CREATING A HEALTHIER IN-DOOR CLIMATE AT SCHOOLS

IMPLEMENT
CONSULTING GROUP

A 18 months controlled study examining how the OpenCloud and class room material impact the indoor climate across 33 primary and lower secondary schools. The study is conducted as a collaboration between ÅBN and Implement Consulting Group, Alinea.

2021

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https://aabn.io/pages/dokumentation (in Danish)

Preface

This report is published by ÅBN in collaboration with Implement Consulting Group, Alinea as part of Realdania's project 'Skolernes Indeklima' (Indoor climate at Schools). The projects has an objective to improve the students welfare, learning and health by improving the indoor climate across schools in Denmark.

"We wish to improve the indoor climate across schools nationwide. We do so by creating an overview of the indoor climate through pilot projects, strategic indoor climate plans, innovation projects, focus on indoor climate research and network events. The objective is to improve the students learning and health."
Realdania, 'Skolernes Indeklima'

This report briefly outlines the project methodology including limitations. It present the conclusions and the test results of the innovation project.

The purpose of this is to visualize the benefits of behavioural products and methods to improve the indoor climate across primary and lower secondary schools nationwide and to document the potential effect on students' learning and health.

The project is financially supported by Realdania. ÅBN would like to thank all involved partners as well as the test schools involved for their interest and active participation in the project spanning two school years and the ongoing COVID-19 crisis.

Executive summary (1/2)

The indoor climate in Danish primary and lower secondary schools are not acceptable. This study span from October 2019 to January 2021 and includes 124 middle school classes in 33 primary and lower secondary schools across Denmark. It shows that the CO2 level exceed the recommended level of 1,000 ppm more than half the time between 8 AM and 2 PM every weekday all year round. The CO2 level exceeds 1,500 ppm a quarter of a normal school day, and 10% of the time the CO2 level is above 2,000 ppm. On some school days, entire lessons have even been recorded with CO2 levels exceeding 4,000 ppm. When the indoor climate reaches these levels, it can have serious consequences for students' well-being, learning and health - not just on that day, but for the rest of their lives.

Investments in ventilation systems are expensive and time consuming. However, this project shows, through a controlled experiment, that behavioural influences can have positive effects that are both considerable in size and lasting over time. Setting up an OpenCloud that glows red in a poor indoor climate and blue in a good indoor climate can, together with a simple habit kit, change the classes' ventilation behaviour over an extended period. Combined with a short-term teaching course, the effect continues at least throughout the school year. With these simple and inexpensive solutions, it has been possible to reduce CO2 concentrations above the threshold values to an absolute minimum over an entire school year.

In the study, the primary and lower secondary schools have been divided randomly into four groups, of which three of the groups after the baseline period (15 October 2019 to 12 January 2020) were supplied OpenClouds, teaching material or both. The remaining group was acting as a control group of the study and therefore did not receive any material. Both during and after the baseline period, the indoor climate is measured systematically with validated IC-Meters at all participating schools. It provides a completely unique insight into the indoor climate at a wide range of Danish primary and lower secondary schools over a period of almost a year and a half.

In the first period of the effect measurement from 13 January to 15 March 2020 (the day before the school closure due to COVID-19), the indoor climate in the control group is worse than in the baseline period. But for the three intervention groups, it looks different:

In the 10 classes where the submitted material on indoor climate was taught, the indoor climate improved a bit:
The proportion of time with CO2 levels above 2,000 ppm fell to 7%
The proportion of time with CO2 levels above 1,500 ppm fell to 22%
The proportion of time with CO2 levels above 1,000 ppm remained unchanged at around 50%

In the 9 classes where an OpenCloud was installed and a habit kit was used, the indoor climate improved noticeably:
The proportion of time with CO2 levels above 2,000 ppm fell to 1%
The proportion of time with CO2 levels above 1,500 ppm fell to 8%
The proportion of time with CO2 levels above 1,000 ppm fell to 23%

In the 10 classes that received both teaching material and an OpenCloud as well as a habit kit, the indoor climate also improved noticeably:
The proportion of time with CO2 levels above 2,000 ppm fell to 1%
The proportion of time with CO2 levels above 1,500 ppm fell to 8%
The proportion of time with CO2 levels above 1,000 ppm fell to 40%

Executive summary (2/2)

During the study, teachers of the classes reported in interviews that the students embraced the nudging by the OpenCloud's colour changes as well as the concept of "Fresh Air Heroes" introduced in the habit kit and were very committed to keeping the class air clean and healthy.

In the subsequent period between 16 March and 10 August 2020, when the Danish primary and lower secondary schools were closed down in whole or in part due to COVID-19, the indoor climate was much healthier than before - also in the control group. A natural and expected consequence of the decrease in activity at the schools' facilities, reduced class sizes and also due to the fact that the schools have been good at following the Danish Health Authority's recommendations to ventilate more to reduce the spread of infection.

The very low CO2 level across all the schools in the study continued in the period after 10 August and until the end of the study in January 2021. During this period, the measurements show that the indoor climate was very healthy and good - also in the control group. At the same time, the teachers reported in the ongoing telephone interviews that the lack of news value about the OpenCloud and the "Fresh Air Heroes" lowered the students' commitment a bit in relation to providing ventilation at regular intervals.

Nevertheless, it seems that the indoor climate in the control group towards the end of the study normalizes towards the poor starting point, while there is still a measurable effect in the classes that were supplied both teaching material and the OpenCloud.

Based on data and interviews we can conclude that the OpenCloud, the habit kit and the teaching material can initiate behavioural changes that create lasting improvements to the indoor climate. After one year, the students who have had the OpenCloud installed and used the habit kit during class, stay almost exclusively in acceptable CO2 levels during the school day.

Appendix:
https://aabn.io/pages/dokumentation

CONTENT

Appendix:
https://aabn.io/pages/dokumentation

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Introduction

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The indoor climate in Danish primary and lower secondary schools is very poor. Period.

In 2017, the Technical University of Denmark and Realdania concluded that 91% of the Danish classrooms have problems with the indoor climate due to lack of ventilation. It reduces the ability to learn and the health of children. Studies have shown that a reduction in the CO2 level in the classroom can lead to approximately 14% better performance and concentration ability. Recent projections even show that long-term improvements in the indoor climate could result in socio-economic improvements (Realdania and Incentive 2020).

The school buildings in Denmark are facing a major renovation to improve the indoor climate. 90% of the country's primary and lower secondary school buildings were built before 1995, which means that the majority of the country's schools are outdated in relation to today's standards.

For Denmark as a knowledge society, it starts with giving our children the best conditions for a good learning environment.

