon, D.P. (2007) "The effects of outdoor air supply rate and supply air filter condition in classrooms on the performance of schoolwork by children (1257-RP)", HVAC&R Research, 13(2), 165-191.

[v] Fx Bakó-Biró, Z., Clements-Croome, D.J., Kochhar, N., Awbi, H.B. and Williams, M.J. (2012) "Ventilation rates in schools and pupils' performance", Building and Environment, 48, 215-223 and Haverinen-Shaughnessy, U. Moschandreas, D.J. and Shaughnessy, R.J. (2011) "Association between substandard classroom ventilation rates and students' academic achievement", Indoor Air, 21, 121-131.

[vi] DTU's Danish experiment shows an improvement in test results of an average of slightly more than 0.1 standard deviation from the mean by changing ventilation levels from Danish to Swedish. In popular terms, this means that in a class of 25 children with improved ventilation, the best 13 would produce about the same performance as the best 12 today. Things are a little different between the best and the weakest; here, it corresponds to the difference between the third best and fourth best being halved. This improvement of 0.1 standard deviation corresponds to 10 points in the PISA score, as the standard deviation in PISA is 100 points.

[vii] Between 2003 and 2009, Danish schoolchildren have moved 10 points in mathematics – unfortunately in a negative direction.

[viii] A study made by *Danmarks Evalueringsinstitut* (The Danish Evaluation Institute) in 2011 shows that pupils opting for Tenth Class in public schools achieve poorer marks than average. The Tenth Class is voluntary as an extra preparation for further education. Pupils opting for Tenth Class in a Post-School environment are evaluated as having different reasons for their choice; nor do they achieve poorer marks – on the contrary.

[ix] Milton, D., Glencross, P. and Walters, M. (2000) "Risk of sick-leave associated with outdoor air supply rate, humidification and occupants complaints", Indoor Air, 10, 212-221.

[x] Shendell, D.G., Prill, R., Fisk, W.J., Apte, M.G., Blake, D. and Faulkner, D. (2004) "Associations between classroom CO_2 concentrations and student attendance in Washington and Idaho", Indoor Air, 14, 333-341.

[xi] The High Cost of Low Educational Performance, OECD. OECD estimation of the relation between test results and financial growth based on test results in from 23 countries between 1960 and 2000.

[xii] A similar relation between test results and later income is found in Chetty R, Friedman, J.N., Hilger, N., Saez, E., Schanzenbach, D.W., and Yagan, D. (2010) "How Does Your Kindergarten Classroom Affect Your Earnings? Evidence from Project Star (September 2010)", NBER Working Paper Series, Vol. w16381.

[xiii] This part of the calculation involves only public schools. Private schools are assumed to cope with their current teacher sick leave at no extra cost. This is a conservative calculation.

[xiv] Jørn Toftum, Pawel Wargocki and Geo Clausen, Center for Indeklima og Energi, Institut for Byggeri og Anlæg , Danmarks Tekniske Universitet *(International Centre for Indoor Environment and Energy, Institute for Building and Works,Technical University of Denmark),* "Indeklima i skoler – status og konsekvenser" (*Indoor Environment in Schools – Status and Implications*, FOA, 2011.