# PUPIL`S HEALTH AND PERFORMANCE DUE TO RENOVATION OF SCHOOLS

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## ABSTRACT

The results from the Norwegian project "Indoor Environment in Schools" show a reduction from about 80 % to 55 % in complaints of poor indoor air quality just after renovation, and to 10 % after another year. There was clear accordance between the renovation enterprise with the measured indoor climate and the pupils own opinion of the working environment. Norwegian authority has set a limit of $CO_2$-consentration to 1000 ppm, and our results indicate that the amount of outside air has to be 9 l/s per person to be sure of getting under this limit. The project included a total of 35 classrooms and about 900 pupils from 8 schools. The basic design has been a pre and post test before and after renovation. Physical measurements, questionnaire survey and reaction time test were used in this project.

## INTRODUCTION

This Norwegian project has been an effect study of rehabilitation in schools with poor indoor air quality, and organised as a coo-operation between the counties of Oppland and Vest-Agder, the municipality of Hå in Rogaland and RF-Rogaland Research.
The main hypothesis in the project "Indoor Environment in Schools" has been: *a good indoor environment in schools would promote the pupils' health, well being and performance.* To test the hypothesis the physical environment in the classrooms were measured, parallel to this the pupils fulfilled a questionnaire survey about health, working environment and the social climate in the class, and performed a concentration test on PC.
The schools were divided into three categories; experiment schools where they have gone through renovations, control "good" schools with assumed good indoor environment and the "bad" control schools with assumed bad indoor environment.
Results of performance and health due to $CO_2$-concentrations were presented elsewhere (1). The physical measurements, the results of the questionnaires concerning health and working environment and the performance results due to the overall effects of the renovation's are presented in this paper.

## METHODS

The data presented here includes field survey from 35 classrooms and about 900 pupils, from 8 schools. The field surveys were performed in February-March 1994, February-March 1995 and February-March 1996, but non of the pupils was examined more than twice. The administration of research and control conditions followed a modified Solomon's four-group design (2).
The physical measurements included the air change, ventilation measurements, air content of $CO_2$. The equipment used were Bruel & Kjær (Tracer gas monitoring). Air temperature, humidity, radiant temperature asymmetry and air velocity values were measured, and PPD

(percentage persons dissatisfied) values were calculated. The equipment used for these measurements were Hydra Fluke Data Logger and Bruel & Kjær 1213.
The pupils were asked to fulfil a questionnaire survey; a modified Ørebro questionnaire, to survey the pupils experience of their own health and working environment, and a questionnaire for social climate in the class.
The pupils also performed a reaction time test SPES; Swedish Performance Evaluation System (3). The test was conducted by each pupil on a computer during a normal class situation. The system included three concentration tests; "simple reaction time", "choice reaction time" and "colour word vigilance", and self report of acute health symptoms, reported as complaints "at present".
The data analyses were performed with SPSS 6.1/7.0 for Windows. Principal factor analysis with varimax rotation and reliability tests of the scales were done on the data sets.

## RESULTS AND DICUSSION

### Physical parameters

The physical measurements included air quality, temperatures in the middle of the room, by the floor, outside and also the air supply temperatures, relative humidity and calculation of PPD values. The results of the $CO_2$-concentration, air change and room temperature are shown in Table 1. At the experiment schools the level of $CO_2$ did decrease from 1515 to 735 ppm due to renovation, and the air change increased correspondingly. The room temperature values were very stable.

**Table 1.** Average values for all the class rooms.

| | $CO_2$ (ppm) | | Air change ($h^{-1}$) | | Room temp (°C) | |
|---|---|---|---|---|---|---|
| | *Pre* | *Post* | *Pre* | *Post* | *Pre* | *Post* |
| **Experiment** | 1515 | 735 | 2,6 | 8,1 | 21,0 | 20,7 |
| **Control "good"** | 905 | 905 | 6,4 | 6,8 | 21,9 | 21,4 |
| **Control "bad"** | 1650 | 1505 | 2,0 | 2,0 | 21,5 | 20,8 |

### Health and working environment

The health symptoms "at present" are divided into 3 indexes, based on principal factor analysis. The first index is a combination of general health symptoms such as headache, dizziness, heavy headed, tiredness, difficulties concentrating and unpleasant odour (Cronbach's alpha 0,79). The second index is a combination of mucous membranes' symptoms such as pain in bronchia, coughing, short-winded, irritation in noise and throat (Cronbach's alpha 0,81). The third index includes eye symptoms such as irritation in eyes and visional disturbances (Cronbach's alpha 0,74).

