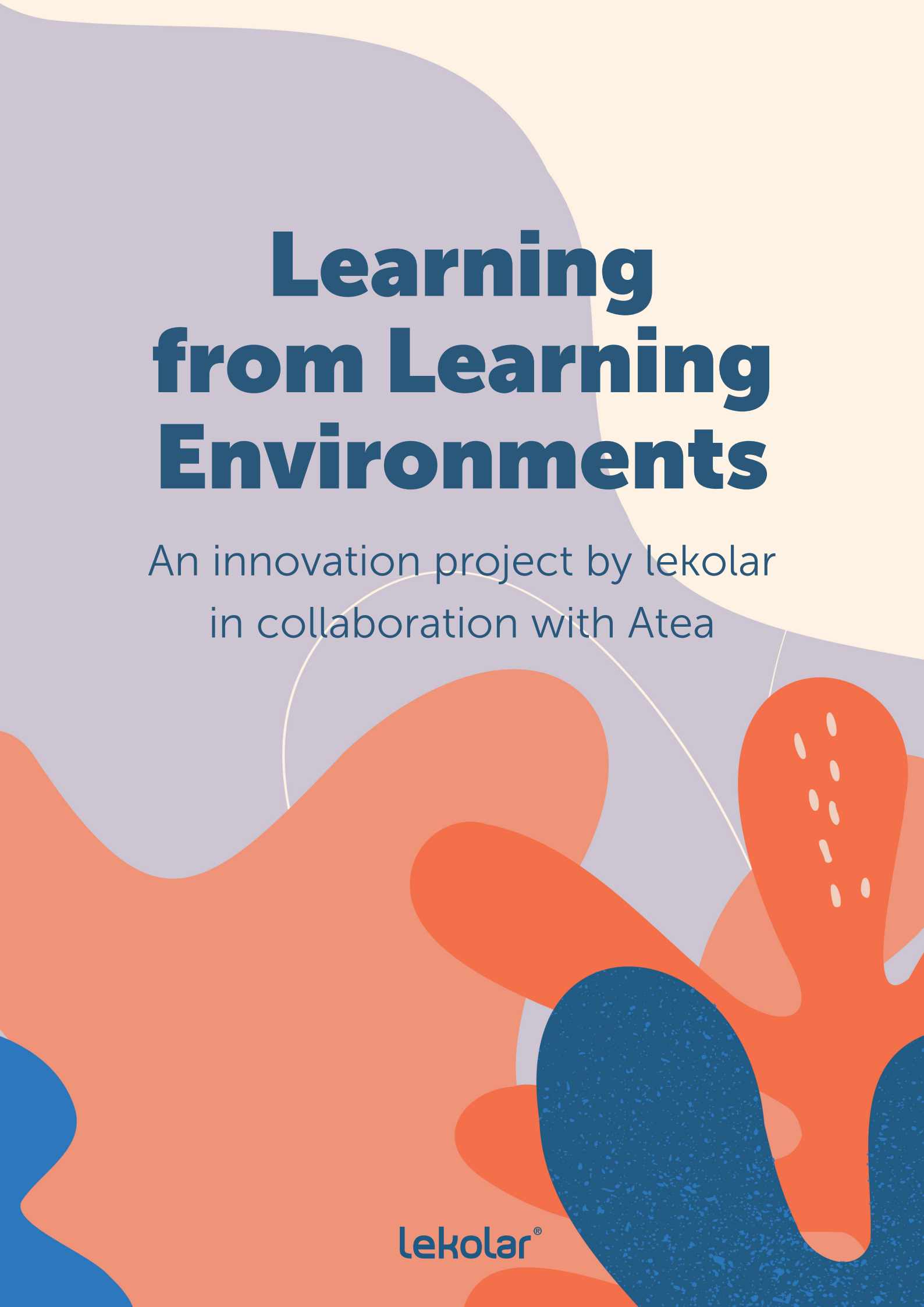
Learning from Learning Environments

An innovation project by lekolar
in collaboration with Atea



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Executive Summary

BACKGROUND. Schools are a significant investment for society and must function for several decades. To meet the future educational needs, the pedagogical vision of schools will need to shift towards innovative learning, focusing more on collaboration, interdisciplinary approaches, and students' well-being. A better understanding of how to optimize the school learning environment is therefore necessary.

PURPOSE. The purpose of this study was to investigate whether, through data collection of movement patterns, physical parameters, surveys, observations, and spatial understanding in a specific case study, we could create an evidence-based service to systematically test, improve, and confirm the optimal functioning of a learning environment. This was done by focusing on two primary objectives:

1. Match learning environment and pedagogy.
2. Increase well-being, safety, variation, and individualization.

IMPLEMENTATION. In this project, we utilized and evaluated a method triangulation consisting of three different data collection methods:

1. Student and teacher surveys.
2. Classroom observations.
3. Physical parameters.

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* OECD's global guidelines "The Future of Education and Skills 2030." A shared understanding of the knowledge, skills, attitudes, and values that students need in the future. With a focus on reshaping the curriculum and developing a conceptual framework for learning in 2030. The frameworks for learning and teaching are co-created by policymakers, researchers, school leaders, teachers, and students from more than 100 countries worldwide.

CASE STUDY. The method triangulation was tested on a case study named 'Toftanässkolan'. The objectives of the case study were to:

1. Design a subject-specific classroom that suits the needs of the teacher, students, and subject matter.

2. Allow the students and teacher to use the classroom during a limited period, divided into two phases.

3. Utilize the method triangulation to measure, analyse, and prove that the classroom design met its specific needs and contributed to increased well-being, safety, variation, and individualization.

CASE STUDY RESULTS. As all three data collection methods produced overwhelmingly positive results, we could conclude that the case study was successful and confirmed all our hypotheses. We also found that our approach of collecting and analysing data in two phases meant we could implement improvements and further optimize the learning environment.

METHOD EVALUATION. The method triangulation we employed worked well for measuring and analysing our case study, confirming all our hypotheses with reasonable certainty, as the results from at least two data collection methods generally aligned. However, the evaluation of individual data collection methods suggested they should be further improved through standardization.

FURTHER STUDIES. Our next step is to standardize our method and apply it to a larger and more complex case study involving multiple schools, classrooms, students, and teachers. The end goal is to develop a more advanced data collection method, capable of evaluating and suggesting adaptations for the entire school environment.

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Introduction

FOREWORD

In 2020, Lekolar and Atea initiated a joint innovation forum to discuss how our respective competencies could be combined in various projects and solutions to improve conditions in schools. Two of the competencies we found particularly interesting were how we could combine Lekolar's spatial and educational expertise with Atea's knowledge of data collection and artificial intelligence (AI) to create a "smart" school. These ideas resulted in the project "Learning fom Learning Environments." In this project we explore how, through data collection on movement patterns and physical parameters, surveys, observations, and spatial understanding, we can create an evidence-based service to optimize the school's learning environment and increase well-being, safety, variety, and individualization. The first part of the project focused on testing a simpler method by measuring a specific learning environment and evaluating the usefulness of the collected information. Ultimately, the goal is to develop an advanced data collection and analysis method that can suggest adaptations for the entire school environment. This method could for example be integrated with scheduling to maximize the utilization of premises or manage student flows in a way that maximizes adult presence and minimizes the risk of bullying. It could also be used to maximize the use of existing furniture and generate interior design proposals for learning environments based on individual specifications and purposes.

Content

This report provides a detailed account of the learning environment evaluation project "Learning from Learning Environments" developed, conducted, and compiled in 2022 by Lekolar, in collaboration with Atea.

The report is made up of seven chapters. In the first chapter, we explain why we believe there is an urgent need for a service that can systematically evaluate learning environments. The second chapter outlines the selected methods we used to evaluate the project's specific case study. The third chapter describes the case study in detail, while the fourth chapter explains how we collected data using the selected methods. In chapter five, we present the results of the collected data, along with our analysis and conclusion. Chapter six evaluates the effectiveness of the selected methods and provides suggestions for their improvement for future learning environment evaluation projects. Finally, in chapter seven, we describe our plans for further developing this service to systematically evaluate the learning environments designed by Lekolar, and how the service can be used in the future.

CHAPTER 1

Background

A service for analyzing and evaluating learning environments

Learning Environments

The physical school environment is sparsely regulated in the School Act, curriculum, and other regulations. In short, it is stated that the premises should be suitable for their purpose. Loosely interpreted, one could also derive that the learning environment should contribute to students feeling safe, having a conducive study environment, and access to digital tools.

> *School Act; Chapter 2: Premises, Equipment, and Access to School Libraries; Section 35: The education must have the premises and equipment necessary to fulfil the purpose of the education.*

> *School Act; Chapter 5: Safety and Conducive Study Environment; Work Environment; Section 3: All students shall be ensured a school environment characterized by safety and teaching characterized by a conducive study environment. A conducive study environment means that there are good conditions for students to concentrate on their studies.*

> *Curriculum (Lgr22) 2.8: Principal's Responsibility; - the school's work environment is designed so that all students, to be able to seek and develop knowledge themselves, are provided with active teacher support and have access to and conditions for using high-quality teaching materials and other educational tools for modern education, including school libraries and digital tools, - all students are ensured a school environment characterized by safety and a conducive study environment.*

The limited guidelines and requirements for the learning environment provide teachers and school leaders with very little guidance on how to design a learning environment and how to follow up on and ensure its quality.

The School of the Future

During the 2020s, many school buildings will be renovated or newly constructed, but there is a lack of research on how the physical learning environment is experienced by teachers and students [1]. Schools are a significant investment for society and need to function for decades to come. To meet the future educational needs, many are shifting their pedagogical vision towards more innovative methods that promote collaboration and interdisciplinary work to foster the development of "21st-century skills" [2].

During the planning, construction, and initial phases of a school, various expert competencies are often involved, including architects, interior designers, educational advisors, representatives from school management and municipalities, among others. Few of these specialized competencies are available once the school is completed, and even fewer after a period of use.

It is all too common to expect that the pedagogical work will automatically change because of the new spatial design. However, both research and design practices show that a new interior does not necessarily automatically change the pedagogical work. As a result, many schools end up with a physical learning environment that does not align with the way teaching and learning occur [3]. In the study "Teacher Transition into Innovative Learning Environments," Imms and Kvan [4] emphasize the importance of connecting the intended use of the space to the teacher's pedagogy, as illustrated on the next page.

Other influential voices [5, 6, 7] also emphasize the importance of providing support to teachers in aligning their learning environment with their pedagogical approach and giving them time to test and reflect on their new learning environment. For example, Böjer [5] suggests that teachers be allocated time to practically test the intentions of the spaces.

1. Frelin, A., & Grannäs, J. (2022). Nya Lärmiljöer : Från vision till pedagogik i två innovativa skolor.
2. Ananiadoui, K., & Claro. M. (2009) 21st Century Skills and Competences for New Millennium Learners in OECD Countries. Working Paper. OECD, Paris.
3. Bøjer, B. (2019). Unlocking Learning Spaces: An examination of the interplay between the design of learning spaces and pedagogical practices.
4. Imms. W., & Kvan. T. (2022) Teacher Transition into Innovative Learning Environments. Singapore: Springer Nature.
5. Nair. P (2014). Blueprint for tomorrow: Redesigning schools for student-centered learning. Cambridge, MA: Harvard Education Press.
6. Lippman, P. C. (2010). Evidence-Based Design of Elementary and Secondary Schools: A Responsive Approach to Creating Learning Environments. Germany: Wiley.
7. Educational Research and Innovation Teachers as Designers of Learning Environments: The Importance of Innovative Pedagogies. (2018). France: OECD Publishing.

According to research by Barret, Zhang, Davies, and Barrett [8], physical factors also have a significant impact on students' learning abilities. In their study, 16% of the variation in improved academic performance was attributed to the learning environment. These findings support the importance of the physical learning environment as a holistic experience with multiple interacting parameters. According to their study, which examined Stimulation, Individuality, and Nature Qualities, almost half (49%) of the 16% of the effect comes from the Nature Qualities category, which includes lighting (21%), air quality (16%), and temperature (12%). Flexibility and ownership contribute to 28% of the effect, while stimulation (complexity and colours) accounts for 23%.