> **It easily becomes the individual teacher's problem to ensure a good indoor climate, but in reality it requires a collective effort**
>
> *Anne Fangel, Alexandra Instituttet*

The challenge is that CO2 is invisible and we can only react to it when we have symptoms such as headaches, fatigue and difficulty concentrating, but then it is too late. With the primary and lower secondary school buildings that Denmark uses today, schools need to be able to collectively react to the CO2 level before it gets poor. The current solutions on the market have a long response time to the reduction of the CO2 level. It requires 1) either technically complicated and expensive systems (automatically controlled ventilation, etc.) that require renovation of the school or 2) an allocated technical operations manager, who with indoor climate meters, must keep an eye on a web-based platform, data, and act when CO2- the level exceeds 1,000 ppm. on the premises.

This study tests whether knowledge about indoor climate and a supportive tool can lead to student-engaged behavioural changes to active ventilation in the classroom over the longer term, thus reducing CO2 levels during the school day. In this study, teaching material is included, which creates focus and learning about the importance of what good ventilation habits and a healthy indoor climate do for the students' learning opportunities.

Chapter 2

SUMMARY: THE CHALLENGE AND THE EFFECT

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The inferior indoor climate in Danish schools are bad for learning, well-being and health, and existing solutions are quite expensive and short term...

IM_

> 3 HOURS

During a school day from 08-14 the CO_2-concentration exceeds the recommended level of 1,000 ppm.

Source: ÅBN, Implement Consulting Group, Alinea og Realdania (2021): Baseline-måling på 40 folkeskoler rundt om i Danmark, 15. oktober 2019 – 12. januar 2020. Realdania (2017): Indeklima i skoler.

4,000 PPM

CO_2-concentration can be reached during a normal school day. That is four times higher than the recommended level.

Source: ÅBN, Implement Consulting Group, Alinea og Realdania (2021): Baseline-måling på 40 folkeskoler rundt om i Danmark, 15. oktober 2019 – 12. januar 2020

LEARNING

becomes difficult when the indoor climate is poor. Continued exposure to poor air can effect well-being and health also in the long run.

Source: Clausen, Geo et al (2017): DTU, Realdania Indeklima i Skoler, og Fisk, W. J. (2017): The Ventilation Problem in Schools: Literature Review. Indoor Air 27(6): 1039-1051

EUR 175.000

is the average cost of an energy renovation which is the minimum recommendation to obtain a indoor climate effect at a school.

Source: Københavns Kommune (2014): Helhedsrenovering af 8 københavnske skoler

THE EFFECT DISAPPEARS FAST

when schools implement behavioural change efforts to improve the indoor climate. One reason is the human factor where the anchoring required to change long term habits requires a lot of effort,.

Source: Fangel, Anne Bøgh, og Kasper Fænø Noer (2017): Indeklima i skoler. Muligheder for adfærdsændringer i hverdagen.

... But we have tested a solution that yields a lasting improvement of indoor climate without breaking the budget.

Without OpenCloud

More than 30 minutes per school day with CO_2-level above 2,000 ppm.

More than 3 hours per school day with CO_2-level above 1,000 ppm

4X RECOMMENDED LEVEL

Max. levels up to 4,000 ppm

With OpenCloud

(After one year)

Less than 1 minute per school day with CO_2-level above 2,000 ppm.

Less than 90 minutes per school day with CO_2-level above 1,000 ppm

2X RECOMMENDED LEVEL

Max. levels up to 2,000 ppm

After installing the OPENCLOUD in the classroom, attention to indoor climate have increased, both among students and myself. The students raise their hands when the cloud turns red.

Serpil,4th grade teacher, Krogårdsskolen

Chapter 3

DESIGN OF SOLUTION AND SURVEY

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OPENCLOUD is a simple intuitive nudging-device, with a broad appeal across ages.

OPENCLOUD

Intuitive visualization of the invisible CO_2-levels.

OPENCLOUD is designed and developed to introduce student-engaged behavioural changes for active ventilation in the classroom.

By switching from blue light to red light, the OPENCLOUD tells students and teachers in the room when to ventilate to maintain a good indoor climate. The OPENCLOUD hangs on the wall and only needs to be plugged into an electrical outlet, making it easy to use. The OPENCLOUD changes back to blue when the room is sufficiently ventilated.

A Blue OPENCLOUD

When the OPENCLOUD is blue, the CO2 level is below 1,000 ppm, the Danish Working Environment Authority's current recommendation for a good indoor climate.

A Red OPENCLOUD

When the OPENCLOUD is red, the CO2 level is above 1,000 ppm, which is where the indoor climate begins to become harmful.

We created a "habit kit" to supplement the OPENCLOUD in the classroom and designed teaching materials in collaboration with Alinea.

HABIT KIT

Appointing a classroom air quality prefect

To best support the OPENCLOUD, we developed a habit kit. The habit kit addressed a number of behavioural barriers for the OPENCLOUD. Including that the OPENCLOUD competes with the break bell (every 45 minutes it rings for a break, and it should preferably be timed with a ventilation), lack of feed forward (what should the student / teacher do when the OPENCLOUD turns red? And where?), Lack of responsibility (who must do it?) and lack of immediate reward by ventilation (what do I get out of doing it?). The habit kit included a short teacher's guide, a sweet story for the students, a 3-step guide, and a puppet show. See Appendix for more information on the habit kit.

TEACHING MATERIAL

In collaboration with Alinea, we developed the digital teaching course "Fresh Air Heroes" in 4 lessons for the subject nature / technology. Through knowledge, play and exercises, the course focused on why humans and all other organisms on earth need oxygen, how plants create oxygen through photosynthesis, and how the body converts oxygen into activity in the body and brain. In addition, the course also gave the students insight into how important it is to breathe fresh air, and how to ensure a healthy indoor climate with e.g. ventilation and cleaning. See Appendix for more information about the course.