The pupils in the experimental schools had a significant reduction in general health symptoms after renovations of the schools than before (Figure 1). For the "good" control schools there were no significant changes, and for the "bad" controls we found an improvement of general health symptoms in the post test. This health improvement is due to better maintenance in these schools. The results of mucous membranes' symptoms varied very much alike the general symptoms, but in lower degree of complaints. There were no changes in eye symptoms from pre to post test for none of the categories of schools.

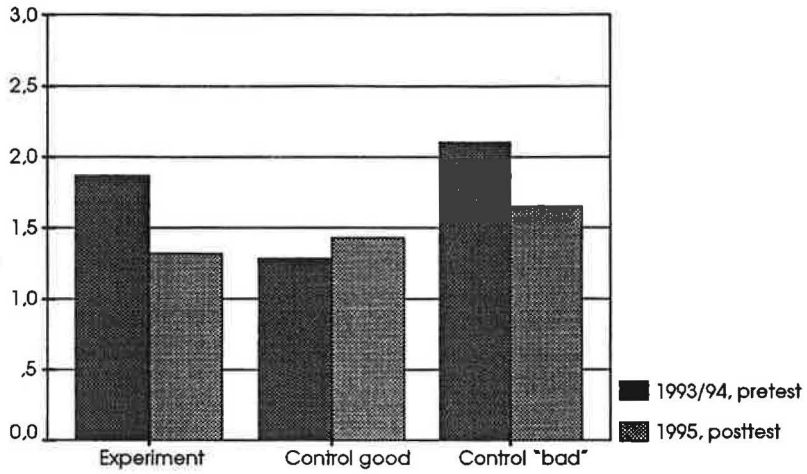


**Figure 1** Average of general health symptoms "at present". Y-axe shows the extent of complaints 0 = no complaints, 1 = little complaints, 2 = some more complaints and 3 = pretty much complaints.

The pupils own opinions of poor indoor air quality "last 3 months" were reduced from about 80 % prior to renovation to 55 % complaints just after renovation. The reduction was not as good as expected, but after another year there were only 10% complaints of poor indoor air quality at the renovated schools. The post tests were performed in newly renovated schools (about 6-10 weeks after "immigration") and the pupils did not have any experience of the indoor climate or their own working environment the last 3 months, and there were probably enhanced levels of odour from the building materials.

**Performance - reaction time**

Both renovation and improved maintenance increased the performance, seen as lower reaction time (Figure 2). The results were however best for the renovated schools. There were no significant change in the control "good" schools.

We discovered an influence of age and gender at the performance tests. In our test group we had pupils that were from 11 to 19 years old, and analyses show that the youngest pupils under 16 years of age perform the reaction time tests poorer than the older pupils regardless to the indoor air quality. The results are based on pupils above 16 years, totally 600 pupils. In regard to gender the results show that boys perform the test better than girls, this may be because the boys are more familiar with the method tool, the computer. Further investigation of pupil's performance has to be carried out.

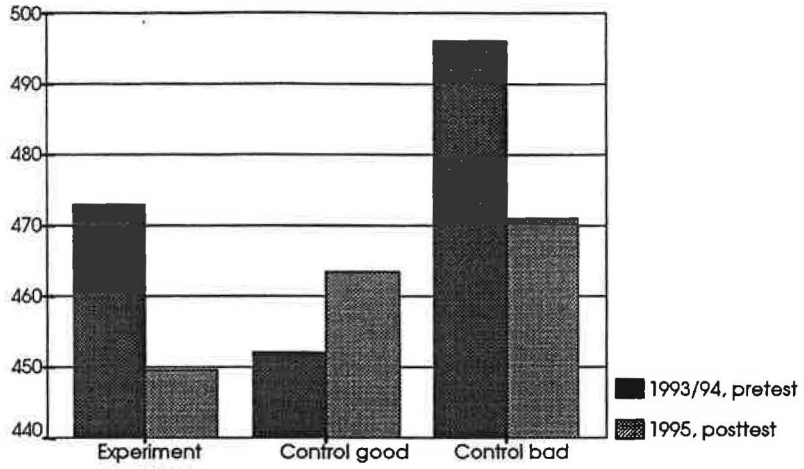


**Figure 2** Performance (ms) expressed as reaction time in millisecond (Y-axe) for the experimental schools and the controls.