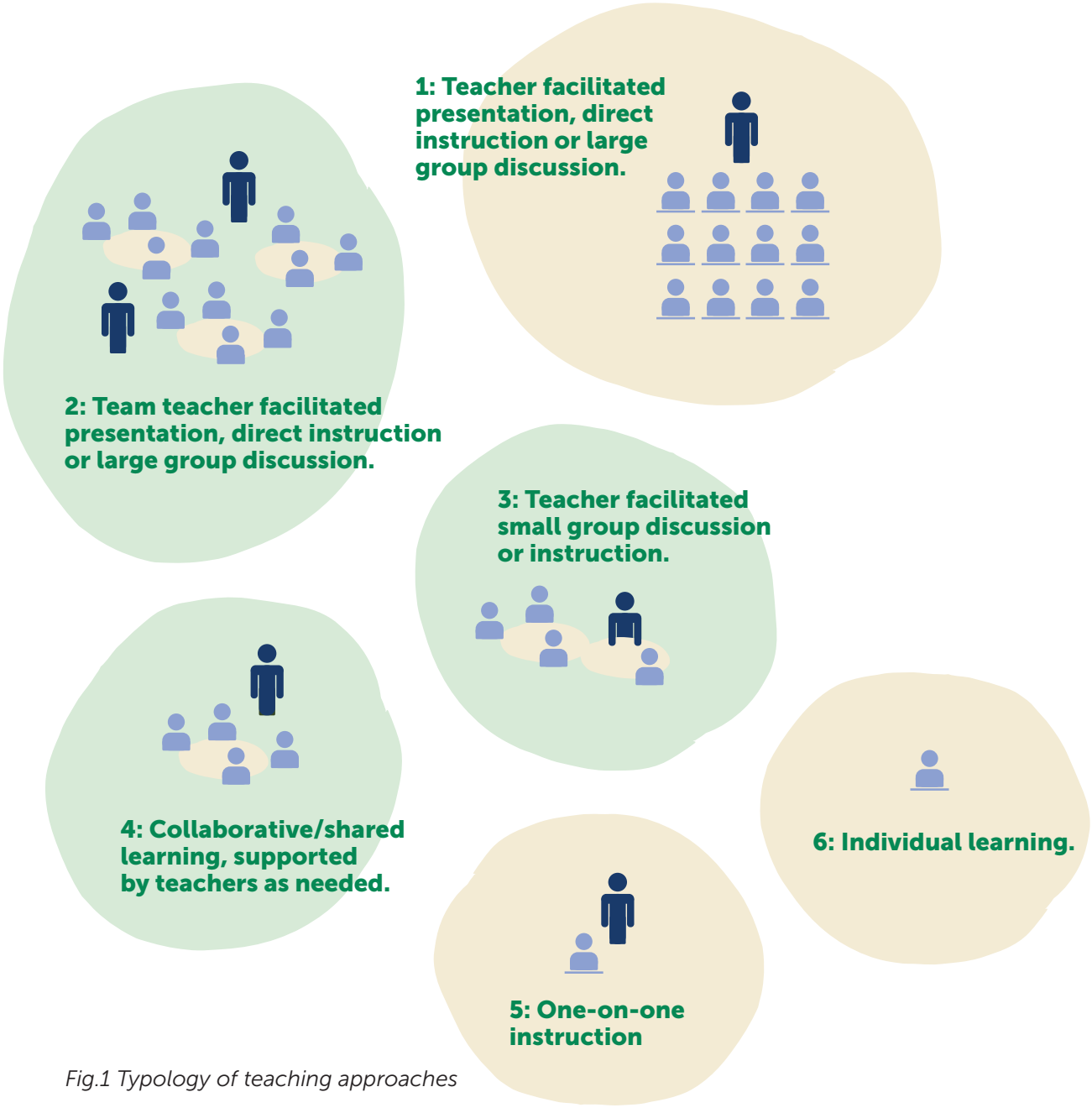


Fig.1 Typology of teaching approaches

8. Barrett, P., Zhang, Y., Davies, F., & Barrett, L. (2015). Clever classrooms : Summary report of the HEAD project

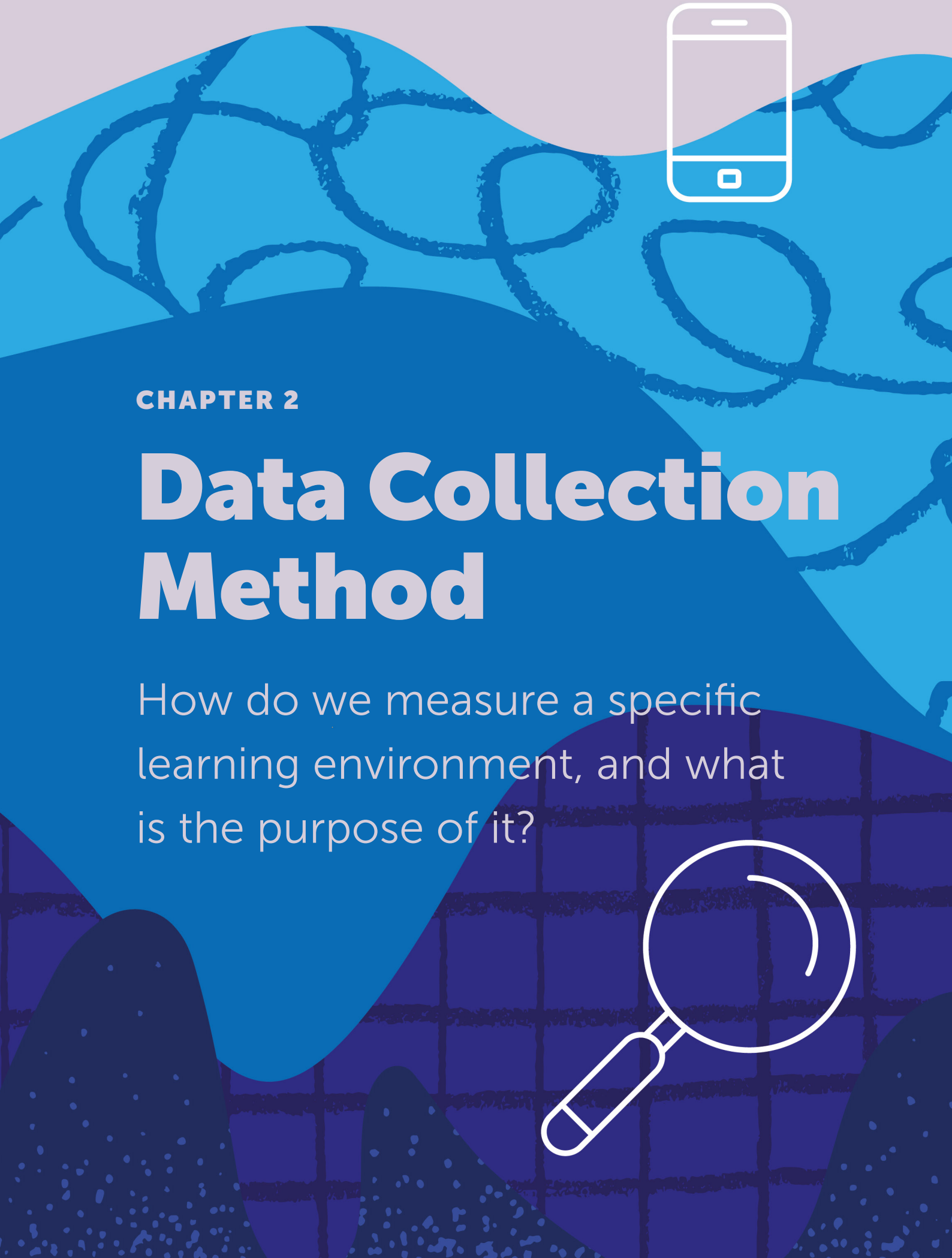
Learning from Learning Environments

How do we ensure a better connection between the physical learning environment and the pedagogical practices in the room? Two of the competencies we have in our companies are 1) Lekolar's spatial and pedagogical expertise, and 2) Atea's knowledge in data collection and AI. We want to explore if, through data collection of movement patterns and physical parameters, surveys, observations, and spatial understanding, we can create an evidence-based service to support teachers in matching the learning environment with the pedagogy, as well as increase well-being, safety, variation, and individualization of the learning environment. We call this project "Learning from Learning Environments."

The first part of the project focuses on finding a method to measure a specific learning environment, in this study, a subject-based classroom. The long-term goal is to develop an advanced and self-learning method that can evaluate and adapt the entire school environment. This way, we will be able to increase the utilization of facilities, maximize the use of furnishings, and generate rearrangement proposals based on individual specifications and different purposes. It will also enable us to manage student flows in a way that maximizes adult presence, minimizes the risk of bullying, and allows for avoiding large gatherings during virus seasons. In the first step, we are exploring the possibilities and benefits of a service that the customer can use to:

- Measure how an existing learning environment performs based on defined specifications.
- Receive suggestions for changes to the learning environment based on the evaluation of the data collection results.
- Verify the impact of changes to the learning environment through new data collection results.

We are investigating this through the case study "Toftanässkolan" (presented in Chapter 3) where we are testing, in a live setting, whether the proposed data collection method provides sufficient useful information to create this service. The measured values we are looking at include physical parameters such as air quality, temperature, sound, light, and movement patterns, as well as perceived parameters such as well-being, safety, variation, and individualization, from both the students' and teachers' perspectives.



CHAPTER 2

Data Collection Method

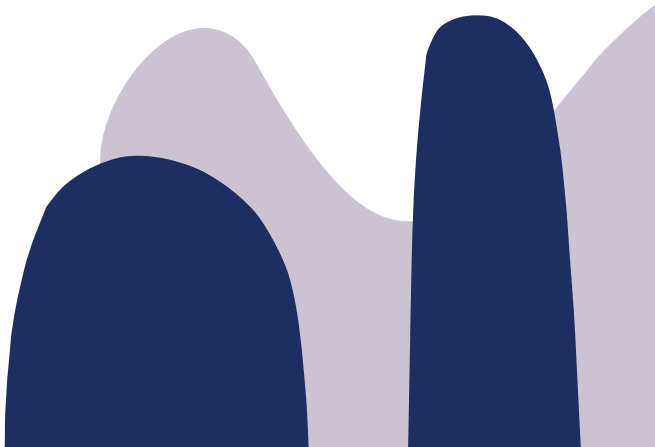
How do we measure a specific learning environment, and what is the purpose of it?

Two primary goals

The purpose of measuring a specific learning environment is to evaluate and ensure that the designed learning environment is practical, functions as planned, and that both students and teachers thrive optimally in it. We do this by focusing on two primary goals:

1. MATCH LEARNING ENVIRONMENT AND PEDAGOGY. The first part is unique to each learning environment project and design development. Problem areas and the design intention of the learning environment are discussed, identified, and agreed upon between the school and Lekolar. It is important that the purpose of designing the learning environment is clear and that different options and solutions have been proposed and evaluated, and that the final design solution of the learning environment matches the type of pedagogy the learning environment is intended for.

2. INCREASE WELL-BEING, SAFETY, VARIATION, AND INDIVIDUALIZATION. These four basic variables are systematically used to measure how both students and teachers thrive in a learning environment. It is important to establish a baseline for each of the variables before the new learning environment is used and evaluated. Ideally, the baseline should be based on how the original learning environment, prior to the new design, was experienced by both students and teachers. In cases where this is not possible, such as for a new school or specific learning environment, one or more measurement methods can be designed to include questions that establish a baseline. For example, by asking students and teachers how the designed learning environment compares to other types of learning environments they have used or are currently using.

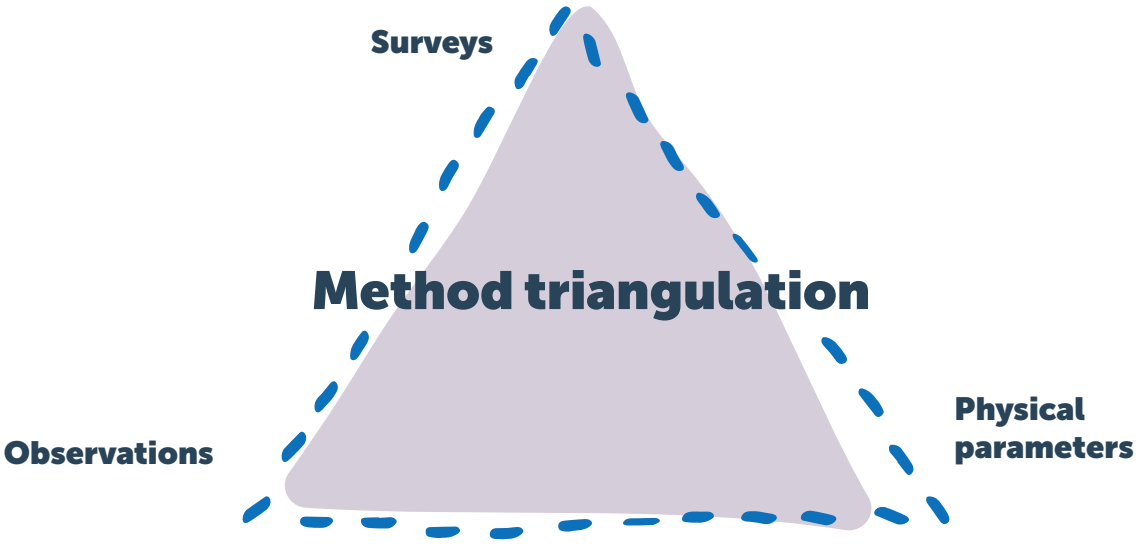


Method triangulation

Method triangulation is often used in social science research because it involves using multiple sources or methods to collect and analyse data. This helps ensure that the results are accurate, reliable, and valid. Although the name suggests it, method triangulation does not specifically have to involve three methods. It can be two or five methods as long as it involves more than one method, and the methods are used to validate each other.

Method triangulation involves compensating for potential weaknesses in one method by using additional methods. Individual measurement methods often have limitations that may prevent the collected data from providing a holistic picture of the project/problem/question and instead risk missing significant information. For example, a combination of qualitative and quantitative methods can be used, or a combination of objective physical methods and subjective person-focused methods. With a qualitative method, qualitative data are collected, which describes a complex problem or phenomenon through a subjective lens, usually in written form. Common qualitative methods include interviews, focus groups, and observations. A quantitative method collects quantitative data, which is data collected in a systematic and mathematically objective way, either in numerical form or in a way that can easily be converted into numerical form. Common quantitative methods include surveys and experiments. Quantitative data are analysed using statistical mathematical calculations.

By using multiple methods in the same research project, the validity of the results can be strengthened, and triangulation can also be used to assess the validity of each individual measurement method.



In this project, we use and evaluate a method triangulation consisting of three different measurement methods:

1. STUDENT AND TEACHER SURVEYS. Subjective information from everyone using the learning environment, both students and teachers. Questions can be asked that provide answers related to both our focus areas: matching the learning environment with pedagogy and our four basic variables. Surveys can also include questions related to potentially confounding variables to ensure these do not affect the students' and teachers' experience of the learning environment.

2. CLASSROOM OBSERVATIONS. Subjective information collected by a passive observer when the learning environment is being used by students and teachers. This method complements the survey method as the observer can systematically and objectively evaluate whether the designed learning environment functions as planned in relation to pedagogy. It also provides an additional perspective on how both students and teachers use and seem to thrive in the learning environment.

3. PHYSICAL PARAMETERS. Objective physical parameters complement subjective measurement methods well by providing information from different physical measurement methods instead of relying on individuals' feedback and subjective experiences either from users of the learning environment (students and teachers) or observers. Physical parameters can also be used as control variables to ensure that confounding variables do not affect the students' and teachers' experience of the learning environment.

Using a triangulation of methods that includes surveys, observations, and objective physical parameters can provide a more comprehensive understanding of learning environments for several reasons:

A) COMPLEMENTARY DATA: Each method provides unique and complementary data that can enhance the understanding of the research question. For example, surveys can provide insights into students' attitudes and perceptions, while observations can provide information about behaviour and interactions, and physical data methods can provide objective information about the environment.

B) INCREASED RELIABILITY: Using multiple methods can increase the reliability of the results. If the same patterns emerge from different methods, it provides greater confidence in the validity of the results.

C) OVERCOMING BIAS: Different methods can help overcome potential biases in the data collection. For example, subjective methods such as surveys and interviews can be influenced by social desirability bias whereby participants may provide answers they believe are socially acceptable. Collection of objective physical data can provide a more accurate and unbiased measurement of the environment.