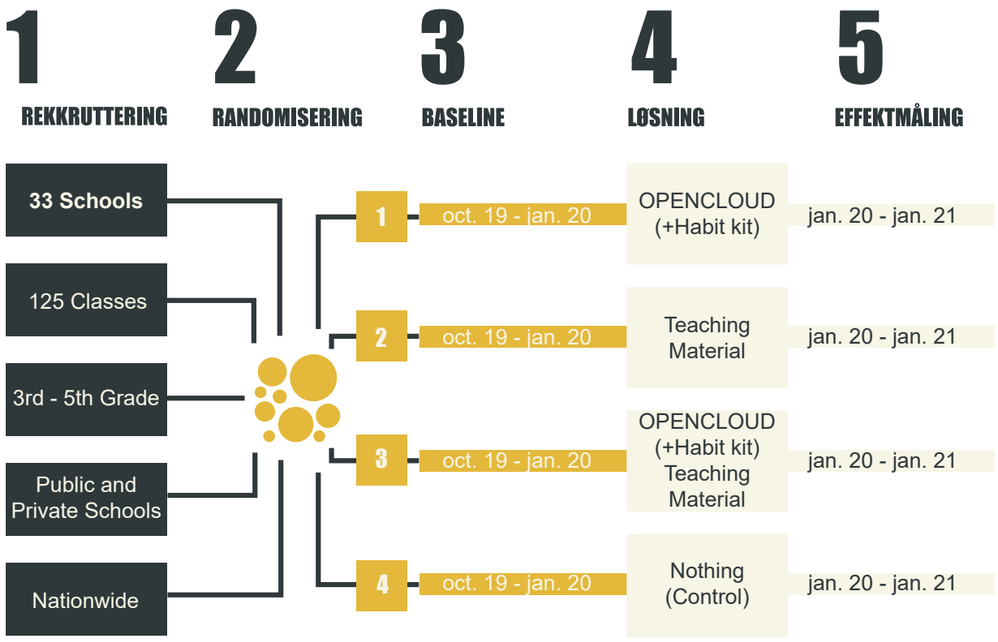
We planned the survey as a randomized controlled experiment with an initial baseline period

To ensure the validity of the measurement results, precise measuring equipment and a scientific study design were necessary. We therefore used IC-Meters, which have high measurement validity and are used in research. In addition, we designed the study as a controlled experiment with baseline and randomized allocation of either one or both solutions or no solution, as well as with effect measurement over a longer period.

We recruited 125 classes at 33 public and private schools around the country - 10 West of the Great Belt and 23 East of the Great Belt. All schools were interested in exploring the possibilities of improving the indoor climate through behavioural changes in classrooms without mechanical ventilation. The participating classes were in 3rd to 5th grade.

At the start of the survey in October 2019, we installed IC-Meter in all participating classrooms. After the end of the baseline period on January 12, 2020, the 33 schools were divided randomly into four groups: 44 classes in a total of 8 schools were given an OPENCLOUD installed in each classroom and sent a habit kit, 26 classes in a total of 7 schools were sent teaching materials on indoor climate, 37 classes in a total of 9 schools had both an OPENCLOUD installed in each classroom and sent out a habit kit as well as teaching material on indoor climate. The remaining 18 classes at a total of 9 schools were not sent anything and acted as a control group throughout the period. In addition to the pure CO2 measurements, monthly telephone interviews were conducted with the class teachers.

The effect measurement was initially set for June 2020 but was extended to the end of 2020 due to the COVID-19 school closures. Thus, the effect measurement ended up lasting from January 13, 2020 to 11 January 2021.



Overview of the 33 participating schools, number of classes and the randomised survey groups they belonged to

SCHOOL		CLASSES	GROUP
Name	Municipality	#	
Brøndbyøster Skole	Brøndby	2	Control
Engholmsskolen	Allerød	2	Control
Hanssted Skole	København	2	Control
Kornmarkskolen Skævinge afd.	Skævinge	2	Control
Skolen på La Cours vej	Frederiksberg	2	Control
Skolen på Nyelandsvej	Frederiksberg	2	Control
Tranegårdskolen	Gentofte	2	Control
Tre Falke Skolen	Frederiksberg	2	Control
Vallekilde-Hørve Friskole	Hørve	2	Control
Avedøre Skole	Hvidovre	6	OPENCLOUD
Krogårdskolen	Greve	9	OPENCLOUD
Langelinieskolen	København	1	OPENCLOUD
Lyngby Friskole	Lyngby Taarbæk	3	OPENCLOUD
Nordskolen, afdeling Jyllinge	Roskilde	4	OPENCLOUD
Sct. Norberts Skole	Vejle	6	OPENCLOUD
Skolen på Amagerbro	København	9	OPENCLOUD
Vibeskolen	Nyborg	6	OPENCLOUD
Den Dansk-Franske Skole	København	1	Teaching
Hanebjerg Skole	Hillerød	2	Teaching
Køge Private Realskole	Køge	1	Teaching
Tømmerup Skole	Kalundborg	2	Teaching
Uhre Friskole	Ikast-Brande	6	Teaching
Viding Skole	Vejle	6	Teaching
Ådalskolen Bohr	Esbjerg	8	Teaching
Billums Privatskole	Lyngby-Taarbæk	3	Both
Brønshøj Skole	København	4	Both
Danehofskolen, afd. Nyborg	Nyborg	1	Both
Fjeldsted Harndrup Børneunivers	Middelfart	3	Both
Kongevejens Skole	Lyngby Taarbæk	7	Both
Munkevængets Skole	Kolding	4	Both
Nørre Aaby Skole	Middelfart	2	Both
Sorø Privatskole	Sorø	9	Both
Tingbjerg Skole	Brønshøj	4	Both

Both quantitative CO_2 data and qualitative data in the form of interviews with teachers were collected

Collection and qualification of CO2 data

The IC-Meter meters emit data every 5 minutes on CO2, noise (dB), humidity and temperature. The setup is made so that we got a notification if a meter had suddenly not sent data for a few hours. In those cases, we contacted the school and solved the problem so that data collection was resumed as soon as possible - either by turning the IC-Meter meter back on power (the most common problem) or by having the school set up a new IC-Meter meter instead of the one that did not work.

The CO2 data collected from the IC-Meters at the 33 schools in the study were retrieved and collected in one large data set using Python (see script in Appendix). The data set was further processed, analysed and visualized in the statistical program R

Data were cleaned so that it only contained weekdays outside the school holidays in the period between 08.00 to 14.00 In addition, extreme observations above 6000 ppm and periods without measurable activity (i.e., continuous average noise level below 32.9 dB for more than 1 hour) were removed from the data set.

With this the total data set went from 3,233,767 observations to 396,581 observations.

Analysis of the qualified CO2 data

The qualified data set was analysed based on the following survey questions:

- How good/poor is the indoor climate in the baseline period?
- How does the indoor climate develop during the project period in the four groups?
- Is there significant difference in the development of indoor climate between the groups?
- Do the different solutions (OPENCLOUD, teaching material, OPENCLOUD + teaching material) have a differet effect? If yes: How big a difference, and does the effect last over time?

Ongoing telephone interview with the teachers

Teachers were interviewed by telephone. The interviews were semi-structured and conducted on a monthly basis in random samples so that all schools were interviewed at least twice during the study period. We asked the following questions in the telephone interviews:

- How well is the project participation going?
- How are the students doing?
- Are you good at ventilating the classrooms?
- (Only schools with OPENCLOUD) What is your experience with OPENCLOUD?
- Is there anything you have started to do differently in relation to ventilation and indoor climate during the project period?
- Is there anything else you would like to mention to us? Are you missing something, or is there something we can help with?

