EDUCATION, INDOOR ENVIRONMENT AND HVAC SOLUTIONS IN SCHOOL BUILDINGS - CONSEQUENCES OF DIFFERENCES IN PARADIGM SHIFTS

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ABSTRACT
This paper takes a retrospective approach to understand the setting of today's educational environments in school buildings. By investigating educational methods, school architecture and the choice of HVAC solutions in school buildings from different time eras, we have investigated whether there is a connection with respect to paradigm shifts. The paper also discusses the experience gained from the use of different HVAC solutions in school buildings, dealing with the school system in different time eras. By taking into account the limitations of different HVAC solutions, and the various maintenance requirements, one should be able to achieve a better educational environment. Many of today's school buildings were not planned to accommodate any dynamic changes of internal life or activities, and therefore performing the remedial actions can be a great challenge. Finally, the environmental task becomes even more important with respect to a rapidly increasing number of sensitised pupils.

INDEX TERMS
Schools, Building design and remediation, HVAC, Policy, standards and guidelines, Improved IAQ practices and technologies

INTRODUCTION
Children of today spend increasingly more of their time in public care and school environments. The educational system has a broad responsibility for the child, and this upbringing and teaching must take place in a teaching environment based on insight, acknowledging the child as a searching, constructive and working human being (the Norwegian official plans for learning for the 10 years of compulsory schooling). The vision is to ensure that the total environment for learning contributes positively to the life quality of children. This means a school environment where the children are comfortable, where they may evolve in a positive way, gain knowledge, develop a desire to learn, and achieve a positive self-confidence.

One has often experienced a direct link between the indoor climate and mental/physical performance. How much each individual indoor climate parameter affects this link is still not quantified. This is largely due to the problem complexity, i.e. the many factors involved.

Previous studies show that measures to improve the indoor climate positively affected children's health and wellbeing (Mathisen, Frydenlund, Haugen et al, 2000). In some schools the measure was removal of floor carpeting, and replacing it with smooth surfaced flooring. In other schools the measure was upgrading the ventilation air volume, which had been very poor to start with.

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Still, too little is documented on the further effect of indoor climate on the children's learning ability. Especially the indoor climate cannot be considered alone without respect to the activities performed within schools. Norway introduced new official plans for learning in 1997 (for the 10 years of compulsory schooling), and these days the pedagogic is subject to an extensive evaluation. But a total evaluation of the environment for learning given the framework of each school, should also take into consideration the premises of the physical school building and the technical installations and solutions. It is also important to be familiar with the past, i.e. the earlier laws and regulations, both educational and for the school buildings, to understand why the schools are built the way they are, and to understand the potentials and the limitations the physical environment makes on today's teaching practices. Further, some consequences of the non-parallel shifts in paradigm for education, school architecture, technical building installations, and health impacts, should be discussed.

METHODS

This paper is based on an examination of past and present Norwegian laws and regulations regarding education, school architecture, technical building installations, and health. This study is put together with practical experiences from different time periods, gained from descriptions in a number of publications.

RESULTS

The period before 1950

As early as 1860 the introduction of an ***Educational law*** greatly increased the number of houses built for school purposes in Norway. The goal at that time was to achieve permanent housing for the school, and the houses were of plain standards, often with just one classroom for all pupils independent of their age level. In addition the home of the teacher often was in the same building. At this time there was an increasing number of children, and the need for expansion of many of these schools quickly arose. Also in 1860 a ***Health law*** was adopted, this was the first Norwegian law affecting ventilation and room climate. In some areas the local health regulations further treated the ventilation in schools.

The Norwegian ***Building authorities law*** of 1896 was in force for all the cities of the nation, except for the three largest ones that made separate building authorities laws in the following years (the cities of Bergen, Kristiania and Trondhjem). One purpose of these laws was to achieve healthy environments in cities planned by architectural principles. The first ***Building authorities law*** covering all the cities of the nation was adopted in 1924. The subsequent regulations treated materials and constructions (i. a. heat boilers and ventilation pipes) but this was mainly for fire safety reasons.

The period of 1950-1965

After the second world war there was an extensive need for school buildings, both due to buildings burnt down during the war and to the large number of births in the following years. During the 1950's the 9 years of compulsory schooling was established, and several new subjects were introduced as compulsory or optional. The increasing number of teaching aids, and a need for specialised rooms, influenced the architecture of school buildings. But the economic situation was a major influence; the national economy was tight, and the school buildings were put up in several subsequent construction stages.