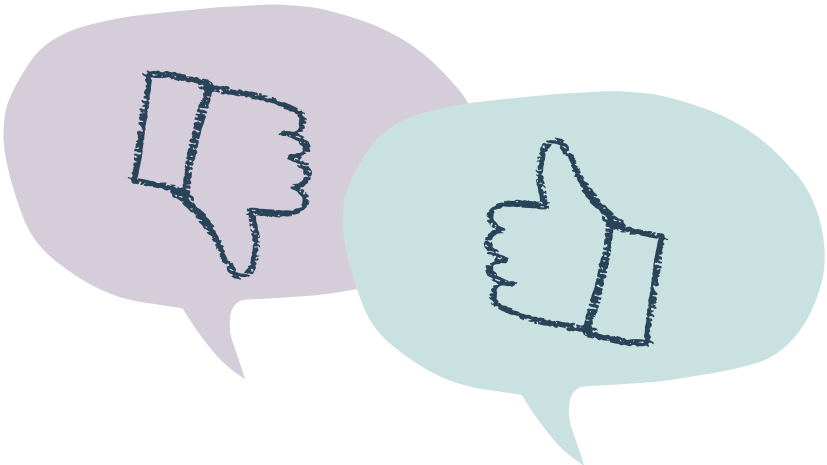
In conclusion, using method triangulation that includes surveys, observations, and physical parameters can provide a more comprehensive and accurate understanding of learning environments. By using multiple methods, researchers can overcome potential biases, increase the reliability of the results, and triangulate the findings to achieve a more comprehensive understanding of the research question(s).

Student and teacher survey

A survey, or questionnaire, is a time- and cost-effective way to gather both quantitative and qualitative data from a larger sample. Surveys are mostly used as a quantitative method and are usually distributed digitally, but they can also be distributed in physical paper form.

It is important that the survey is developed and designed correctly, which requires both experience and knowledge. The collected data is only useful if it results in accurate and consistent information about a specific problem or subject area. Validated survey questions and a logical survey structure are therefore important during the survey design process. Validated survey questions are questions that have been extensively used and validated, so they have been developed and tested to collect accurate and relevant information in the best possible way.

The next step is to choose the type and number of questions to be included in the survey. A survey should always include only questions that are necessary to answer the project's purpose and/or hypotheses. Each question should be clear, easy to understand, neutral, and unbiased. The language level should be adapted to those at the lowest educational level in the target group. It is recommended to avoid open-ended questions that are phrased in a negative way or imply causality. Survey questions are either open-ended (free-text responses) or have a limited number of specific options to choose from. Open-ended questions result in qualitative data and are more flexible but require more time to analyse. Questions with several specific response options result in quantitative data but require more time to compile to ensure that all reasonable and potential choices are included.



Class observations

Observation is a technique that involves systematic selection, viewing, listening, reading, touching, and noting of the behaviour and conduct of individuals, or things and phenomena. Researchers using this method strive to understand behaviour by getting to know individuals in their natural environment to better understand their behaviour, values, emotions, and conduct. The technique is considered a scientific data collection method as it is specially designed to address specific research questions and is systematically planned and executed.

The observation method has many advantages. The biggest advantage is that it is direct; we can collect data as it occurs. The observer does not need to ask individuals about their behaviour and rely on individuals' memory and retrospective reports. The observer can simply observe individuals while they speak and act.

The observation method is superior to both survey and experimental methods when it comes to collecting data based on non-verbal behaviour. Sometimes the observation method is specifically used for individuals who have less capacity to provide meaningful verbal information. For these individuals, the observation method is ideal, for example for children, older adults, or individuals with cognitive disabilities.

However, the observation method also has some disadvantages. Despite the advantages of the natural environment, the observation method has very little control over unknown variables that may affect data collection. The researcher's presence (as an observer) and natural and inevitable biases from the observer often create an imbalance and bias in the data collection.

Finally, with the observation method, it is not possible to learn about what has already happened. It is also difficult to observe data about intentions, opinions, attitudes, and preferences.

Physical parameters

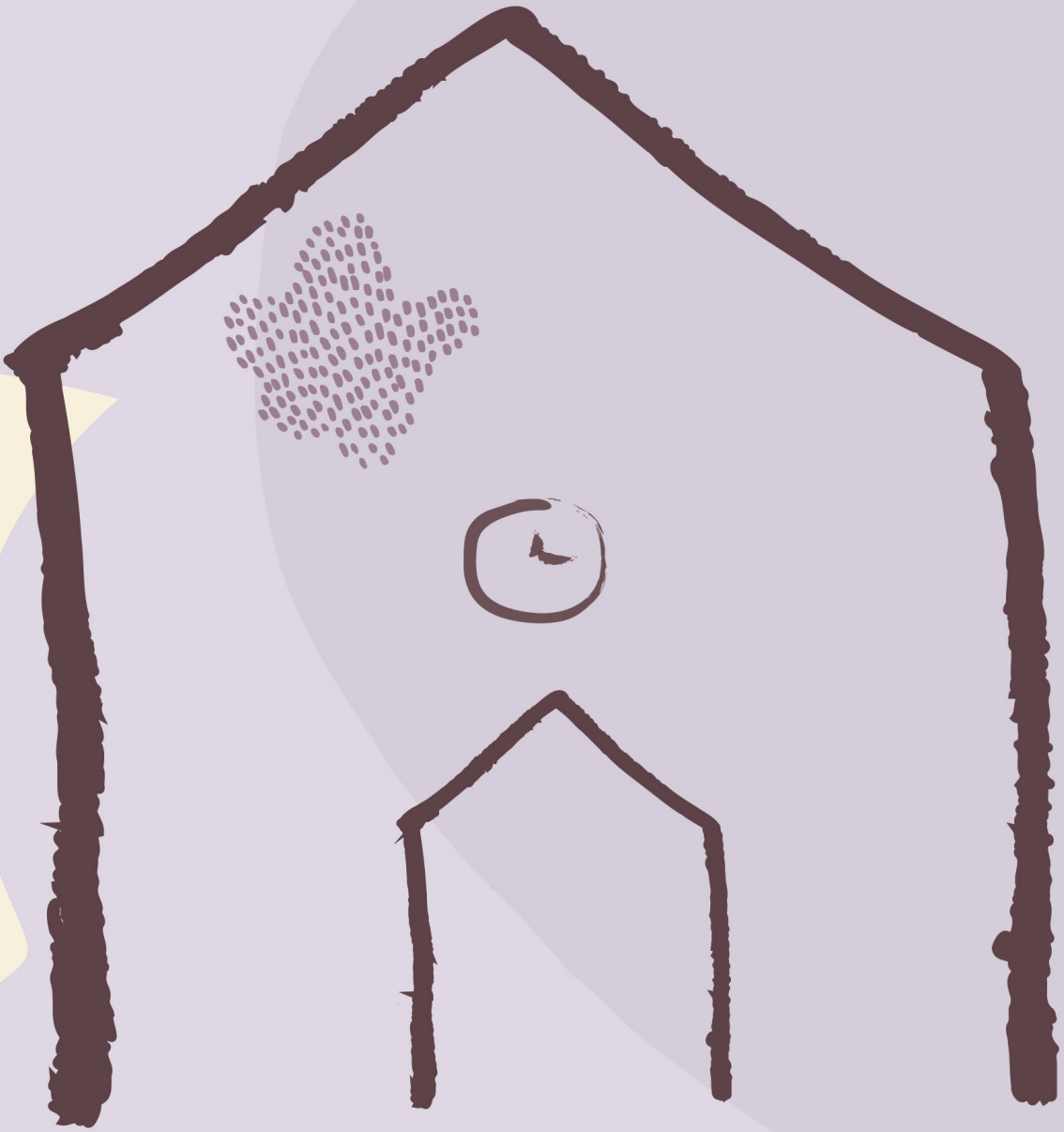
Collecting data using physical parameters can be beneficial for multiple reasons. When researchers use objective physical data collection methods, such as video recording or sensors, to gather data about the learning environment, the data is less likely to be influenced by subjective biases that can arise from observations or self-reports.

Physical parameters can also provide more precise and detailed information about the learning environment, such as temperature, lighting, and noise levels, which may not be captured as accurately through subjective methods. This information can help researchers identify specific aspects of the environment that may impact pedagogy and the well-being of students and teachers in the learning environment.

By using physical parameters, researchers can establish a standardized data collection protocol that can be replicated in future studies. This increases the reliability and validity of the results and allows for comparisons across different studies.

Physical parameters can be used in experimental designs to identify causal relationships between learning environments and pedagogy. By controlling for other variables and manipulating the environment, researchers can determine whether changes in the environment lead to changes in pedagogy.

In summary, the use of objective physical parameters in social science research can improve the quality of data collection, increase the reliability and validity of the results, and enable the identification of causal relationships.



CHAPTER 3

Case Study

How do we create a dynamic subject-based classroom, ideal for varying activities?

Purpose of the case study

The purpose of the case study was to:

1. Design a subject-based classroom that catered to the specific needs of the teacher, students, and the subject matter.

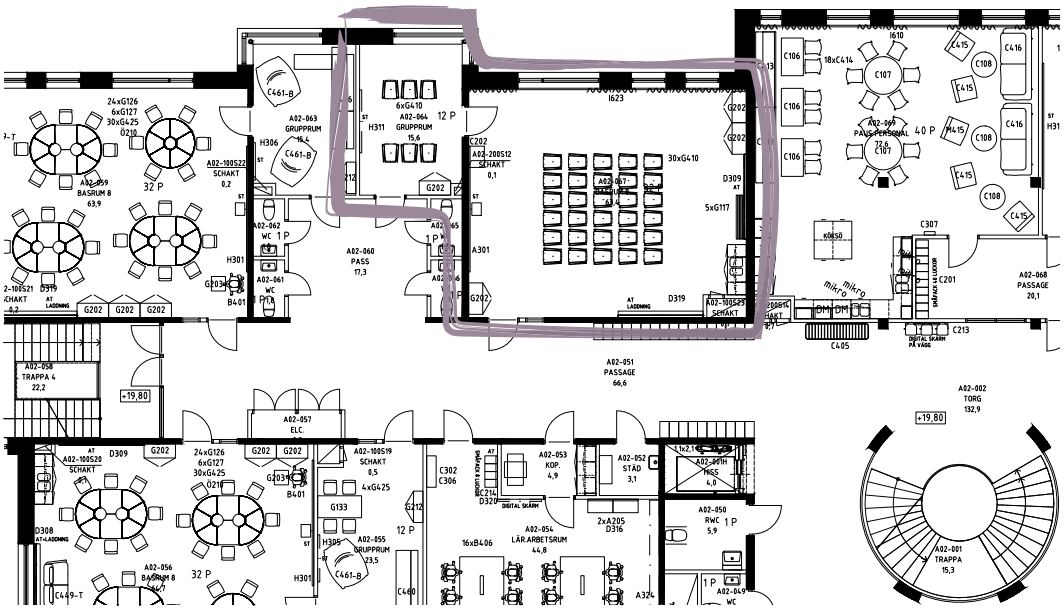
2. Allow the students and teacher to use the classroom during a limited period, divided into two measurement phases.

3. Utilize method triangulation, as described in Chapter 2, to measure, analyse, and scientifically and methodologically demonstrate that the interior design of the subject space met its specific needs and contributed to increased well-being, safety, variation, and individualization.

LOCATION OF THE CASE STUDY - TOFTANÄSSKOLAN

The case study took place at Toftanässkolan, which offered a suitable location and provided contact with a teacher, Joakim Bengtsson, who was willing to participate in the study. Toftanässkolan is a municipal primary school that started its operations in the autumn term of 2019. Over time, it will accommodate approximately 700 students in grades 1-9. The school is situated in the east part of the city Malmö in southern Sweden, adjacent to the green areas of Gyllins garden and Husie mosse. Toftanässkolan has a partnership with MFF (Malmö Fotbollsförening) where they jointly oversee a football academy for grades 7-9. The school is led by Principal Claes Jeppssen.

Joakim Bergström
Social studies teacher, Toftanässkolan



Limitations of the case study

PHYSICAL SETTING. This case study was conducted in a typical subject-based classroom for secondary school, consisting of a main room measuring 63.4 m2 (1) and a smaller group room measuring 15.6 m2 (2). The rooms are located on the second floor of the school, with ample natural light and views from five windows. The main room is equipped with a small kitchenette on the back wall to the right and an interactive whiteboard that occupies most of the left wall. Apart from that, both the main room and the group room were empty of furniture at the start of the case study.

BASIC INFORMATION. The study involved 4 classes in 7th grade, with an average of 28 students per class. All classes had the subject of social studies in the subject space, taught by the same teacher and following the same curriculum. Each class had 2-4 students with neurodiverse conditions, such as autism or ADHD. The students had their own laptops as their primary tool for work, while all written communication between the teacher and students was conducted through a learning platform.

Background and process

PROBLEM DESCRIPTION. Toftanässkolan is a newly built school with new furniture in all its premises. In the younger grades, the classrooms are individually furnished, but when it comes to the secondary school level, all subject rooms have a generic setup consisting of a single desk and chair per student, regardless of the subject being taught in the room. This setup works for some subjects but creates difficulties for others as it does not support the specific requirements of the subject being taught in the room.

The issue with a generic classroom setup is something that Joakim Bengtsson, a social studies teacher at Toftanässkolan, has struggled with since the school opened. Since social studies is primarily taught through group work and discussions, it has been challenging to provide students with a calm environment suitable for these activities.

The goal of our case study was, therefore, to optimize the interior design and furniture in the room to align with the specific way social studies is taught and to enhance the students' and teacher's sense of well-being, safety, variation, and individualization.

Basic information:
Social science year 7. 1 teacher, 4 Classes (28 students per class) 112 students in total. 8-16 students with neurodivergences. Equipment: laptops.