Appendix:
https://aabn.io/pages/dokumentation

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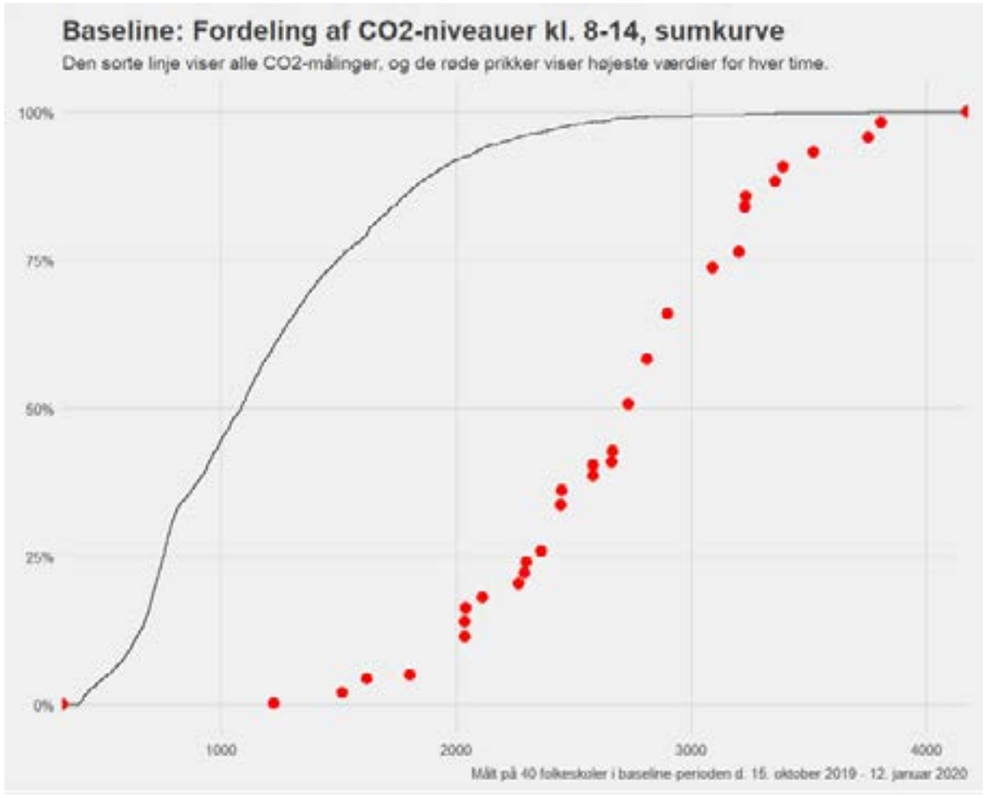
Chapter 4

ANALYSIS AND INTERVIEWS

The baseline survey confirms that the indoor climate in Danish schools is too poor and often even decidedly unhealthy



The indoor climate is poor more than half of the school day

- > 50% of the time, the CO_2 level is above 1,000 ppm, which is the recommended level. I.e.. more than 3 hours a day, the CO_2 level is higher than the recommended value.
- 25% of the time the CO_2 level is above 1,500 ppm. I.e.. 1.5 hours a day, the CO_2 level is 1.5x higher than the recommended value.
- 10% of the time the CO_2 level is above 2,000 ppm. I.e.. 36 minutes a day, the CO_2 level is 2x higher than the recommended value.

CO_2-levels often reach such high level that it can affect well-being, learning and health

- In 90% of school hours, the CO_2 level at some point reaches above 2,000 ppm.
- In 50% of school hours, the CO_2 level at some point reaches above 2,500 ppm.
- In 25% of school hours, the CO_2 level at some point reaches above 3,000 ppm.

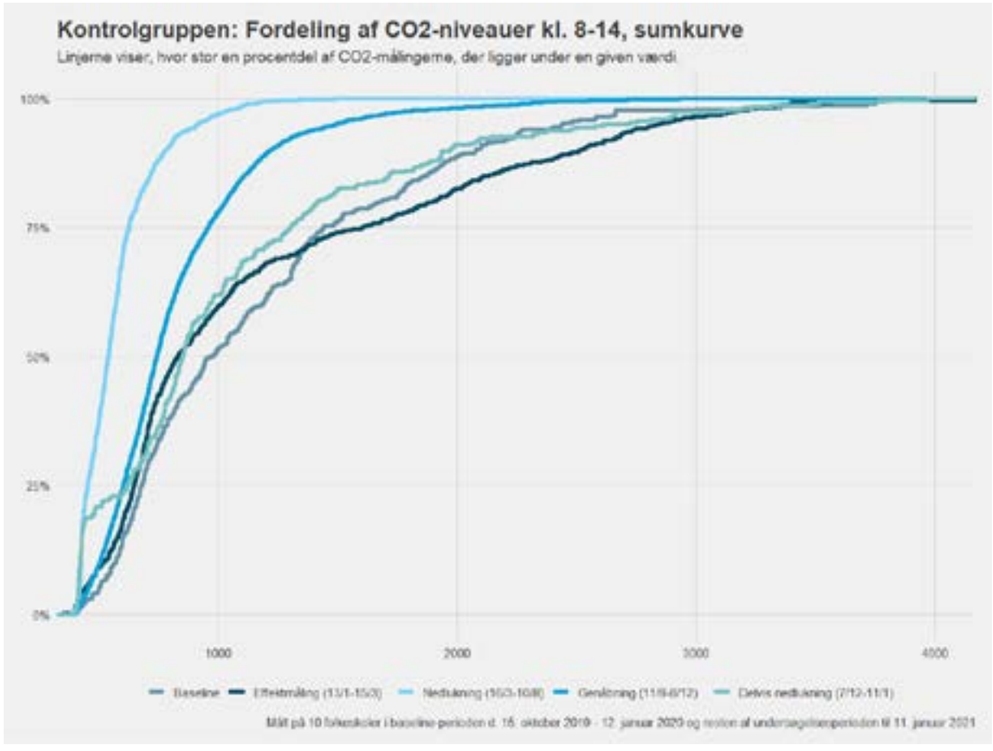
The indoor climate in the control group improves during COVID-19, but returns to baseline level

From baseline to the first effect measurement period, there is no significant change in the indoor climate. Thus, the CO_2 level in the 9 primary schools in the control group is above 1,500 ppm approx. 25% of the time in both periods.

During the COVID-19 closure period from and including 16 March 2020, there were a sharp improvement in the indoor climate. The CO_2 level is thus less than 1,000 ppm over 90% of the time, and it generally does not exceed 1,100 ppm.

