Relation between ventilation and the learning skills of pupils in classrooms.

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SUMMARY

Goal of the study was to investigate the relation between the level of ventilation and the performance of school children in classrooms
In one school in two classrooms the same ventilation system was installed. The two classrooms were located at the same façade. The system had a possibility of supplying full outside air to the classroom or the position with full recirculation of air. The temperature in the classroom was kept as constant as possible.
The performance of two groups in the age of about 12 years was studied.
The pupils had to carry out four different tests:
• comparing symbols
• the position of the legs of the clock
• spelling language
• calculation
The weeks before the real test the pupils already had carried out the same type of test to overcome the effect of adaptation to these type of tests.
The average CO_2 concentration at the beginning of the tests was approximately:
• conditioned classroom 738 ppm
• unconditioned classroom 1267 ppm
The average CO_2 concentration at the end of the tests was approximately:
• conditioned classroom 747 ppm
• unconditioned classroom 1870 ppm
The results of the tests are roughly that no significant effect was found for the more visual related tests such as comparing symbols and the legs of the clock. For the more cognitive tasks such as spelling and calculation significant effects were found. The improvement in relative score for the tests made under CO_2 controlled conditions was in the order of about 15%.

1. INTRODUCTION

The indoor environment in classrooms is often not very good. The ventilation is in most cases insufficient. This leads to high pollutant loads in classrooms. Every person who have visited classrooms in schools have the experience that if you enter a classroom it does not smell fresh. There is a saying that in classrooms you may lean against the air. Measurements carried out in classrooms by many different investigators show that at the end of a few lessons the CO_2 concentrations in schools frequently go beyond 3000 ppm. On itself CO_2 is not a relevant pollutant for the indoor air, because it is an inert gas. CO_2 however is often used as a marker for so called bio-effluents. These are secretion products produced from for instance respiration (breathing) and evaporation (sweating) of persons.
The negative relation between a stuffy atmosphere in classrooms and learning skills and attention deficit is regularly mentioned in publications and lectures. Just a few relevant papers can confirm this hypothesis. The main aim of this study was to investigate the relation between the level of ventilation and the performance of school children in classrooms.

2 DESIGN OF THE EXPERIMENT

2.1 General

In a school in two adjacent classrooms the same ventilation system was installed. The two classrooms were located at the same façade. The system had a possibility of supplying full outside air to the classroom or the position with full recirculation of air. The temperature in the classroom was kept as constant as possible..
The performance of two groups, each about 25 pupils in the age of about 12 years, was studied.
The pupils had to carry out four different tests:
• comparing symbols
• the position of the legs of the clock
• spelling language
• calculation

Table 1 Design of the experiment

Group	**CO_2 controlled ventilation**	**No purpose provided ventilation**
8A	Day 1	Day 2
8B	Day 2	Day 1

The idea was to carry out the four tests at the beginning of the morning or afternoon lessons and repeat the same type of tests at the and of the morning or afternoon lessons. Each test series of four tests should not take more time than about 30 minutes.

2.2 Pilot study

A pilot study was carried out before the final and real test series. The reason for the pilot study was to check whether or not the types of tests ware usable and not too much time consuming. The pilot study was carried out in two other schools than where the final tests took place. From the results of the pilot study we determined a real learning effect by repeating these types of tests. Therefore during the final real test series the weeks before the real test took place, pupils already had to carry out the same type of tests to overcome the learning effect of adaptation to these types of tests.

3. TYPE OF TESTS

3.1 General

The tests were set up after consulting some specialists from universities and other TNO institutes.
The four different tests consist of:

- comparing symbols
- the position of the legs of the clock
- spelling language
- calculation

The first two tests were more visual oriented, while the last two tests more cognitive skills require.
Examples of the different tests will be given in the next paragraphs.

3.2 Comparing symbols

In the test with comparing symbols pupils had to check whether or not two of the same symbols occurred in one line of 7 symbols. The test consists of 45 lines with randomly produced symbols. The pupils got about 5 minutes to carry out the test.

Example:
Instruction
Observe the symbols on **one line.**. Deteremine The essence is to determine **the same symbols in one line**.

Ξ	≅	⊆	∫	⊆	⊗	⊇	ja ●	nee 0

In this line the same symbol occur twice.. Your answer is yes (ja in Dutch).'