PROCESS AND SPATIAL ANALYSIS

Joakim was highly motivated to participate in our case study and collaborated with us to create a new spatial solution in line with his teaching and the specific activities of the students. We started by closely examining the challenges that Joakim and his students faced daily in the room. We identified the following issues:

1. **Most students leave the classroom during group work; only one or two groups remain. This makes it difficult for Joakim to assist the students whilst also making it challenging for the students to find Joakim when needed, as he needs to move around among the groups scattered throughout the school.**

2. **Noisy and disruptive movements with the furniture when students gather or switch activities; the tables make noise, and both tables and chairs are in the way.**

3. **Joakim enjoys moving around and helping but finds it difficult to navigate the room and reach the students.**

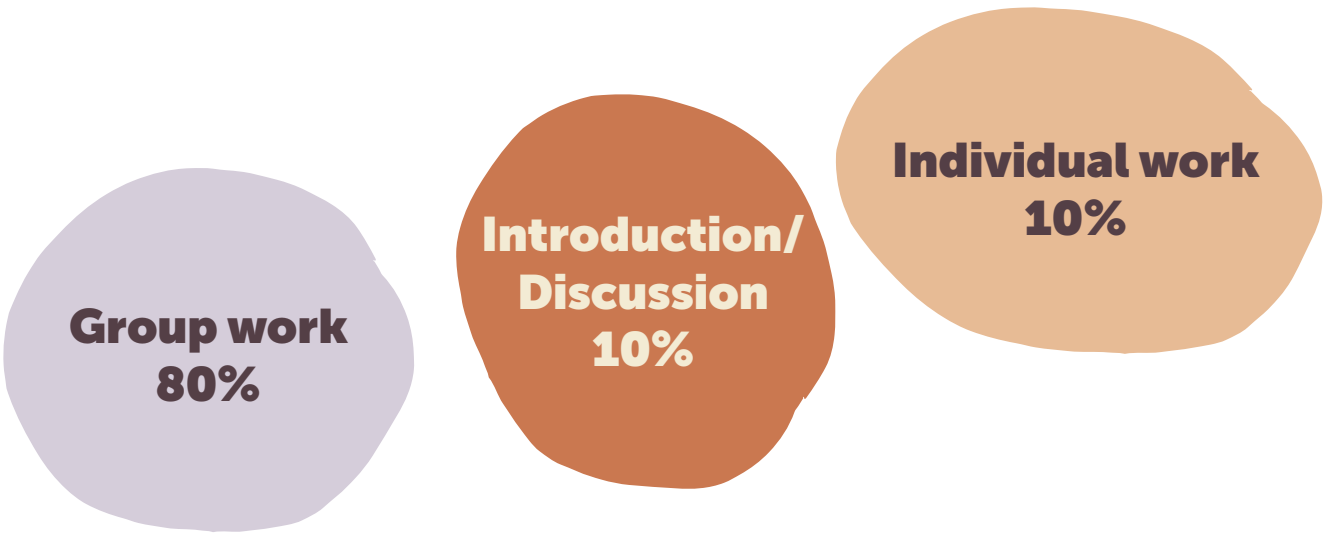
4. **The furniture arrangement makes it challenging to have discussions in the classroom as many students sit with their backs to their classmates.**

5. **Joakim feels confined to the front of the room near the whiteboard, which he rarely uses.**

Needs analysis

We initiated the needs analysis by defining and mapping out the activities that took place in the room. Since the subject of social studies (according to the curriculum) aims to stimulate and engage students in open exchanges of ideas on global topics, the design of the room should also encourage and engage in such activities. Joakim estimated that his lessons primarily consisted of an introduction where he covered a topic and assigned a task that the students then explored and discussed in groups. The groups' results were then presented and discussed in a forum within the classroom. Occasionally, the tasks were also solved individually by the students. Therefore, the activities we focused on were **Introduction/ Discussion, Group work, and Individual work,** with a clear emphasis on Group work, which Joakim estimated accounted for at least 80% of the time in the classroom. We took this activity estimation into account in the further analysis.

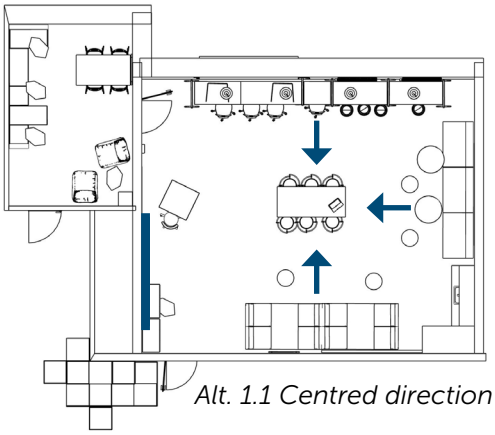
> *The teaching of social studies aims to develop students' familiarity with democracy and human rights. The instruction should provide students with the conditions to analyse social issues from different perspectives and develop an understanding of how various interests and opinions emerge and are expressed. Through the instruction, students should also be given the opportunity to express and test their own positions in encounters with different viewpoints. Thus, students should be stimulated to engage and participate in an open exchange of ideas on social issues.*
>
> *Curriculum (Lgr22), Swedish National Agency for Education 2022*



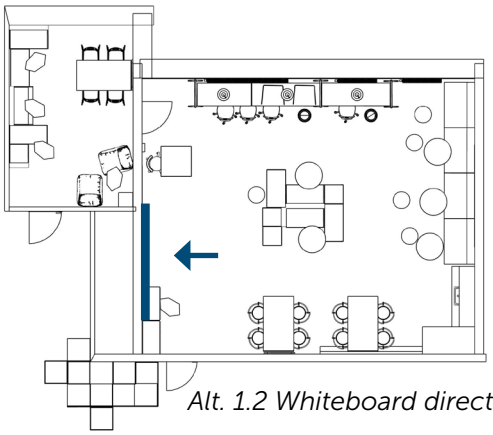
DIRECTION IN THE ROOM – SUPPORTING THE TEACHER'S MOVEMENTS

As one of the challenges Joakim had in the classroom was feeling confined, partly due to the furniture and partly due to the placement of the large whiteboard, we started the process by exploring alternatives for spatial arrangement. The goal was to free up the room and make it easier for Joakim to move around more freely. Joakim did not want a desk or to be positioned in front of the whiteboard. He felt that having a space to put his laptop on, which could be connected to the screen, would be sufficient. Based on Joakim's needs, we chose to primarily focus on two spatial alternatives.

OPTION 1: CENTRED ROOM. The furnitures were placed around the walls with a clear view towards the centre of the room. Here, a table or sofa was placed that could be used by both students and the teacher. The idea was for it to serve as a multifunctional piece of furniture where Joakim could sit or stand, and where students could approach and receive help, as well as an additional group work area. This shifted the focus in the room from the front wall to the centre, which became the gathering point. At the same time, there was still a clear view of the whiteboard when needed. Joakim was provided with a small, height-adjustable table on wheels for his laptop that he could move around to the desired location, as well as a teacher's chair on wheels that he could roll around the room on.

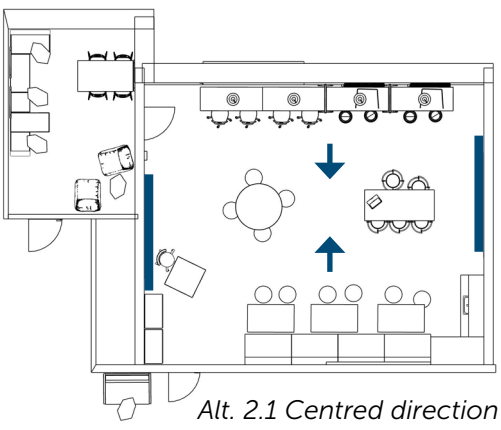


Alt. 1.1 Centred direction

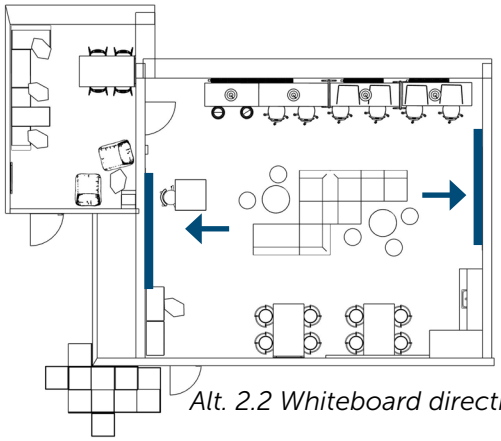


Alt. 1.2 Whiteboard direction

OPTION 2: NON-DIRECTIONAL ROOM. The students' furnitures were placed along two walls and freestanding in the middle of the room. Another whiteboard was placed on the wall opposite the existing whiteboard. This neutralized the wall that already determined the room's direction and gave Joakim more opportunities to position himself anywhere and utilize the whole room. Joakim could stand by either wall with a whiteboard or in the middle of the room, depending on the need. All students had a clear view of both whiteboards and the teacher. In this proposal, Joakim also had a small table and a chair on wheels that he could easily move around the room according to needs, activities, and desired direction.



Alt. 2.1 Centred direction



Alt. 2.2 Whiteboard direction

ACTIVITY-BASED FURNISHING – SUPPORTING SUBJECT AND PEDAGOGY

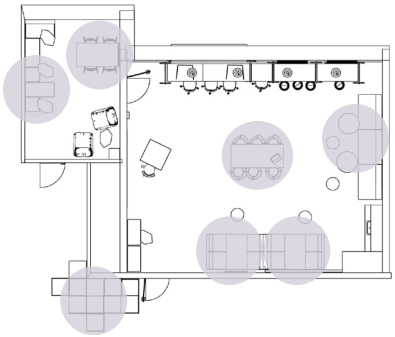
The next step in the analysis was to examine the activities taking place in the room. As mentioned earlier, there were primarily three forms of activities in the room, with group work being the dominant activity. Based on these activities, we designed four different design layout options that facilitated and strengthened these activities.

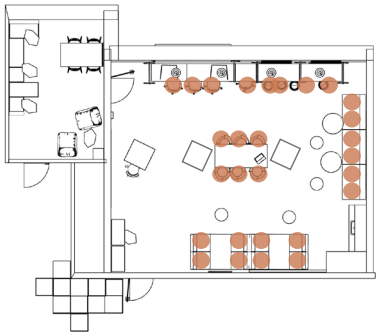
GROUP WORK. One challenge the teacher faced was that most students left the room during group work. Therefore, our goal was to create more spaces inside the room that invited group activities and thus encouraged the students to stay. We experimented with different arrangements and furnitures that allowed the groups to work closely and focused, with reasonable space from each other.

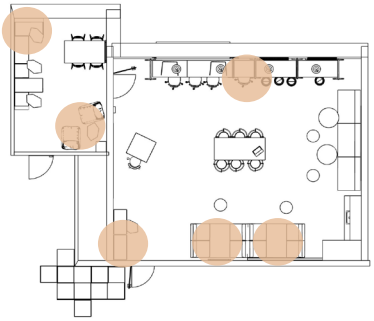
INTRODUCTION/DISCUSSION. To create an inclusive environment where everyone could easily participate in a discussion, our goal was to position the students so that the majority could see each other without having to change seating position too much. The placement of the furnitures played a role, but the type of furniture was also important to explore. For example, both freestanding chairs and ottomans can be easily turned around during activity changes.

INDIVIDUAL WORK. Although social studies as a subject does not focus much on individual work, it does occur occasionally. Therefore, the activity was considered in the proposed arrangements, with furnitures that could easily transition between group work and individual work. We also explored including places with extra concentration possibilities.

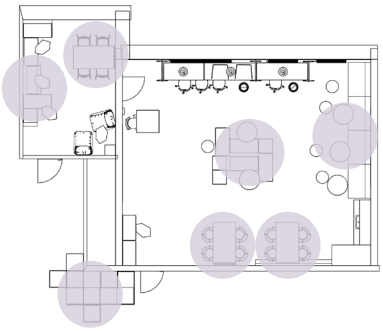
Option 1

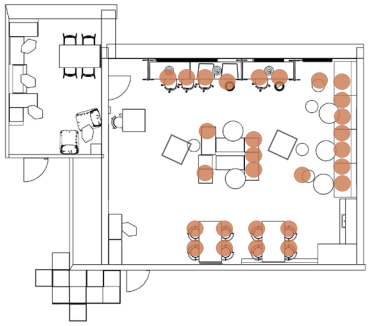


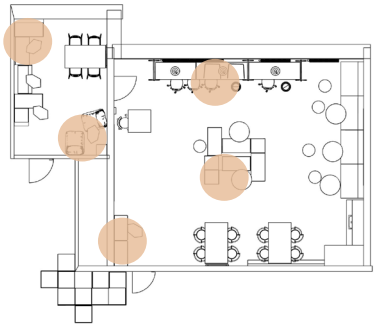




Option 2







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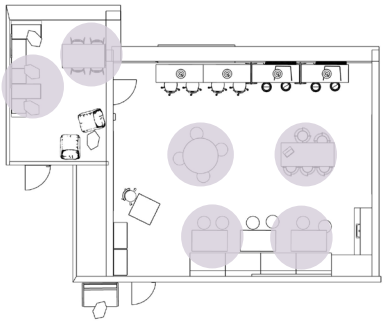
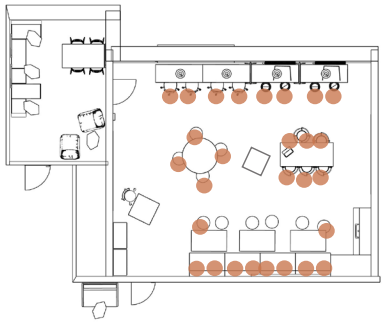
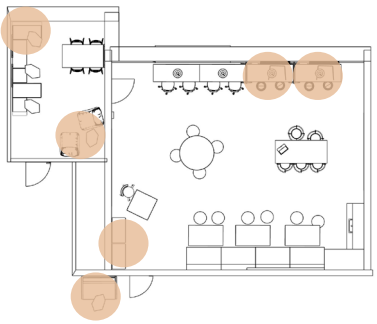
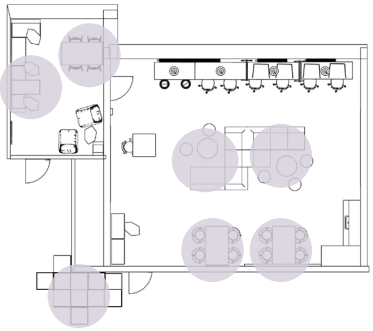
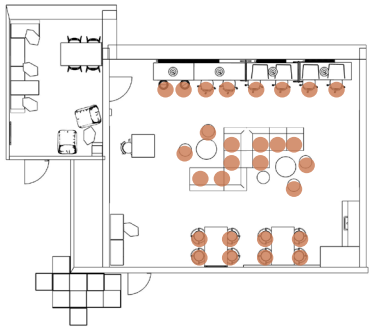