In the reopening period from August 11 to December 6, 2020, the indoor climate is still significantly better than normal, but now the CO_2 level is 'only' below 1,000 ppm for approx. 75% of the time.

In the last period of partial closure of the schools from December 7, 2020 to January 11, 2021, the indoor climate is almost back to normal, i.e. only just statistically significantly lower than in the baseline period.

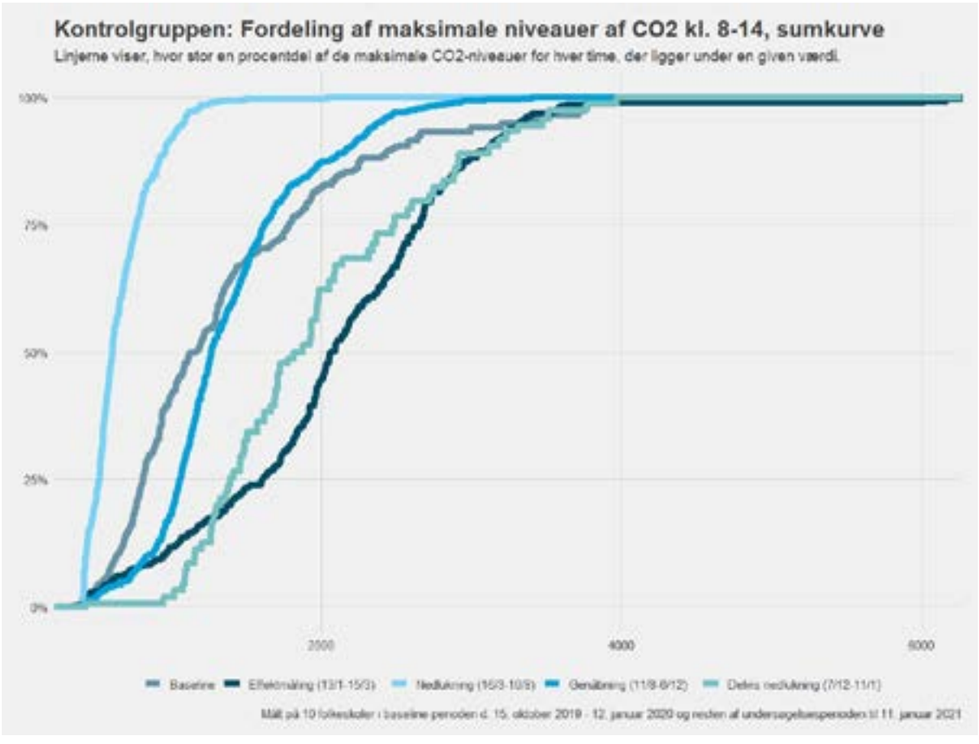


The Control groups maximum CO_2-levels increase after baseline period and during partial closure of the schools

> **We would have loved to have an OPENCLOUD as some of our classrooms used in the project are quite small.**
>
> *Anna Grethe, vice principal, Vinding Skole*

When we look at the maximum CO_2 levels per hour during the school day, the picture is pretty much the same. However, the maximum CO_2 levels are significantly higher in the first effect-measurement period January 13 to March15, 2020 and during the partial school closure December 12, 2020 to January 11, 2021. Thus, the indoor climate is worse in these two periods than in the baseline period.

In the telephone interviews, the teachers emphasized that they obviously did not notice much about their participation in the study, but that COVID-19 gave them greater attention to ventilation. In addition, some emphasized that they were sad that they did not get an OPENCLOUD for their class as part of participation in the project.

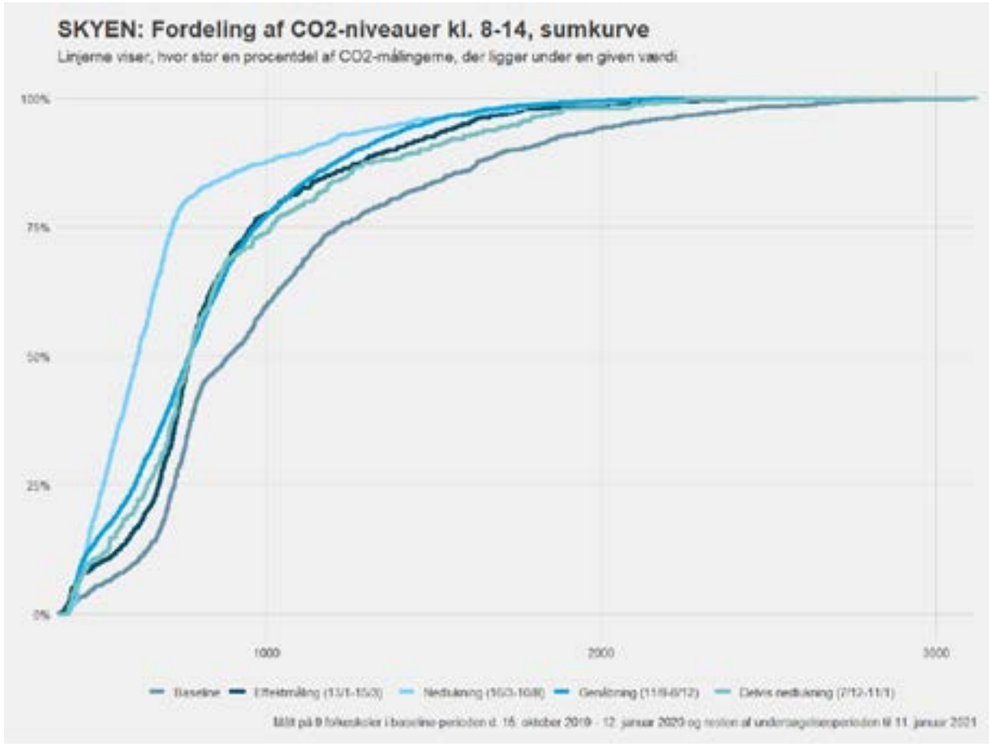


Classes with an OPENCLOUD experienced significant improvements of the indoor climate that lasts throughout the project period

The eight schools with OPENCLOUD installed went in the first effect-measurement period from having CO_2 levels below 1,000 ppm approx. 75% of the school day to approx. 60%. Compared to the total baseline for all schools (see page 16), this corresponds to the classes in this group each having reduced the amount of time with poor air per day from 3 hours to 90 minutes.

After the school closure on March 16, 2020, the indoor climate was further improved and returned to the below 1,000 ppm approx. 75% of the time in January 2021.

Furthermore, in the period after the baseline measurement, there is virtually no time when the CO_2 level exceeds 2,000 ppm. In total, this corresponds to less than 1 minute per school day, compared to 36 minutes in the baseline period.