**Renovation enterprises and effects**

An overview of the different renovation enterprises together with our results (decrease/increase from pre test to post test) of working environment and physical measurements for two of the schools in the project, are presented in Table 2 and 3. To see the relation between the parameters read the table row by row.

**Table 2** School 1 renovated in 1994/1995, pre test 1994, post test1995.

| Working environment: "complaints last 3 months:" | Physical parameters | Enterprise |
|---|---|---|
| draught (decrease) | | installed better windows |
| stuffiness air (decrease) | decrease $CO_2$<br>increase in air change<br>decrease in number of persons | installed mechanical balanced displacement ventilation |
| dry air (decrease) | | dust bounded surfaces |
| | increase in min. temperature<br>decrease in max. temperature<br>decrease in temp. gradient | improved control of heating system, constant air supply, installed temp. sensors outdoors |

The pupils at school 1 reported a reduction in general health symptoms and mucous membranes' symptoms "at present", and also a decrease in general health symptoms "last 3 months" in the post test compared to pre test. The pupils performance was also improved after renovations.

**Table 3** School 2 renovated in 1995, pre test 1995 and post test 1996.

| Working environment: "complaints last 3 months:" | Physical parameters | Enterprise |
|---|---|---|
| stuffiness air (decrease) | decrease $CO_2$<br>increase in air change | installed mechanical balanced displacement ventilation |
| dry air (decrease)<br>static electricity (increase) | decrease in relative humidity | dust bounded surfaces |
| high temperature (decrease) | decrease in floor temperature | improved control with heating system, constant air supply, and new radiators |
| low temperature (increase)<br>cold floor (increase)<br>heath from stove(decrease) | decrease in floor temperature | displacement ventilation and new radiators |

The pupils at school 2 reported less general health symptoms "at present", but no change in mucous membranes' symptoms "at present" or general health symptoms "last 3 months" after renovation compared to before. The performance was improved after renovations.

**How much air is necessary ?**

Figure 3 shows the $CO_2$-consentration in relation to air change per person. Air change is equal to how many times the air is changed during one hour. The measurements include 374 school hours for half of the schools in the project The class rooms were about 60 $m^2$ with a height of 2,7 m.

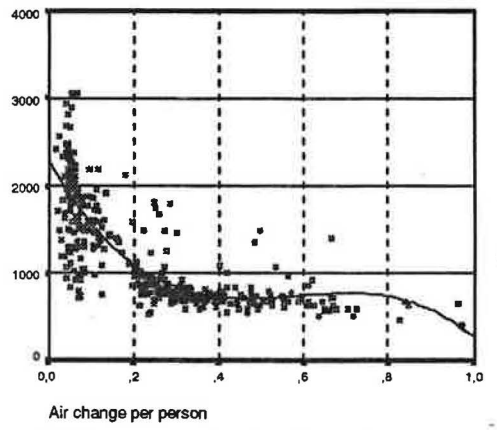


**Figure 3** $CO_2$-consentration (ppm) and air change per person for all the schools

Norwegian authorities have 1000 ppm as a limit of $CO_2$-consentration during school hours (4). The figure shows a cross-over just above 0,2 air change per person to keep the $CO_2$-consentration beneath this limit. So what is the necessary amount of outside air ? If we look at a classroom with 30 pupils, the air volume will bee 162 $m^3$, and the necessary amount of outside air will be 970 $m^3/h$ per class room. This means 9 l/s per person to be sure of getting

under the limit of Norwegian authorities. Special amount of air due to building materials is not included.

## CONCLUCIONS

- the pupils own experience of health are improved due to renovation
- the pupils performance measured as reaction time are improved due to renovation
- the enterprise show good connection with the physical parameters and the pupils own opinion of their own working environment
- necessary amount of outside air in a typical class room is 9,0 l/s pr. person, to be sure of getting under the limit a $CO_2$-consentration on maximum 1000 ppm

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