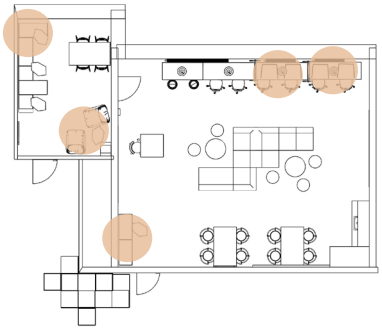




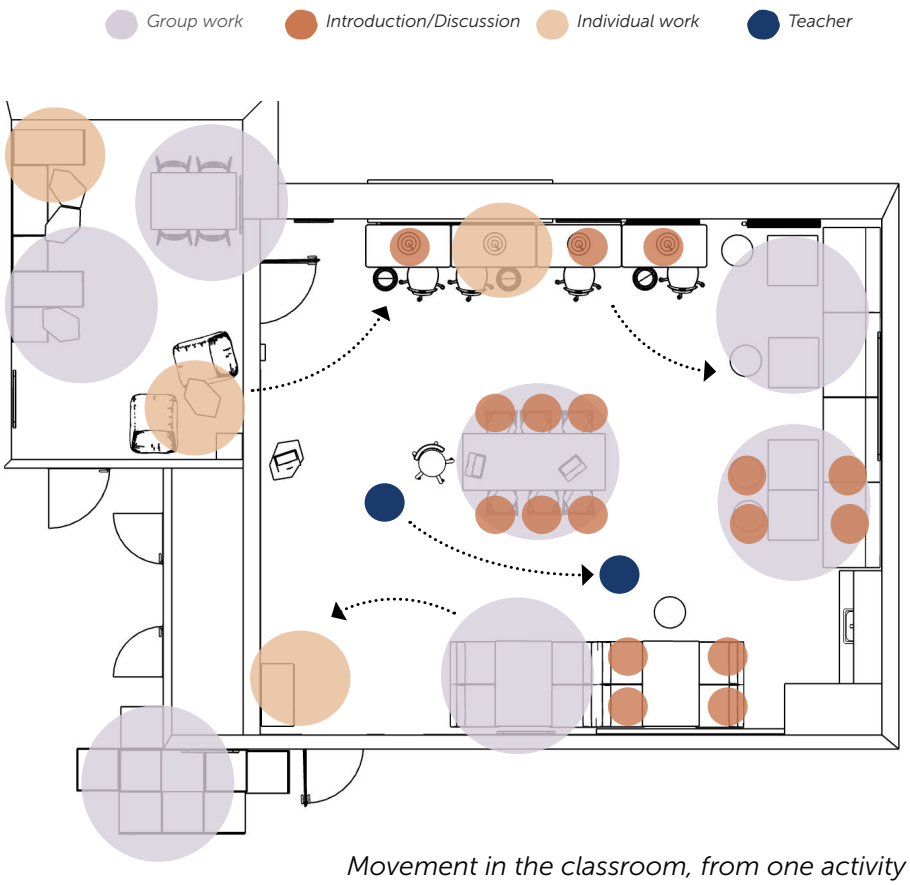
Option 4







Group work *Introduction/Discussion* *Individual work*



Movement in the classroom, from one activity to another.

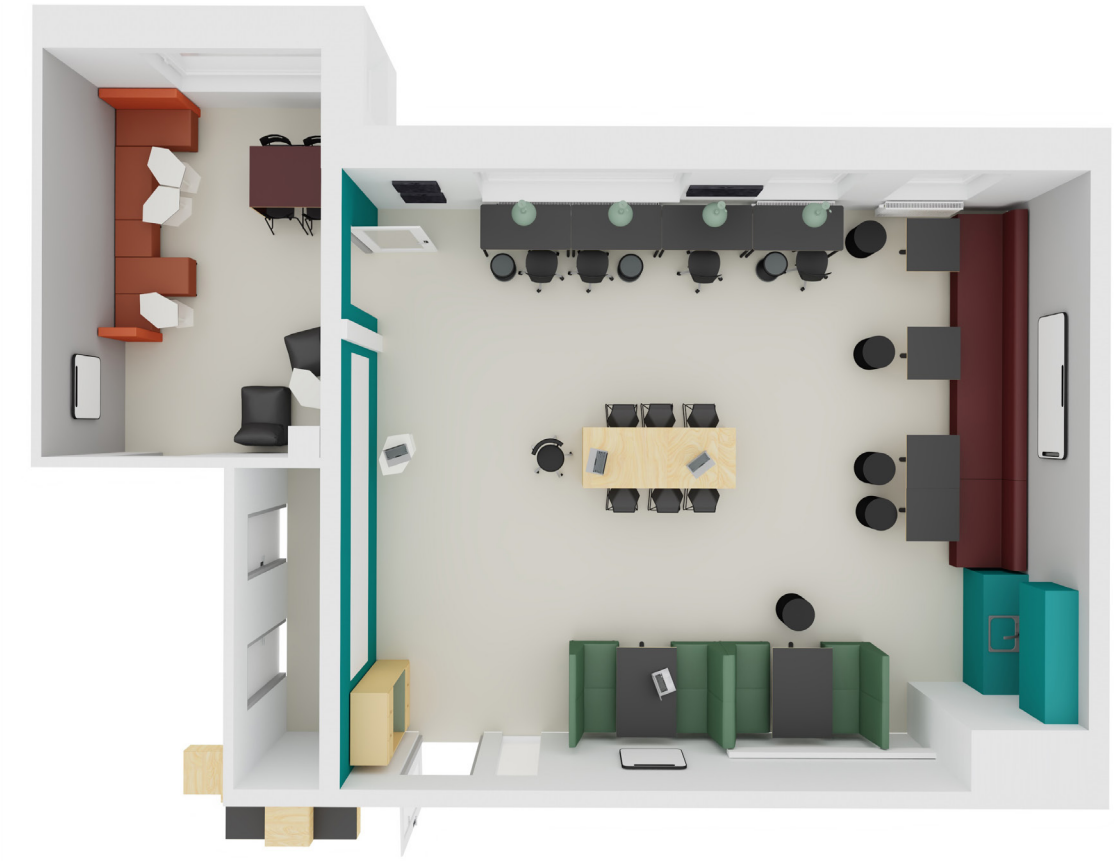
ACTIVITY TRANSITION

Another challenge Joakim faced was the disruptive noise and commotion that occurred when students transitioned from one activity to another. The arrangement of chairs and tables made it difficult to move around the room, and the scraping and clattering of furnitures added to distracting noise. Therefore, a key focus area became activity transitions in the classroom, aiming to free up space so that students could gather in groups as easily and quietly as possible and then return to their individual places for discussion or introduction. We also wanted to make it easier for Joakim to physically reach all students and assist them more quickly. The arrangement was important, but the type of furniture also played a significant role in this part of the analysis. To achieve better sound quality, we exclusively worked with furniture made of different fabrics, rubber pads, wheels, and materials that promoted acoustic enhancement.

VARIED SEATING OPTIONS – INDIVIDUALIZATION AND WELL-BEING

We all have a need for variation and the ability to choose what we prefer in different situations, both adults and children. Unfortunately, we tend to forget to provide children and youth with choices, which can hinder their identity development and create a sense of powerlessness and indifference towards the environments they are placed in.

Being able to choose where and how to sit is an important part of one's well-being and, above all, how secure one feels in a room or place. For example, some students may find it stressful to sit in a place where all other students can see them, while others may prefer it. Preferences and needs can also vary from day to day or week to week. Therefore, it was important to give students more options of different furniture, where in the room they wanted to sit, and how they wanted to sit. At the same time, we also had to consider a few students with concentration difficulties who required a seating area where they could screen off the room. Children and youth also grow at different speed, so it was important to find a solution that rejected the generic mindset and instead offered a variety of furniture and heights that suited the students' different physical development and body sizes.



SELECTED SPATIAL ARRANGEMENT

Based on the needs analysis and the four design proposals we developed, Joakim chose the proposal that he believed best suited his and the students' needs. The selected solution was Option 1: Centred Room.

DESCRIPTION. The selected classroom was designed with a spatial arrangement consisting of four groups of furnitures, three of which were placed along the walls, and one was freestanding in the room. The choice was thus made for the centred room as Joakim felt that the existing whiteboard was used so little that an additional one on the opposite wall was unnecessary.

The four furniture groups consisted of 1) green compartment sofas with accompanying tables, 2) red lounge sofas with tables and poufs, 3) height-adjustable tables with adjustable chairs on wheels, and 4) a large wooden counter table with accompanying bar stools.

The placement of the furnitures freed up the remaining space in the room, allowing the students to move easily between the furnitures and providing free passage in and out of the room, as well as to the smaller group room. This also facilitated Joakim's ability to physically reach individual students and groups without disturbing the other students in their workflow.

The wooden counter table in the centre, with a height of 85 cm, served as a multifunctional piece of furniture. Joakim used the table both as his teacher's desk for introductions and discussions, and as a table where students could come for help or discuss things in smaller groups. The table could also be used by a group during group work activities.

The green sofas were ideal for group work with four students. The sofas had high backs that created a "room" within the room where students could discuss with each other in peace. The high backrests and the placement of the sofas also prevented the risk of students sitting in the green sofas feeling exposed when other students walked behind their backs (towards the entrance or kitchenette).

The red sofas were suitable for discussions and were placed so that the students had a free view of the entire room. Using the poufs, students could easily sit facing each other in groups of four during group work activities and then easily move back to the sofas during presentations or discussions.

The tables and chairs by the window were intended to facilitate a more focused work style. Here, students could sit and look out through the windows if they felt that the room with all the other students was making it difficult for them to concentrate. Screens were hung on

the wall which the students could set up on the table to create a more secluded and sound-reduced space. The students could easily rotate on the chairs during presentations.

The furniture groups were given the working names: Green Sofas, Red Sofas, Window Tables, and Centre Wooden Table.

The small room next to the subject room was furnished with a sofa, a small counter table, and a couple of beanbag chairs. The room was used as a complement for group work and individual work. The sofa had small satellite tables for laptops and could be used by students who wanted to work more privately. The counter table worked well for a group of four students. Students who felt the need to withdraw a bit could also use the small room and the beanbag chairs as a more reflective and calmer oasis.

All the furniture had different identities, both in terms of design and materials such as colour, fabric, and seating options. The tables, chairs, and sofas also varied in height so that students could choose what suited their bodies best.

Hypotheses

The goal of the room design was thus to create a subject room that facilitated the teacher's teaching method, encouraged students to stay in the room, and contributed to increased well-being, security, variety, and individualization for both teachers and students. To evaluate whether the design of the subject-based classroom addressed these issues, we formulated five hypotheses against which our method triangulation was measured.

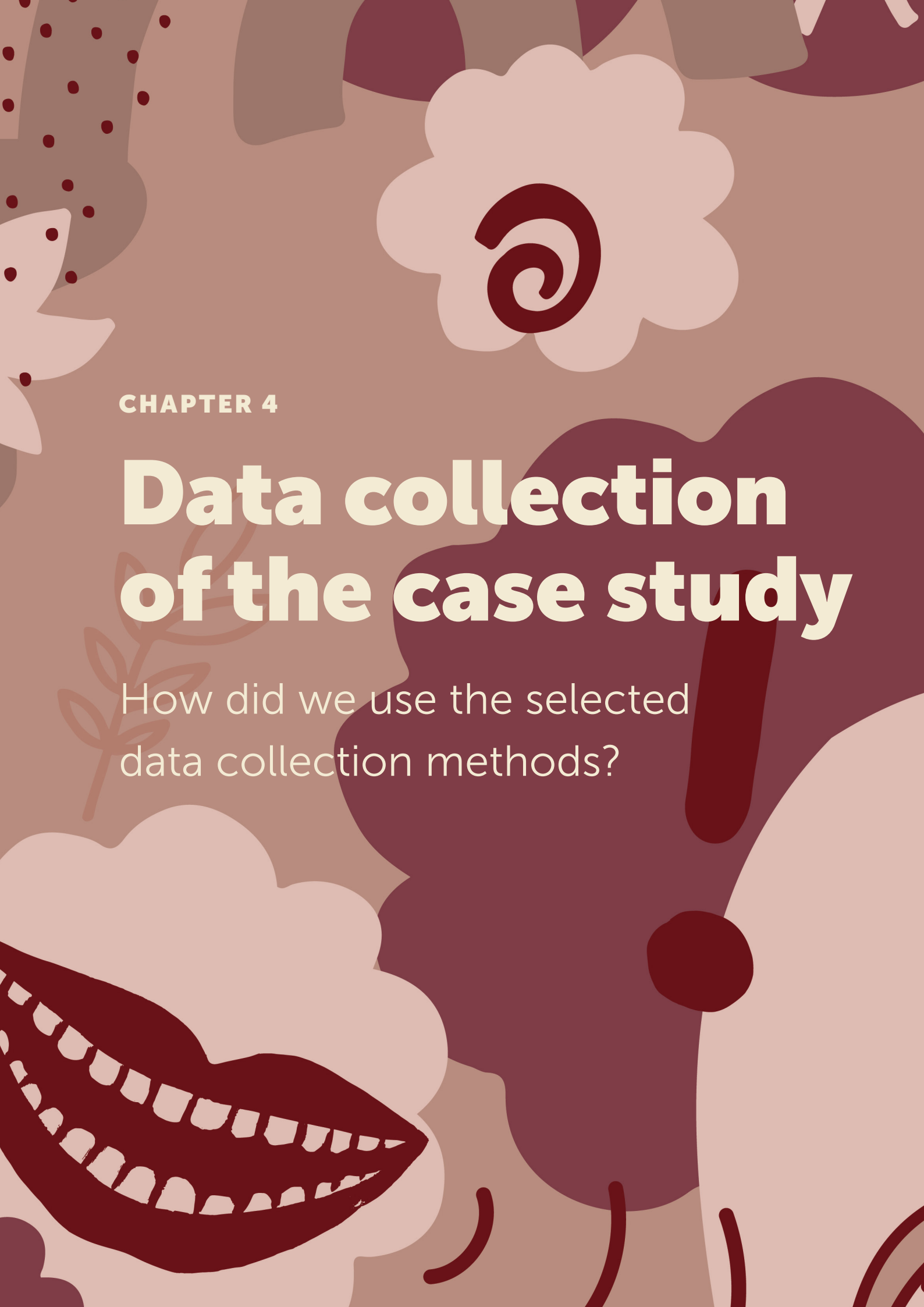
1. The subject-based classroom facilitates group work activity, resulting in at least five groups staying in the rooms (including the small group room).