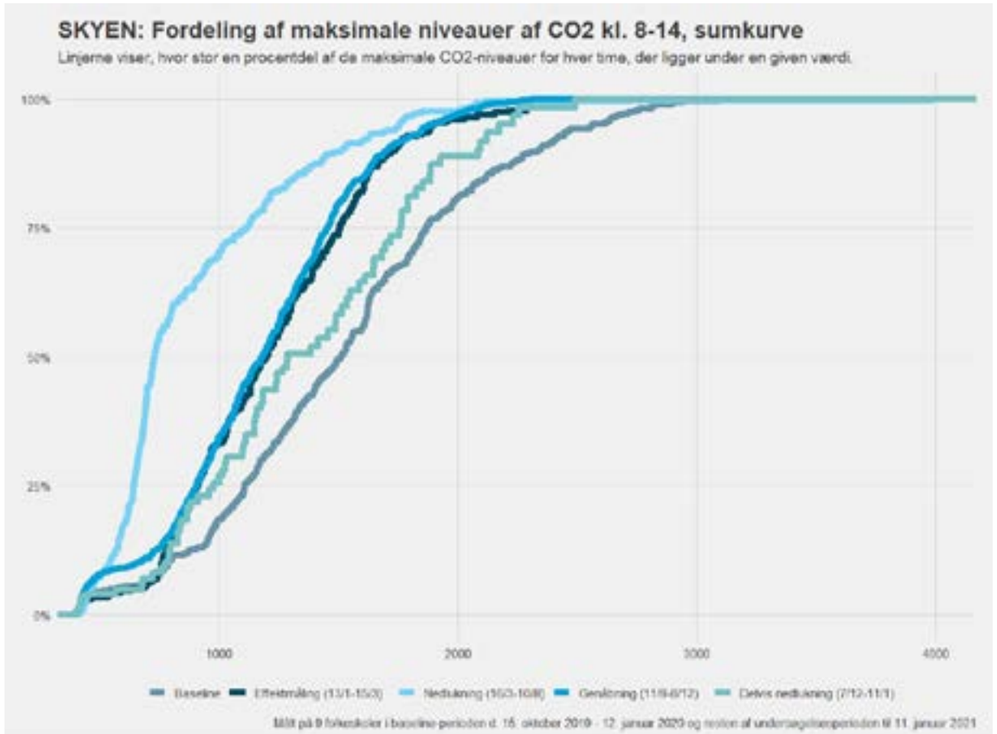


OPENCLOUD received a lot of initial attention and the good habits stuck over time

> **After installing the OPENCLOUD in the classroom, attention to indoor climate have increased, both among student and myself. The students raise their hand when the cloud turns red.**
>
> *Serpil, 4th grade teacher, Krogårdskolen*

When observing the maximum CO_2 levels on an hourly base, the improvement in the indoor climate is also measurable over the entire project period. During the baseline period, maximum CO_2 levels exceed 2,000 ppm for 20% of the hours. In the first effect-measurement period up to the school closure Mar. 16, 2020, there are virtually no maximum CO_2 levels above 2,000 ppm, while in the last measurement period Dec. 7, 2020 to Jan. 11, 2021 it is approx. 10% of the hours when the max. level just exceeds 2,000 ppm.

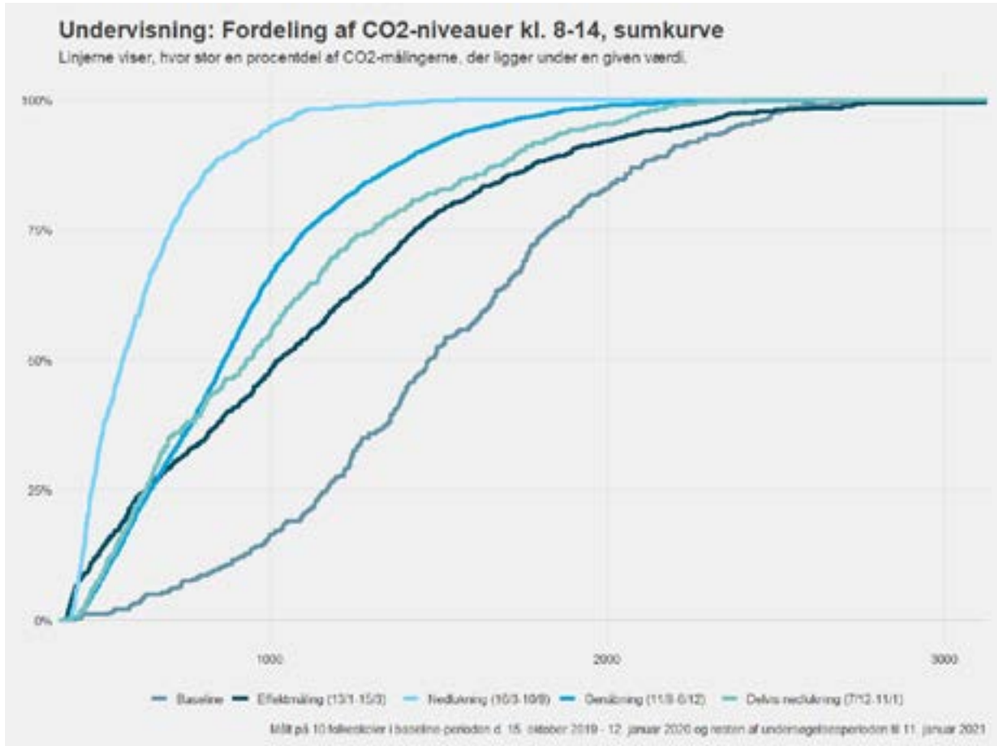
In the telephone interviews, the teachers express satisfaction with the OPENCLOUD. They said that especially in the beginning there was a 'hype' and 'great attention' around it, but that the students became less aware of it as time went on. Several teachers were therefore in doubt as to whether the OPENCLOUD actually worked after the summer holidays of 2020 when the students returned from the first school closure.



The teaching material yielded a lasting improvement in indoor climate however only at a moderate level

During the baseline period, the indoor climate was extremely poor in the group of classes divided into 7 schools, which subsequently received the teaching material. Thus, during a normal school day, the CO_2 level was above 1,000 ppm approx. 85% of the time and it exceeded 2,000 ppm for 20% of the time.

After sending out the teaching material, this group experienced a significant improvement in the indoor climate, but not more than to a point where the CO_2 level exceeded 1,000 ppm approx. 50% of the time during a school day. In the period with the first school closures from Mar. 16, 2020, the indoor climate was largely exclusively good, but then it dropped to approx. same level as in the first effect-measurement period.