∀	Ψ	⊄	⊃	∫	⇓	⊂	ja 0	nee ●

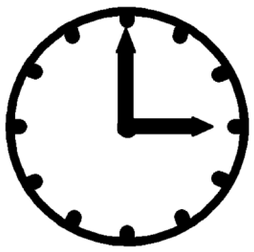
In this line the same symbol does't occur . Your answer is no (nee in Dutch).'

3.3 The position of the legs of a clock

For this test the pupils got 3 minutes. In these three minutes they had to draw six times the legs of the clock. in the clock face.

Example:

Three o' clock



De large leg is pointing to 12 while the small leg is pointing to three. This example is easy, but for instance forty minutes past seven is less easy.

3.4 Spelling language

The test with spelling consists of 8 lines with each about 8 words. There were on average about two spelling errors in each line. There were lines with 0 to maximum 5 spelling errors.
The pupils were asked to give the number of wrong spelled words
The example given here is from the original report and so in Dutch.
Example:
Het is hier op school erg luek sind juf Maartje op school is gekome.

0	1	2	3	4	5 or more errors
			X		

Het is hier op school erg l***eu***k sind***s*** juf Maartje op school is gekome***n***
There are three wrong spelled words in this sentence.
Translation to English:
It is here on school very pleasant since teacher Marian has started.
Examples of errors in English
It is here on school very plaesant sinse teacher Marian has startet.
So also in this sentence in English there are three wrong spelled words.

3.5 Calculation

The letters **a** to **g** were given a numerical value, a = 1 and g =7. Pupils got 8 sums within about 8 minutes in which they should add or subtract. The answer was always a name of a child, such as **ada** or **eef**.. It was allowed to use paper and pencil.
Example:
a =1 b=2 c=3 d=4 e=5 f=6 g=7
Adding:
ad = 14
ab = 12
---- +
The right answer is = 26
The calculation test was the most difficult cognitive task

to perform during the tests.

4. CONDITIONS DURING THE TESTS

The tests were carried out under normal school conditions. The teachers try to teach a normal as possible. The only difference with the normal lessons was that in the beginning of the morning or afternoon tests were carried out during about 30 minutes.
No one in the school neither the director nor the teachers knew in which classroom the ventilation was controlled. For both classrooms the instruction to teacher and pupils was not to use any ventilation provisions.
The temperature and CO_2 concentration is given in table 2

Table 2 Time and conditions during the tests

Date	Time h	Group	Air temperature °C	CO_2 concentration ppm	Condition
11 april	13.30	8A	20.0	733	CO_2 controlled ventilation
11 april	15.30	8A	21.3	874	CO_2 controlled ventilation
11 april	13.30	8B	19.1	1157	No purpose provided ventilation
11 april	15.30	8B	19.5	1615	No purpose provided ventilation
13 april	9.00	8A	20.2	1376	No purpose provided ventilation
13 april	11.00	8A	20.3	2126	No purpose provided ventilation
13 april	9.00	8B	17.8	742	CO_2 controlled ventilation
13 april	11.00	8B	18.2	620	CO_2 controlled ventilation

The maximum difference of the air temperature between the start of the lessons in the morning or the afternoon and the end of the lessons in the morning or the afternoon was 1.3°C. The average temperature difference between start and end of the lessons was about 0.6 °C
The CO_2 concentration in case of CO_2 controlled ventilation is kept between 600 ppm and 900 ppm. That is below the recommended value in the Netherlands which is 1200 ppm. A CO_2 level of about 750 ppm equals, with an outside concentration of 350 ppm, to a flow rate per pupil of about 11 dm^3/s, while 2000 ppm equals to a flow rate of about 3 dm^3/s.

5. RESULTS AND ANALYSIS

Starting point for the analysis is that each of the pupils was their own reference. The difference between the performance at the start of the morning or afternoon lessons and the end performance at the end of the morning or afternoon are compared. The statistical analysis method used is called ANOVA. In statistics, analysis of variance (ANOVA) is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables.
The most important results are presented in table 3. A number of statistical values are presented. Not all values are explained in this paper. For the real background of the statistical analysis, one should study the original report. [1]
The average error per pupil under the different ventilation conditions are the most interested ones. The average error is given as well as the spreading of all pupils' errors. This last information is shown between brackets.