2. The placement of furniture in the subject-based classroom facilitates movement for students and teachers, allowing them to transition between activities without causing disruptions and thus creating a better sound environment.

3. The subject-based classroom provides an interior design that supports and inspires students to participate in discussions and debates.

4. The subject-based classroom's interior design offers students more seating options and different furniture choices, thereby increasing the sense of autonomy and well-being.

5. The subject-based classroom, through an interior design that supports the subject matter and has a clear identity, creates a better sense of well-being for both teachers and students compared to a regular classroom with tables and chairs.



CHAPTER 4

Data collection of the case study

How did we use the selected data collection methods?

Student survey

The student survey was compiled using a combination of previously validated questions, a small number of open-ended questions, and a handful of questions specifically developed for this research project. Most questions used a Likert scale response format, which typically represents participants' attitudes towards a specific subject using a 5- or 7-point scale response option (for example: very positive, positive, neutral, negative, very negative). The survey was compiled using Qualtrics, one of the world's leading electronic survey and data management platforms. An anonymous survey link was sent to the teacher, Joakim, who forwarded it to the students and instructed them to complete the survey during class time.

The survey consisted of 28 questions:

SURVEY QUESTION

WELL-BEING

1. How do you generally feel in Joakim's classroom?
2. How do you generally feel in your other traditional classrooms with regular individual desks and chairs?
3. Compared to your other classrooms with regular individual desks and chairs, do you feel better or worse in Joakim's classroom?
4. Would you prefer to have more classrooms like Joakim's classroom at school?
5. Do you use Joakim's classroom even when you don't have a lesson?

VARIATION

1. Do you sit in the same place in the classroom every lesson?
2. How often do you change seats during the lesson?
3. Where in the classroom do you prefer to sit?
4. Do you think there are enough alternative seating options in the room?
5. What furniture or furnishings do you miss?

SAFETY

Compared to your other traditional classrooms with regular individual desks and chairs...

1. ...how easy is it to connect with your teacher (Joakim) in Joakim's classroom?
2. ...how easy is it to present to your classmates in Joakim's classroom?
3. ...how easy is it to get attention in Joakim's classroom?
4. ...how easy is it to work in groups in Joakim's classroom?
5. ...how easy is it to work alone in Joakim's classroom?
6. ...how easy is it to concentrate in Joakim's classroom?

INDIVIDUALIZATION

1. Where in Joakim's classroom do you usually sit when the lesson starts?
2. If you could choose freely, where in Joakim's classroom would you prefer to sit?
3. Why do you like that specific place in the classroom the most?
4. How often are you allowed to sit in your preferred place?
5. Why are you not allowed to sit in your preferred place?
6. How often do you sit in a place where you don't feel comfortable?

THE SMALL ROOM

1. How often do you use the small room for group work?
2. How often do you use the small room for individual work?
3. Would you like to have more access to the small room?

CONTROL VARIABLES

1. What is your gender identity?
2. What do you think of the school you attend?
3. What do you think of the subject of social studies?
4. Statements about your classmates.
5. Statements about your teacher, Joakim.

Teacher survey

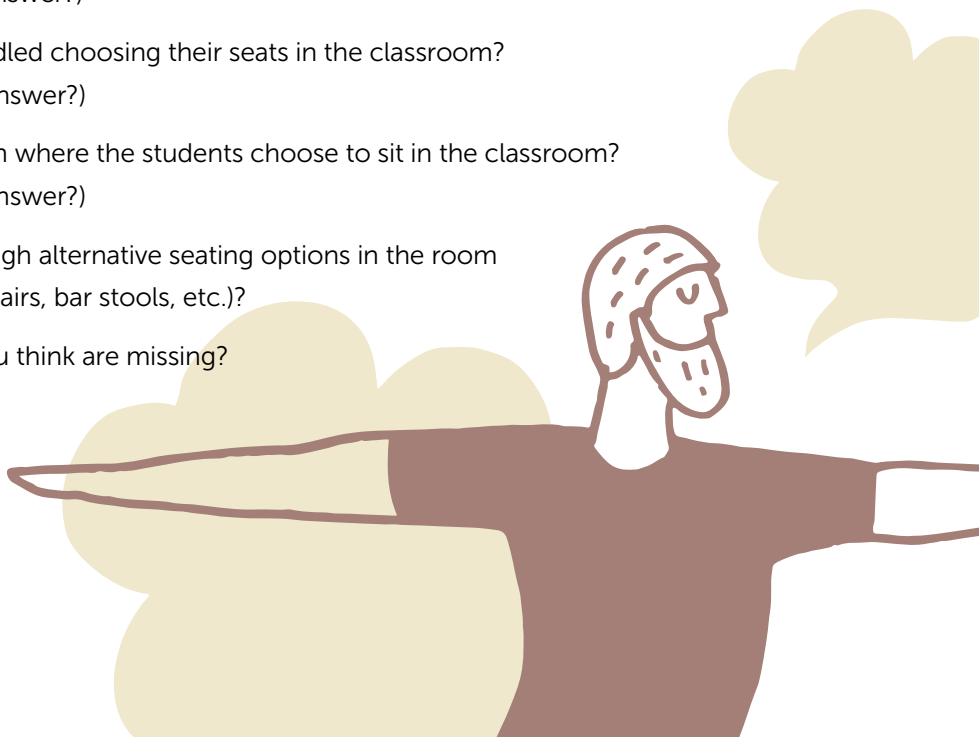
The teacher survey was slightly shorter and primarily consisted of paired questions: a Likert scale question followed by an open-ended question asking the teacher to explain why they gave that specific answer. This survey was also developed in Qualtrics, and a survey link was sent to the teacher.

PRACTICAL QUESTIONS

1. How does the classroom function during group work?
   (1b. Why did you give that answer?)
2. How does the classroom function during discussions?
   (2b. Why did you give that answer?)
3. How does the classroom function during individual work?
   (3b. Why did you give that answer?)
4. How does the classroom function during introductions?
   (4b. Why did you give that answer?)
5. How well does it work to transition between the just mentioned different activities?
   (5b. Why did you give that answer?)
6. How well does it work to move around the classroom in general?
   (6b. Why did you give that answer?)

STUDENT FOCUS

1. How do you perceive the students' level of well-being in the classroom?
   (1b. Why did you give that answer?)
2. How have the students handled choosing their seats in the classroom?
   (2b. Why did you give that answer?)
3. Have you had to intervene in where the students choose to sit in the classroom?
   (3b. Why did you give that answer?)
4. Do you think there are enough alternative seating options in the room
   (e.g., sofas, stools, tables, chairs, bar stools, etc.)?
5. What furniture, if any, do you think are missing?



WELL-BEING

1. How do you generally like the classroom? (1b. Why did you give that answer?)
2. How do you generally like traditional classrooms with regular individual desks and chairs? (2b. Why did you give that answer?)
3. Compared to classrooms with regular individual desks and chairs, do find this classroom better or worse? (3b. Why did you give that answer?)
4. Would you prefer to have more classrooms like this one in the school? (4b. Why did you give that answer?)
5. Did the interior of the classroom meet your expectations? (5b. Why did you give that answer?)

SAFETY

1. How do you feel about not having a fixed place (lectern) in the classroom? (1b. Why did you give that answer?)
2. Is it easy to communicate with the students in the classroom? (2b. Why did you give that answer?)
3. Compared to traditional classrooms with regular individual desks and chairs, is it easier or more difficult to discuss/present to the entire class in the classroom? (3b. Why did you give that answer?)

Classroom observations

The observations took place during a social studies lesson with teacher Joakim Bengtsson. All observations were conducted by the observer sitting at the back of the classroom (near the kitchenette) throughout the entire lesson, solely observing the teaching and the room without interfering, talking to students/teachers, or asking questions. Using a list of observation points, the observer wrote down her notes. The students were aware of the observer's presence as she had previously visited the classes and presented the project to students and teachers.

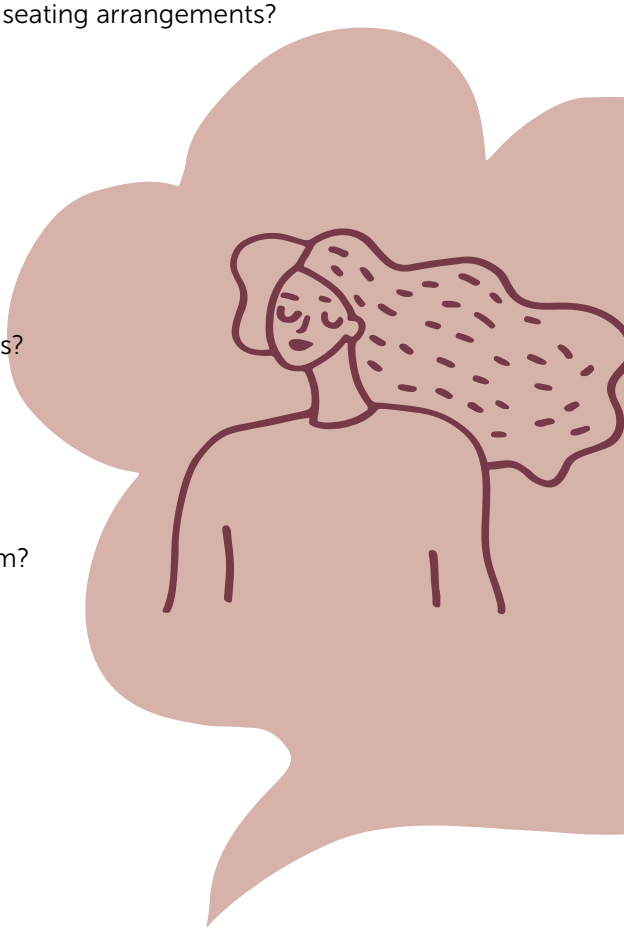
OBSERVATION POINTS

ROOM ENTRY

1. Where do the students sit down first, second, third, etc.?
2. Which furniture groups seem most popular - and for whom?
3. Are any conflicts arising?
4. Does the teacher need to guide or intervene in students' seating arrangements?

INTRODUCTION/DISCUSSION

1. Is the room utilized with a centre-oriented direction?
2. Can everyone see?
3. Is there focus in the room?
4. Do students feel comfortable speaking during discussions?
5. Where is the teacher positioned?



GROUP WORK & INDIVIDUAL WORK

1. How many groups/students remain in the main classroom?
2. How many groups/students use the small room?
3. How many leave the main classroom?
4. Do the intended group furniture arrangements work?
5. Is it chaotic?
6. How is the transition from introduction to group work?
7. Are the mobile whiteboards used?
8. Where is the teacher positioned?

CONCENTRATION

1. Can students concentrate during group/individual work?
2. Are the tables near the windows used?
3. Are the mobile screens used?
4. Is the small room used for this purpose?

MOVEMENT & ACTIVITY

1. Quick transitions
2. Disarray
3. Movement
4. Noise level

FURNITURES

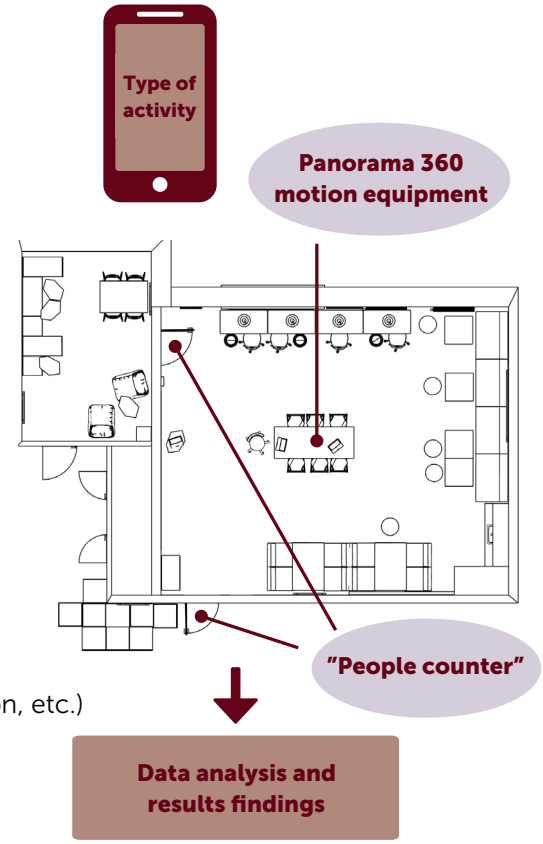
1. How well do the central tables with stools work?
2. How well do the tables with chairs near the windows work?
3. How well do the green booth sofas work?
4. How well do the red sofas with ottomans work?
5. How well does the sofa in the small room work?
6. How well do the tables and chairs in the small room work?

During the class, the observer continuously observed and noted the activities and room usage with comments and keywords noted directly in the document (on her laptop) under the above-mentioned observation points. After the class ended, the observer reviewed the notes and compiled a more comprehensive summary based on her comments and keywords. The text has not been further processed since then.

NOTE

All students in the school had their own laptops, but due to students copying too much text from the internet, Joakim's classes had a computer ban for a period of 3 weeks, which coincided with the observation of Class 7c and 7d. Therefore, the students were writing in notebooks. During the observation of Class 7a, the students had returned to using their laptops.

Physical parameters



The physical environment was measured using three parameters:

1. Activity logging
2. Movement patterns (including people counters)
3. Sound level

Three control parameters were also measured:

1. Temperature
2. Air quality (particle size, presence of hazardous particles, radon, etc.)
3. Light quality

ACTIVITY LOGGNING. Based on our needs analysis and developed hypotheses, we were interested in seeing if the teacher's estimated activity distribution was accurate - 80% group work, 10% introduction/discussion, and 10% individual work. We also wanted to understand the students' movements depending on the type of activity. The three relevant activity types to be recorded were 'Group work,' 'Introduction/Discussion,' and 'Individual work.'