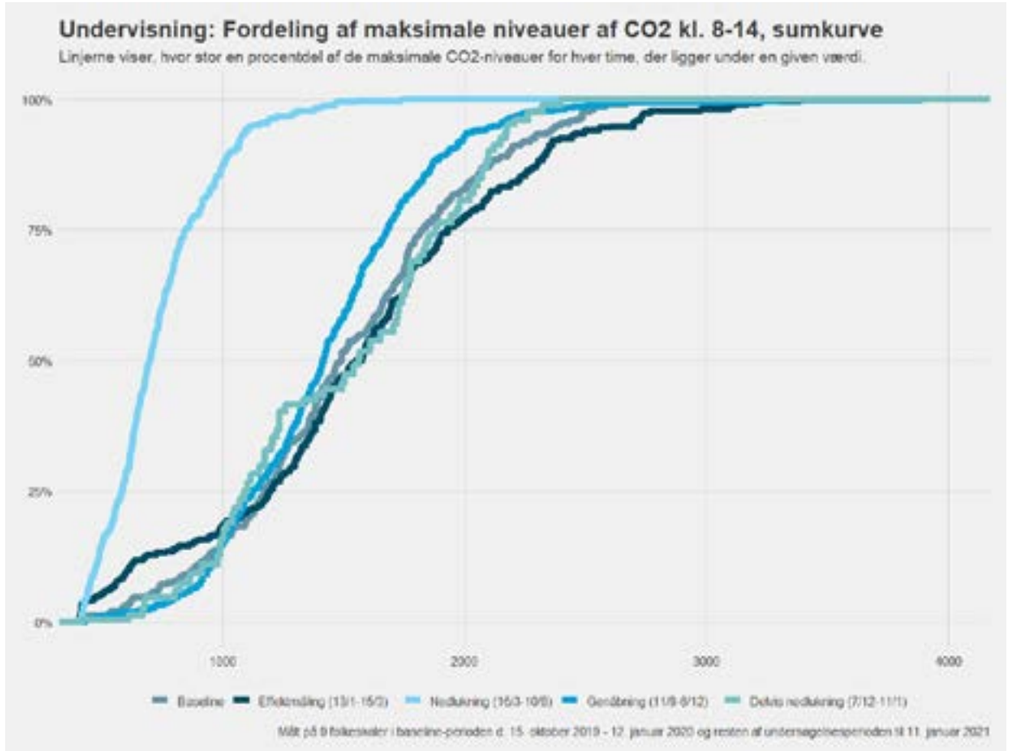


The teaching material yielded a lasting improvement in indoor climate however only at a moderate level

> **The teaching makes the kid aware of the problem but new angles must be introduced on an ongoing basis to maintain the awareness.**
>
> *Anna Grethe, vice principal, Vinding Skole*

As shown in the figure below, there was no significant change in the distribution of the maximum CO_2 levels per hour when we compare the baseline period with the first and last effect-measurement period.

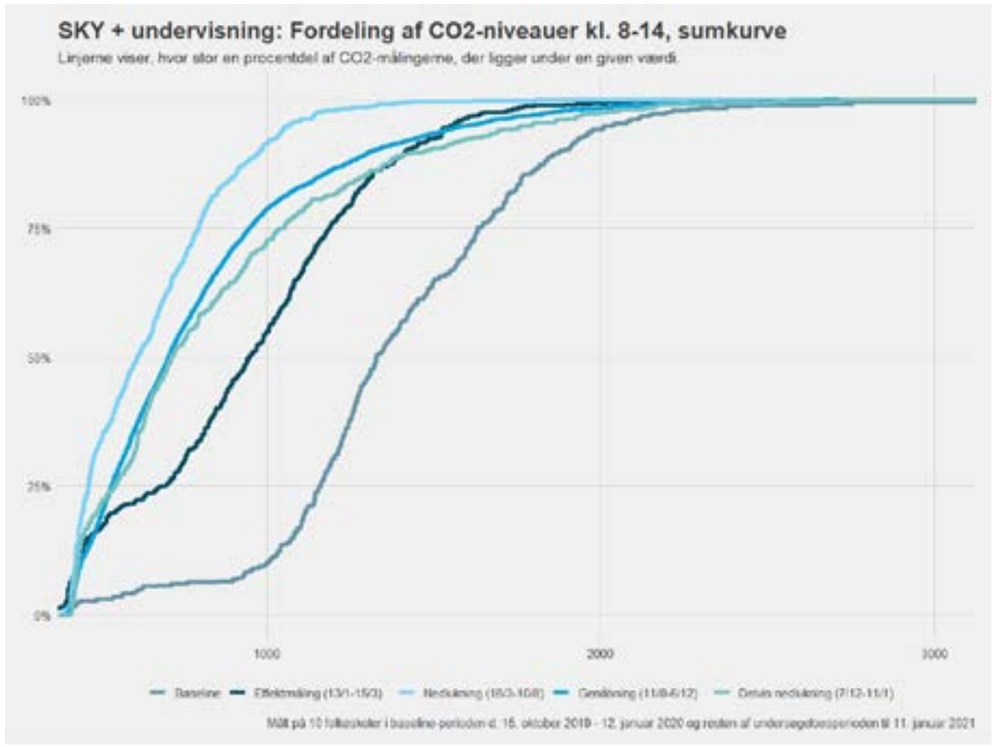
Furthermore, the telephone interviews with the teachers in this group of classes reflect that even though the teaching material was well received, it should preferably be followed up with some concrete tools if it is to have a real effect on the daily behaviour regarding ventilation.



In classes where both OPENCLOUD and teaching material was used the indoor climate improved significantly with a lasting effect

The group of schools receiving both the OPENCLOUD and teaching materials had a very poor indoor climate during the baseline period. Thus, during a normal school day - the CO_2 level - similar to the group that only received the teaching material - was above 1,000 ppm approx. 85% of the time and it exceeded 2,000 ppm for 10% of the time.

In the first effect measurement period, this was greatly improved, but only to a moderate level, where the CO_2 level was below 1,000 ppm approx. 50% of the time. Subsequently, the indoor climate was greatly improved in connection with the school closures and stabilized in the last power measurement period of approx. same level as the group with the OPENCLOUD, where the CO_2 level only exceeded 1,000 ppm approx. 25% of the time and where it only exceptionally exceeded 2,000 ppm.