Until 1960 natural ventilation, together with window airing, was the common concept of ventilation in Norwegian school buildings. Airing through windows in the classrooms was a necessary routine to achieve a minimum of air change. These procedures were adequate when

the pupils followed regular teaching hours of 45 minutes, and were instructed to spend recess outdoors. At this time the Norwegian *Building regulations* (from 1949) did not yet have any specifications regarding the amount of ventilation air change. The *Building regulations* from 1965 gave the building counsel the right to demand the "necessary ventilation" for amongst others, school buildings.

During the 10 years period from 1960 to 1970 the Norwegian schools were built with mechanical outlet ventilation. But many schools soon experienced problems due to overheated classrooms. The architects were (and still are) fascinated by large window areas, and many classrooms even had south facing windows without any solar shading. This could not, and did not give well functioning solutions from an indoor climate perspective. During the winter these large windows gave risk of draught. The comfort was made even worse because these new schools had a light building construction with little capacity for accumulating heat, in contrast to the heavy constructions which was used in older buildings.

Impulses of the period 1965-80

The Norwegian ***Building law*** from 1965 was enforced for the whole country. The municipalities were still allowed to make local rules that are amendments or exceptions to the law under some terms. The subsequent *Building regulations* from 1969 both included a chapter on school buildings and gave marginal values for ventilation air change, e.g. for different rooms in schools. As an example the marginal value for classroom was 7 m^3/m^2h, which was to be considered as the minimum ventilation air change allowed at the time. But in practice the minimum ventilation air rate was often considered as criteria for design, and a final verification of the actual air rate was rarely performed.

In 1969 the ***Education law for the primary school*** was adopted. This was followed by *Model plans for learning* in 1974. The pedagogical principles included group works, and new remedies were introduced to the school situation. There was a need for new types of rooms within the school buildings, as well as flexibility for later changes.

In the 1970's a new type of school buildings was introduced to Norway, especially by British influences. These open plan schools were physically planned for other pedagogical methods than in the traditional classroom schools. There were few permanent indoor walls, and fitted carpets were often chosen to control the noise level. Also the technical installations had to be adapted to the new surroundings, which often had larger "inner zones" and heating units by the outer walls was insufficient.

Balanced mechanical ventilation was introduced into schools around 1970 and became the common choice; it gave better control with the air distribution and was also thought to provide increased comfort compared to earlier systems. Many of these early balanced systems were rather complex and showed to be unsatisfactory during operation. Especially in the open plan schools it was common to combine heating and ventilation in a joint hot air system. This solution implies that the inlet air could be heated above temperatures acceptable with respect to a satisfying indoor climate. In addition recirculation of ventilation air was common. In extreme cases close to 100% of the air was recirculated. This might have been influenced by a strong-willed energy saving effort after the energy crisis of 1973. There was little or no control with the congestion of contamination in the air. The alternative to recirculation was introduced with the heat recovery unit, which reduced the energy use and at the same time reduced the contamination transfer because the ventilation air flows were kept apart from each other.

Developments in the period 1980-2000
Under the ***Planning and Building Act*** of 1985 the Technical regulations (1985) expressed that:
"Buildings with installations shall be planned, designed, constructed, maintained and operated in such manner that the indoor climate is perceived satisfactory. No health hazard and unsatisfactory hygienic conditions shall occur, neither for the users of the building nor for its neighbours, when the rooms are used as intended."

Working people gained their own protection law in 1956, and the working environment was included in a renewed protection law of 1977. However these laws did not give rights to the pupils attending school. The pupils had rights regarding health services under the ***Public health laws*** (dated 1957 and 1982), but this was not used to improve the learning environment in schools. In stead of the children's work environment law, the work ended in a *Regulation on environmentally focused health protection* (dated 1995). The procedures following this regulation have to some extent helped to put the focus on indoor climate in school and necessary measures.

During the 1990's 10 years of compulsory schooling was established in Norway (Reform of 1997), this was the first time that the age level for the youngest pupils was changed. The introduction of the 6-years old pupils gave new challenges to the schools, and extensive measures was taken to adapt the school areas both indoor and outdoor to this age level.

With the latest ***Planning and Building Act*** dated 1997, the *Technical regulations* (1997) introduce the concept that the necessary air supply is to be determined from the use of materials, the number of occupants and the activities. The tables of minimum values for room types were thrown out of the regulations. Instead the fresh air supply should be at least 7 l/s person (during light activity level), in addition to at 0,7-2 l/s per m^2 gross floor area depending on the documentation on the materials used. In general the Technical regulations is now based on function rather than detailed demand on design. The appurtenant Guidance gives some pre-accepted solutions.

This papers earlier remark against large classroom windows facing south, is no argument against the use of windows in general. Daylight is an important factor of children's life quality. With regard to the healthy aspect of daylight, a requirement of 1% daylight-factor in rooms for occupation was introduced into the *Guidance* following the latest *Technical regulations*.