To record the three activities, a solution was specially developed using Microsoft's Power Apps platform. The teacher was provided with a dedicated mobile phone where he recorded the type of activity through an app that generated a list in SharePoint. With a simple button press, the activity itself was logged, along with the class involved and start- and end-times for each activity. The date and time were generated automatically, along with the duration calculation. All registrations could then be compiled into a report to be combined with the data from other physical parameters. The reports also provided answers, for example, to how often or how long different types of activities lasted, giving the teacher the opportunity to ensure that instructional goals were met.

The mobile phone also had the tools installed that were normally used for attendance, making it as easy as possible for the teacher to remember to record the activities without needing an additional tool.

PEOPLE COUNTERS. Two people counters were used to measure the number of people in the classroom. The Axis "People counter" recorded the number of students entering and exiting both the small room and the main classroom, along with the timing and duration. With two people counters, one placed above the entrance to the main classroom and one above the entrance to the small room, it was possible to register when someone changed rooms or completely left the main classroom. The registrations could be visualized in a graph via an interface, with the number of students displayed on one axis and the time on the other. This allowed for analysis of how long students stayed in the main classroom, how often they moved between rooms, and how many students were present in the main classroom at the same time.

MOVEMENT PATTERNS. To track how students moved around the classroom, depending on the chosen activity or any of the other developed hypotheses, a 360-degree motion sensor was installed in the ceiling in the middle of the classroom. Movements were recorded via an interface and software for "heat mapping," which meant that each registered movement created a colour intensity, with more movement resulting in higher intensity from low (green) to high (red). Panorama 360 motion equipment from the supplier Axis was used to measure movement patterns. The purpose of the heat map was to record movement from both teachers and students during different activities, transitions between activities, favoured furniture groups, and to highlight any bottlenecks or physical clutter in the classroom.

PHYSICAL PARAMETERS ANALYSIS. The intention was to create a "heatmap" (movement) based on each measurement point created in the teacher's "activity app" using the Axis 360 motion sensor placed in the ceiling. The heatmap was then visually compared based on classroom activity. At the start of the measurement, a "reference heatmap" was created for verification purposes. Using the activity list and the corresponding heatmaps, the movement of students within the different learning environments of the classroom, including entering and exiting, was analysed. Our focus for the analysis of movement patterns was on students since several similar studies focusing on teachers has been conducted before, and equipment for that type of movement analysis is already available on the market. Since there was less information available on student movement patterns, we wanted to see if the chosen technical solution could provide answers to our hypotheses.

Sound level & control parameters

For sound level mesurements, as well as the control parameters of temperature, air quality, and light, equipment from the supplier Airthings (specifically ”Airthings for business/school”) was chosen. The sensors were installed in both the main classroom and the small room. The sensors could display both values and threshold values directly on the devices in the classroom and could be analysed in the Airthings app. In the app, custom or pre-made reports could be generated or integrated with other systems for potential automation solutions, such as ventilation or sun protection. The app could also produce reports to, for example, detect early warning signs of increased virus risk if such conditions arose.

The sensors had their own QR code that students could scan with their mobile phones to monitor the values daily. The purpose of the equipment was to ensure that the lessons in the main room were held within approved levels and to indicate to teachers and students if any of the parameters did not match the threshold values.

SOUND LEVEL. Room acoustics involve measuring and controlling the sound in a room. Good room acoustics are based on a set of conditions for the production and reception of pleasant sounds and sound levels. Quality of auditory perception and sound control are the two main aspects that contribute to a room’s acoustics. Comfortable and clear auditory reception, as well as absence from background noise, not only improve overall communication but also contribute to better concentration and learning efficiency. Sound levels should be kept within 30-45 decibels (dB) in educational facilities. Prolonged exposure to sound levels higher than 85 dB can lead to hearing damage.

TEMPERATURE. The recommended temperature level should be between 18-25 ºC to maintain a good indoor environment. Slightly cooler temperatures are recommended for optimal learning ability and efficiency.

AIR QUALITY. Children and adolescents are particularly sensitive to all types of air pollutants due to their high breathing and metabolic rate levels. In educational settings, students often have limited personal space due to large student numbers. To measure and evaluate the overall air quality in a classroom, several different tests must be conducted.
The most important and common ones are the following:

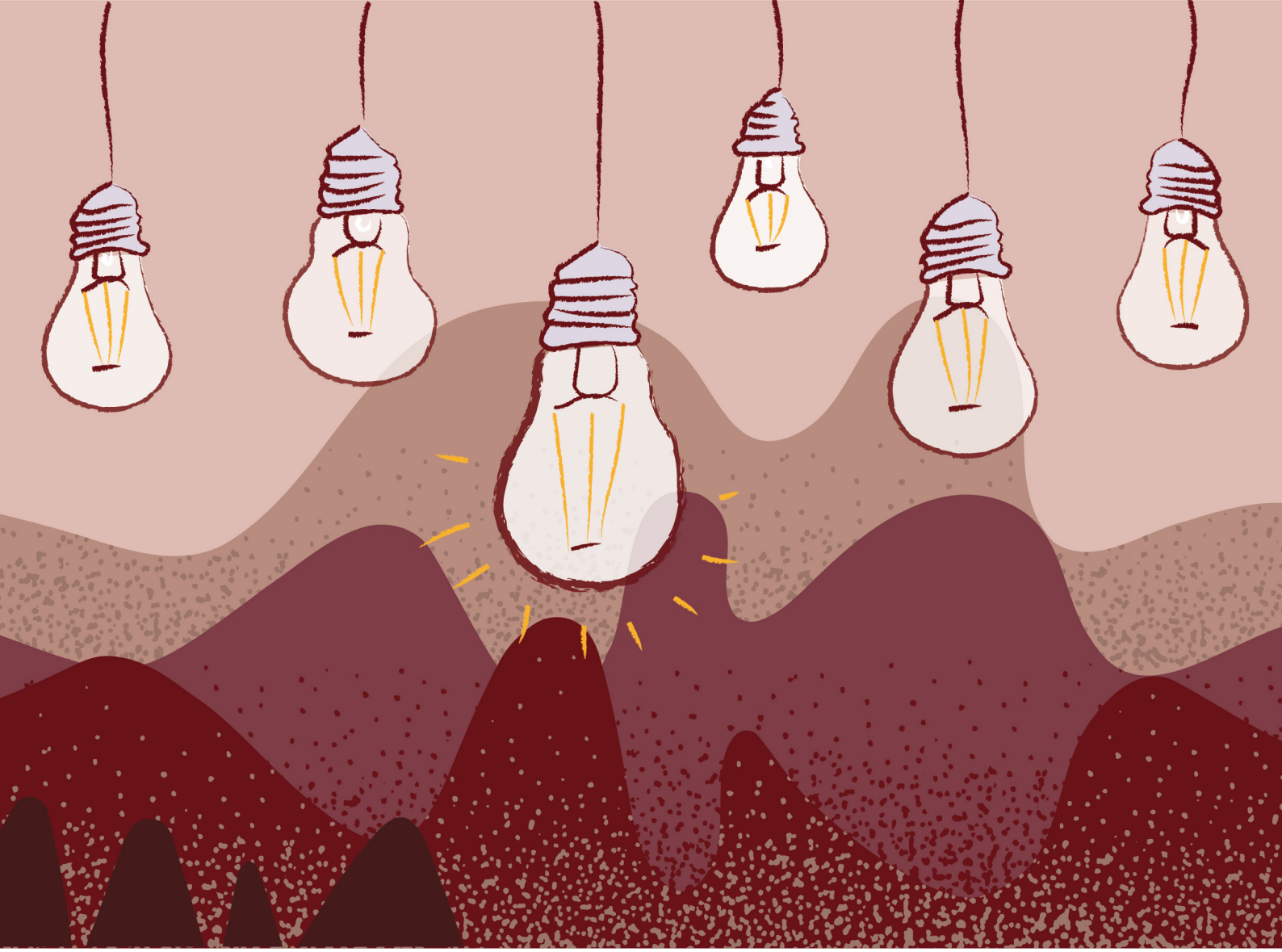
AIRBORNE PARTICLES - PM1 AND PM2.5. In every cubic centimetre of air, there are thousands of small particles. The particles come from various sources, both anthropogenic and natural. Two common measures of particles found in the air are PM1 and PM2.5. Simplified, these measurements show the mass of particles in the air that are smaller than 1 and 2.5 micrometres (µm) in diameter, respectively. These small particles are among the air pollutants that cause the most health problems and are often brought into buildings from the outside. Exposure to these particles can trigger asthma and allergies, as well as cause irritation in the eyes, nose, and throat. High levels can indicate issues with air filters or ventilation systems.

CARBON DIOXIDE LEVEL (CO2) . High levels of CO2 negatively affect concentration and cognitive abilities while also contributing to increased fatigue at levels above 1200 ppm. In typical indoor environments such as offices and schools, the levels should be kept within 600-800 ppm for a healthy learning environment.

HUMIDITY. Humidity can significantly affect comfort, respiratory health, and the risk of certain diseases. Optimal levels range between 30-60%. Appropriate humidity levels are particularly important for students and teachers with allergies, asthma, or other respiratory conditions.

VOC - CHEMICALS FROM PAINT, CLEANING AGENTS, ETC.

VOC (volatile organic compounds) is a group of chemicals often found in both home and school environments. These chemicals typically originate from paint, cleaning agents, office equipment, or common perfumes, and can cause serious health effects both in the short and long term. VOC levels can be reduced through improved ventilation and the identification and removal of potential sources. The levels should be kept below 400 ppm (particles per million).



LIGHT QUALITY. The benefits of good natural light (light from the sun) in the right amount are not only that it contributes to improved visual ability but also to physical and mental well-being. This is due to natural light having soft and diffuse qualities that vary in value and colour; something static, electronic light lacks. Deep classrooms with few windows can create an imbalance in light quality between the rear part of the classroom and the area near the windows. While natural light should be the primary light source in all school premises, it often needs to be supplemented with electronic light when daylight diminishes, and it goes dark outside.

CHAPTER 5

Results and analysis of the case study

What did the collected data show?

Phase 1: 1 March 2022 - 29 April 2022

Student survey results (Phase 1)

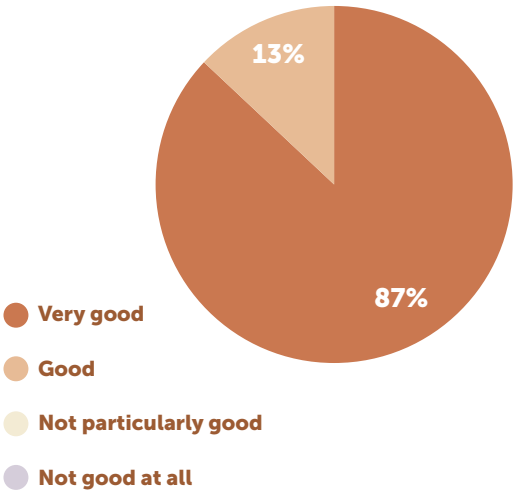
DATE: 26–28 APRIL 2022

A total of 92 students participated in the first student survey. The participants were distributed across the 4 classes (7a, 7b, 7c, and 7d) with class sizes ranging from 20 to 26 students. Out of the 92 participants, 54 were boys, 36 were girls, and two students used a non-binary gender identity.

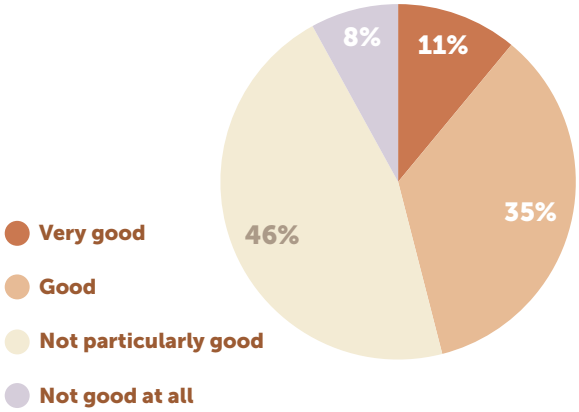
WELL-BEING

The well-being in the classroom was very high, with 100% of the students responding that they either felt 'very good' (87%) or 'good' (13%). None of the students answered, 'not particularly good' or 'not good at all'. This response was in stark contrast to how the students generally felt in classrooms with regular individual desks and chairs. Only slightly more than half (57%) of the students felt 'very good' (11%) or 'good' (46%) in those classrooms. When we asked them to compare whether they enjoyed this classroom better or worse than classrooms with regular individual desks and chairs, almost all (96%) said they enjoyed it 'much better' (71%) or 'better' (25%), while only 1% said they found it worse.

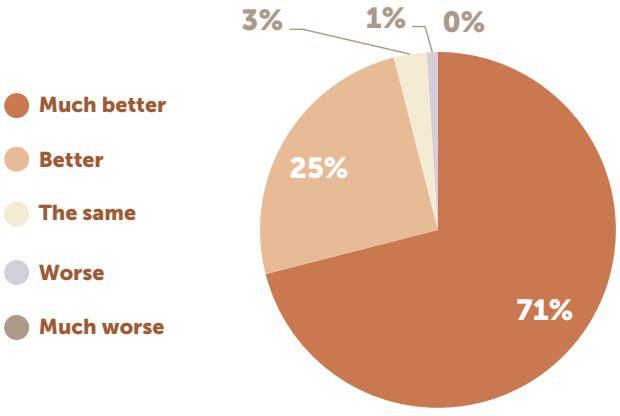
How do you generally feel in Joakim's classroom?



How do you generally feel in your other traditional classrooms with regular individual desks and chairs?



Compared to your other classrooms with regular individual desks and chairs, do you feel better or worse in Joakim's classroom?



INDIVIDUALIZATION

73% of the students said they 'always' (24%) or 'often' (49%) got to sit in their preferred place, while 83% said they 'rarely' (46%) or 'never' (37%) had to sit in a place they didn't enjoy. When asked why they liked their chosen place in the classroom, the answers varied depending on the spot they had chosen. The green sofas were primarily appreciated for their comfort and suitability for group work:

"Because you sit opposite each other, and it's a bit more secluded from the other places, which allows for better concentration."

"They are comfortable, and I can focus better than sitting on chairs."

"The green sofas are very comfortable, and they give a feeling of a private space where you can relax. Sitting opposite someone during a conversation is good; you don't have to twist and turn."