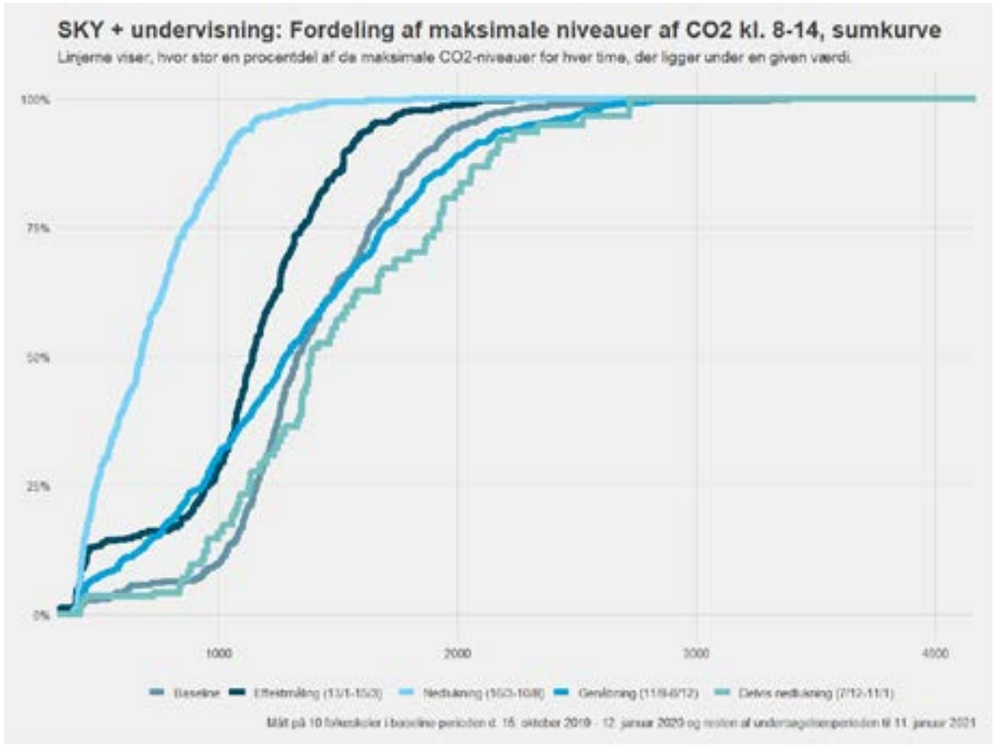


Using both OPENCLOUD and teaching material did not show any significant effect over using the OPENCLOUD on its own.

> **The kids found it very interesting when I blew on the Cloud and it turned red. Now they don't give it that much focus anymore.**
>
> *Vibeke, 5th grade teacher, Sct. Norberts Skole*

The same trend applies, albeit less markedly, when looking at the maximum CO_2 levels for each hour during the school day in the first effect-measurement period compared to baseline. The difference, however almost completely offsets at the end of the project, so that in fact no distinction can be made between the indoor climate in the baseline and in the partial closure Dec. 7,2020 to Jan. 11, 2021.

The teachers stated in the ongoing telephone interviews that they were happy with OPENCLOUD, but that the news value fell after the summer holidays. In addition, there was a consensus that the teaching material was good, although the teachers judged that it must have been a little more than 5 lessons and had to be followed up if it was to have a lasting effect.



Chapter 5

CONCLUSION AND PERSPECTIVE

OPENCLOUD quickly improves the indoor climate with a lasting effect

Our study shows that it is possible to create lasting indoor climate improvements in Danish schools - even without massive investments in building renovation. After measuring the indoor climate in a baseline period, sending teaching materials and OPENCLOUDs to randomly selected schools and then following the development for a whole year, we can conclude that we can change behaviour and that it makes a difference by creating healthier air during the school day. Both the teaching material and OPENCLOUD seem to make a positive difference, but OPENCLOUD has the largest and most lasting effect.

Released with a habit kit, OPENCLOUD has enabled a lasting change in behaviour among students and teachers, which has resulted in CO_2 levels exceeding 1,000 ppm 90 minutes a day and virtually never exceeding 2,000 ppm. This must be seen in contrast to the baseline measurement, where the CO_2 level exceeded 1,000 ppm over three hours and was above 2,000 ppm for more than 30 minutes. Every day, all year round.

In addition, the study also underline that behaviour around ventilation means an enormous amount to the quality of the indoor climate. During the partial school closures as a result of COVID-19, all schools - also in the control group - had a significantly better indoor climate than usual, even on days when there were almost normal activity in the youngest classes.

Similar to the teachers' statements in our ongoing telephone interview, we conclude it is a result of an increased focus on ventilation, more outdoor teaching and smaller class sizes.

As everyday life has taken root and - especially the younger classes - have more or less resumed the usual classroom teaching, OPENCLOUD and the teaching material have proven to be decisive in maintaining the improvements of the indoor climate.

On the basis of this report, we recommend that OPENCLOUD is used together with the habit kit for primary and lower middle schools, if necessary together with the teaching material, to create lasting improvements of the indoor climate through behavioural changes among teachers and students.

One question remains to be answered. Does it make a difference at all for the student and for society that the CO_2 level in the classroom goes from an average of 30% to 10% below the recommended maximum limit for the rest of the student's school time?

Recent calculations of the socio-economic benefits of improved indoor climate (Realdania and Incentive 2020) estimate that an improvement in the CO_2 level from approx. 1350 ppm to 950 ppm results in students' academic performance rising from index 91 to index 100 and their absenteeism decreasing significantly. If these projections can be taken at face value, the long-term effect of the results in this project will be that in 9 years a socio-economic gain of approx. EUR 215 per student. Extrapolated to 650 students for 30 years, this will mean that the state's tax revenue will increase by approx. EUR 670.000, and that the municipality's tax revenue will increase by approx. EUR 1.6 Million.

There is no doubt that there are major uncertainties associated with these estimates. But at the same time, there is no doubt that a cheap and lasting improvement of the indoor climate with a solution that simultaneously engages the students in a common problem can only benefit the student, the teacher, the school and society.

Chapter 6

LITERATURE

Clausen, Geo et al (2017): DTU, Realdania Indeklima i skoler (https://realdania.dk/publikationer/faglige-publikationer/indeklimaiskoler)

Fangel, Anne Bøgh, og Kasper Fænø Noer (2017): Indeklima i skoler. Muligheder for adfærdsændringer i hverdagen (https://realdania.dk/-/media/realdaniadk/publikationer/faglige-publikationer/indeklima-i-skoler/alexandra-institut-rapport.pdf).

Fisk, W. J. (2017): The Ventilation Problem in Schools: Literature Review. Indoor Air 27(6): 1039-1051

Københavns Kommune (2014): Helhedsrenovering af 8 københavnske skoler (https://www.kk.dk/file/1715/download?token=Uddad30i)

Realdania og Incentive (2020): Samfundsøkonomiske gevinster ved forbedret indeklima (https://realdania.dk/publikationer/faglige-publikationer/samfundsoekonomiske-gevinster-ved-forbedret-indeklima)

Appendix:
https://aabn.io/pages/dokumentation