DISCUSSION
During the last 100 years the pedagogical contents that the school system is based on have changed dramatically. The pedagogical reforms in the Norwegian school system have mainly been adopted at intervals of 12-15 years during the 20^{th} century, partly as a result of the social development and economic development with change in the conditions of living, and partly politically initialised. Most visible is perhaps the fact that these reforms gradually have increased the years of compulsory schooling in Norway, and that an increasing number of pupils have been given the opportunity of education within the school system.

But even though the *Model plan* for learning (from 1974) concerned the educational principles, there were no national standards for the planned solutions, and even today both traditional classroom schools and schools with more flexible, open or partly open plan

solutions are built. The last type is also in accordance with teaching after the last *Educational reform* (from 1997).

The school buildings reflect the different ideals of architecture and school politics, and the need for new school buildings is often based on developments in the educational laws. The content within the education has changed, requiring the use of specialised rooms and different types of areas for teaching purposes. One result of the educational reforms has been hectic building activities in some periods. Also technically there has been a constant development, especially in the field of ventilation.

As early as 1860 the health law put forward the importance of sanitary conditions as well as airing as an effort to remove contaminated air. But it was not until 1969 that the building regulations included special remarks on school buildings together with the minimum demands for ventilating different type of rooms. Only balanced mechanical ventilation fulfils the demands of the latest *Technical regulations* (from 1997), with respect to both air change and comfort criteria. But there are still possibilities for functional improvements and energy saving measures.

There are two main strategies for ventilating rooms in schools, these are dilution and displacement ventilation. Dilution ventilation has been common for many years, while a few HVAC consultants have been in favour of displacement ventilation in school buildings. This really was an alternative in the more strictly organised school environments a few years ago. One advantage of displacement ventilation in general is that the under tempered inlet air gives a cooling effect. In today's school environments it is evident that this principle makes limitations regarding flexibility. As an example the pupils working places are often close to inner walls, sometimes in the draught zone of displacement ventilation, other times various equipment are blinding off the inlet for the displacement ventilation. The pupils no longer move around as groups only, this pattern has changed with new plans of learning. When there are movements in the class area, the displacement effect is affected, and the ventilation efficiency resembles the efficiency of dilution ventilation.

Most of the buildings used for school purposes today are obviously not new; instead they were built under another set of circumstances than the requirements of today, both pedagogically and technically. In connection with upgrading of the older school buildings the installation or change of ventilation components often requires large investment due to the extensive intervention into the building construction.

Worth notice is that the oldest of the school buildings in Norway is not the ones which gives the most extensive problems with the building and with regards to health. The schools built in the period 1960-80 sort out negatively, and because there was a considerable building boom during these years this affects many pupils. As an example 45% of the area of the primary school in Trondheim was built during this period. Some of these schools are now described as condemnable, because it is preferred to demolish in preference of the investments needed to upgrade the buildings and the technical installations.

Also several technical systems have proven to be inadequate for the educational areas within school building, these are i. a. hot air systems, recirculation of air, roof radiant heating. In addition several architectural details, i. a. fitted carpets, south facing classroom windows without solar shading devise have a negative impact on the indoor climate. Especially during

the 1990's efforts have been made to remove these elements from the Norwegian school buildings. Solar shading devises are frequently installed.

CONCLUSION AND IMPLICATIONS

Even though several of the laws and regulations are established in the same time period, there are differences in the focus and content, which makes the interaction between fields of expertise difficult. It is in the nature of laws and regulations not to overlap with each other.

Developments in one field cannot automatically be transferred into schools without adjustments in the other fields. For example the Educational reform of 1997 required adjustments in both buildings, interiors, outdoor areas, the teaching staffs education, upgrading of technical systems etc.

This paper illustrates the importance of teamwork in planning, operation and developments in schools. Even though each of the involved parts, i. a. educators, architects, HVAC consultants, building consultants and health authorities, have specific laws and regulations within their fields, one have to take into consideration the developments within the other spheres. A perfectly working HVAC system, might only be well-functioning under stabile situations. Whenever there are developments in the other fields such as learning methods, the pupil's routines and application of rooms, materials used by the architect, or isolation in the building construction, this could affect the performance of the HVAC system and the satisfaction of the pupils.

REFERENCES

HM Mathisen, F Frydenlund, E Haugen, J Jenssen, K Buvik, K Høyland: Godt inneklima i skoler – tiltaksforskning : Evaluering av to inneklimatiltak i Trondheim. Rapport TR A5149. SINTEF Energiforskning, 2000

Norwegian official laws and regulations