Table 3 Results of the comparison between the two ventilation conditions (n=48)

Type test	Mean Square (effect)	F	df	P	Average error per pupil			
					No purpose provided ventilation		CO_2 controlled ventilation	
					start	end	start	end
Calculation	13,55	6,50	1,46	0,01	1,65 2,31 (1,26 –2,03) (1,69 – 2,94)	2,31 (1,69-2,94)	1,85 2,25 (1,41 –2,30)	2,25 (1,59– 2,91)
Spelling	108,00	44,4	1,46	0,00	5,17 6,10 (4,65 –5,69) (5,53 – 6,68)	6,10 (5,53–6,68)	4,94 5,75 (4,42 –5,45)	5,75 (5,08– 6,42)
Symbols	2.08	0.51	1,46	0,48	3,58 3,60 (2,73 –4,44) (2,67 – 4,54)	3,60 (2,67– 4,54)	3,42 3,02 (2,59 –4,25)	3,02 (2,29– 3,75)
Clock	1,17	2,31	1,46	0,14	0,52 0,38 (0,29 –0,76) (0,18 – 0,57)	0,38 (0,18– 0,57)	0,65 0,40 (0,37 –0,92) (0,19 – 0,60)	0,40 (0,19-0,60)

In the results of table 3 are corrected for the test sequence.
A very significant effect is found for calculation and spelling. P= 0.01 for the calculation test and 0.00 for the spelling test. The difference in the absolute number of errors is very small but significant. One van compare the increase in errors between the beginning and the end of the test series for the bad ventilation condition and the CO_2 controlled ventilation taken form table 3. Table 4 presents the results of this analysis.

Table 4 Average increase of errors due to bad ventilation for spelling and calculation.

Ventilation condition	average increase in errors between begin and end	
	calculation	spelling
CO_2 controlled ventilation	0.40	0.81
No purpose provided ventilation	0.66	0.93

In figure 1 the relative score in percentage is shown against the CO_2 concentration during the tests.

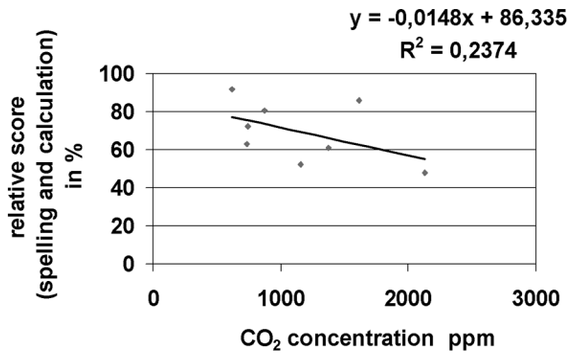


Figure 1 The relative score against the CO_2 concentration.

The relative score in figure 1is 100 % when no mistakes or errors are made during the tests. The relation between the relative score and the CO_2 concentration presented is not very strong but significant.

6. CONCLUSIONS

On the basis of this study where under controlled conditions in two classrooms the performance of 48 pupils of about 12 years old are investigated for bad ventilation conditions and CO_2 controlled ventilation, one may conclude:

• Pupils perform better on spelling tasks and calculation tasks with CO_2 controlled ventilation than with no purpose provided ventilation in classrooms.

• The effect can be expressed in about 4 % less errors for spelling tasks and 6% less errors for calculation tasks under CO_2 concentration increase of about 700 ppm.

• The relative score on spelling and calculation together (see figure 1) indicates that a decrease in CO_2 concentration of about 1000 ppm delivers an approximately 15% improvement.

• The CO_2 concentration increase during the tests in case of no purpose provided ventilation was not as high as planned and found in literature. The maximum CO_2 concentration at the end of one morning was about 2100 ppm, while in literature 3000 ppm is regularly measured. On the basis of this study bigger effect might be expected for higher CO_2 concentrations.

7. RECOMMENDATIONS

• Improvement of the ventilation in schools is recommended. Not only the performance of pupils but also the working environment of the teacher will improve. This may lead to lower absenteeism of teachers.

• In this study the temperature in the classrooms was kept as stable as possible. In real life the temperature in schools might also lead to attention deficit. The role of temperature needs further investigation.

REFERENCES

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