The red sofas were also liked because they were comfortable and allowed students to see the whiteboard:

"Because then you have a view of the entire classroom, and it's comfortable."

"They are comfortable, and you sit at the back of the classroom, so you can see the whiteboard well."

The window tables were primarily liked because it was easier to concentrate there:

"Because it's easier for me to concentrate."

"I like sitting at the window tables when I really want to work. Many choose to sit on the sofas, but when you sit facing the window, you can't see what's happening behind you, and you work better then. I sit in the sofas when I don't feel stressed about work."

None of the students said they preferred to sit at the wooden table in the middle.

VARIATION

While the overwhelming majority (91%) of students thought that the classroom had enough alternatives for different ways of sitting (sofas, stools, tables, chairs, bar stools, etc.), most students (73%) chose to 'always' (17%) or 'often' (56%) sit in the same place in the classroom for each lesson. Relatively few students changed seats during the lesson (35% said 'sometimes' and 49% said 'rarely').

Just over half (57%) of students used the small room either 'often' (14%) or 'sometimes' (43%) for group work, while it was used significantly less for individual work. 36% of students said they 'never' used it for individual work, and 46% said they rarely did.

83% never or rarely got to sit in a place they didn't like

91% thought there were plenty of good options for seating

SAFETY

97% of the students said they would prefer to have more classrooms designed in this way, and 63% said they used the classroom even outside of lesson time. When we asked students how easy it was to work in different ways in the classroom, the responses were also overwhelmingly positive.

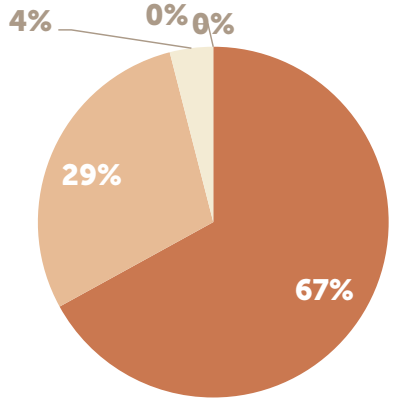
Compared to classrooms with regular individual tables and chairs, 95% thought it was 'much easier' (66%) or 'easier' (35%) to work in groups in the classroom. 78% found it 'much easier'

(30%) or 'easier' (48%) to work individually in the classroom. 81% found it 'much easier' (42%) or 'easier' (39%) to present to their classmates in the classroom. The overwhelming majority of students also found it 'much easier' (37%) or 'easier' (40%) to concentrate in the classroom and 'much easier' (32%) or 'easier' (42%) to interact with the teacher in the classroom.

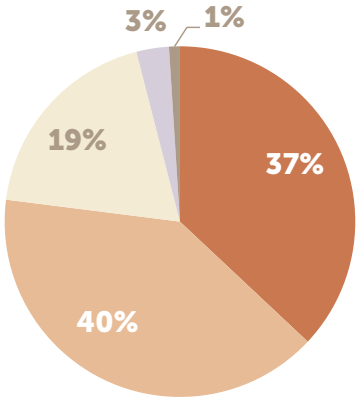
When asked about how easy it was to get attention in general in the classroom, the responses were slightly weaker, with 20% finding it 'much easier' and 45% finding it 'easier', while one-third (33%) thought it was the same as in classrooms with regular individual tables and chairs.

Compared to your other traditional classrooms with regular individual desks and chairs...

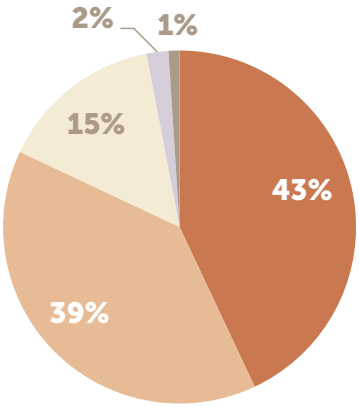
...how easy is it to work in groups in Joakim's classroom?



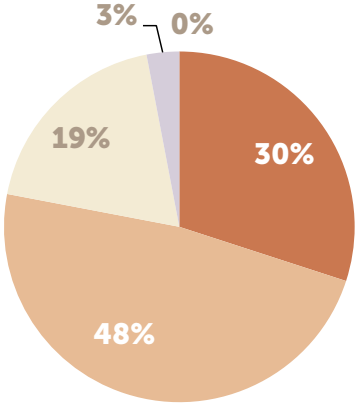
...how easy is it to concentrate in Joakim's classroom?



...how easy is it to present to your classmates in Joakim's classroom?



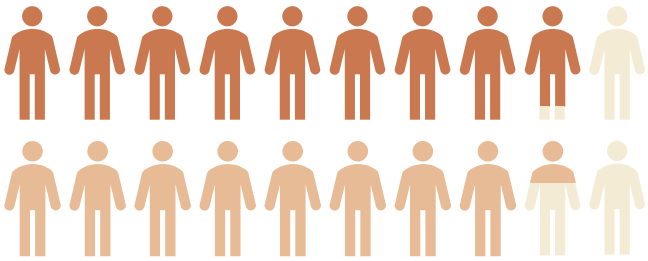
...how easy is it to work alone in Joakim's classroom?



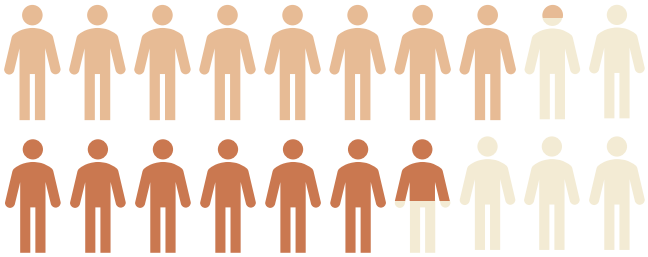
Control variables

GENDER IDENTITY

Boys said that they slightly more often (always: 36%, often: 57%) than girls (always: 22%, often: 44%) got to sit in a place they felt most comfortable, but both boys (48%) and girls (44%) said they rarely had to sit in a place they didn't feel comfortable in. Everyone felt 'very good' (boys: 89%, girls: 86%) in the classroom and said they wanted more classrooms of this type in the school (boys: 96%, girls: 97%). However, boys said they felt 'very good' (15%) or 'good' (50%) in classrooms with regular individual tables and chairs as well, compared to girls where only 3% felt 'very good' and 39% felt 'good'. This led girls to say that they felt 'much better' (81%) in the classroom than boys did (65%), compared to classrooms with regular individual tables and chairs.



89% of the boys and 83% of the girls felt very good in the classroom



81% of the girls and 65% of the boys felt much better in the classroom, compared to traditional classrooms with regular individual tables and chairs

CLASS

Compared to the other three classes, 7a enjoyed the classroom the least, although the students' responses were still predominantly positive. 7a consisted of 65% boys, which could potentially have impacted the responses as a gender identity difference was identified in the data analysis. However, class 7d also consisted of 65% boys, and their responses were generally as positive as class 7b (46% boys) and 7c (54% boys). Instead, the difference in the data analysis could be attributed to the students' relationship with the school, the subject, and/or the teacher, or another variable not accounted for in the research project.

ATTITUDES TOWARDS SCHOOL, SUBJECT, AND TEACHER

An overwhelming majority (94%) of students either liked the school they attended 'very much' (39%) or 'moderately' (55%). The same applied to both the subject and the teacher.

Teacher survey results (Phase 1)

The teacher found the subject-based classroom to work 'quite well' for group work but commented that it would have worked even better if ***"the furniture could be moved and adjusted for different lessons."*** The teacher thought the classroom worked 'very well' for discussions because ***"almost everyone can see each other and avoids looking at each other's backs."*** For individual work, the teacher found the subject-based classroom to work 'quite well' but noted that ***the red sofas and the tables did not match in height.***

During introductions, the teacher found the subject-based classroom to work 'very well.' However, he pointed out that it would have been even better if ***the green sofas could be swopped with the red sofas so that everyone could see better.*** When asked about the ease of transitioning between activities (introduction/discussion, individual work & group work) and moving around the classroom in general, the teacher responded, 'very well' to both, as he said that ***"it feels much more spacious when the furniture is placed along the walls."***

The teacher thought the students handled choosing their seats in the classroom 'quite well,' and he 'rarely' had to intervene in their seating choices. He believed that there were enough different seating options for the students and ***overall enjoyed the subject-based classroom 'very much.'*** He thought the subject-based classroom was 'much better' than classrooms with regular individual tables and chairs because he felt that the traditional classrooms were "not adapted for today's students and their work methods. This classroom, he thought, ***"created a better working environment that feels more homely, and the noise level is generally better."***

The teacher also greatly appreciated not having a fixed seat in the classroom, as it allowed him to move around freely according to needs and activities. ***Generally, the teacher was very satisfied with the subject-based classroom*** but wished that the furniture could have been slightly more mobile as he believed that ***"being able to adapt and change is extremely important for the learning environment."***

NOTE: In the interior design solution, we had taken into consideration that the room could be modified according to needs and activities. The tables, chairs, and red sofas were on wheels so they could be easily placed together for longer group activities and then rearranged for discussions. However, the research project required that the placement of the furniture remained fixed during the measurement period of the case study.

> **"Being able to adapt and change is extremely important for the learning environment."**
>
> **Joakim Bergström, teacher Toftanässkolan**

Survey conclusion

The data collection from the first survey was a success as the results from both surveys were overwhelmingly positive. Both students and the teacher enjoyed the subject-based classroom very much. In all questions from both surveys, the designed subject-based classroom was preferred by a large margin over traditional classroom with regular individual tables and chairs. The data from the teacher survey also confirmed that the case study's goal to match the learning environment and pedagogy had been achieved; the teacher found that the classroom worked much better with the type of activities it was used for, compared to traditional classrooms. Based on the survey responses, it was also evident that the second goal had been achieved as both students and the teacher confirmed that the designed subject-based classroom increased well-being, variation, security, and individualization for the students.

However, a few students reported not being able to sit in their preferred place as some areas were more popular than others. Several students mentioned that it was often too crowded in the red sofas because many students preferred to sit there. A few minor issues with some of the furniture's functionality were also highlighted in both surveys. The backrests of the green sofas were high and blocked the view of the whiteboard for some of the students sitting there, and the tables for the red sofas were considered too high (or the red sofas were too low).

Class observation results (Phase 1)

The observations were conducted in the following 3 (out of 4) classes:

CLASS 7A Date: 26 April 2022. Lesson duration and time: 80 minutes, 10:35-11:55. Number of students: 24. 7a primarily had group work, and the lesson consisted of Introduction 10% and Group work 90%.

CLASS 7C Date: 30 March 2022. Lesson duration and time: 80 minutes, 13:50-15:10. Number of students: 26. 7c had primarily individual work, and the lesson consisted of Introduction 5%, Individual work 60%, and Introduction/Discussion 35%.

CLASS 7D Date: 30 March 2022. Lesson duration and time: 80 minutes, 10:30-11:50. Number of students: 26. 7d had primarily individual work, and the lesson consisted of Introduction 10%, Individual work 70%, and Introduction/Discussion 20%.

The observation summary is written against our five hypotheses.

Hypothesis 1: The subject-based classroom facilitates group work, with at least five groups remaining in the rooms (including the small room)

– WELL-BEING AND VARIATION

Based on the observations, it became clear that almost all students chose to stay in the rooms. In two of the classes, all 6 groups remained in the main room, and 1 group went into the small room. In the third class, 6 groups also stayed in the main room, with one group in the small room. However, halfway through the lesson, one of the groups in the main room chose to leave the subject-based classroom. Both the green and red sofas worked very well for group work and were used by 4-5 groups. The central tables also worked well and were used by one group. The window tables were used by one group but were not optimal for the purpose as the students were seated in a row. The group that left the room sat at the window tables. In the small room, both the table and sofa worked for group activities and were used by all classes.

Hypothesis 2: The placement of furniture in the subject-based classroom facilitates easier movement between activities for students and teachers, minimizing disruption and creating better sound quality – WELL-BEING AND VARIATION

The observations showed that transitions between activities were quick and easy, partly because there was plenty of space to move around in the room and partly because many students remained in the same place throughout all activities. The students did not move around the room after each activity (as expected) but worked in groups with the peers they initially chose to sit with. Once students had secured their desired spot, the observations indicated that they were reluctant to move elsewhere. There was also no noise or disturbance in the room during activity changes since the furniture did not need to be moved. There were generally low noise levels. The room had good acoustics overall, making it easy and seamless to move around. When students returned to the subject-based classroom from the small room or other areas of the school, they easily returned to their previous seats without causing any disruptions. Joakim also moved around the room easily, being able to transition between groups and sit with them when they needed assistance.

Hypothesis 3: The subject-based classroom's interior design supports and inspires students to participate in discussions and debates – VARIATION, INDIVIDUALIZATION & SAFETY

The observations showed that the interior design worked excellently for discussions in all classes. Students contributed to the discussions from their seats, and Joakim stood at the central table, which was clearly visible to the students. All students could see each other. The room had good sound quality, and as the students turned inwards towards the room and each other, everyone's voices were heard clearly. In classes where many students sat at the central table, Joakim moved closer to the whiteboard, making it difficult for four students sitting with their backs to the whiteboard in the green sofas to see him. This was also the case when using the whiteboard, which occurred slightly more frequently than Joakim anticipated. The affected students chose not to move to the poufs in the room (which were there for this purpose) but remained seated or partially stood up. The students were highly engaged in the discussions.

Hypothesis 4: The subject-based classroom's interior design provides students with more seating options and different furniture to choose from, thereby increasing the sense of autonomy and comfort – WELL-BEING, INDIVIDUALIZATION & SAFETY

Based on the observations, it became clear that it was important for the students in all classes to secure their favourite place in the room. Students were stood outside the classroom for up to fifteen minutes before the lesson started, eagerly waiting for the teacher to unlock the door so they could rush in and take their preferred seats. If they arrived later, they simply took any available seat. The students were very determined and evenly distributed themselves in the room without conflicts or arguments. Most had a specific spot they headed for, there was therefore no confusion or wandering about to find a seat. The students mostly sat in specific groups that seemed to have been decided on before they entered the room. As a result, the lesson could start on time since very few students arrived late. The teacher never had to intervene in the students' seating arrangements during the observations.

The students distributed themselves relatively evenly, first between the sofas and then the window tables. The central table was chosen last (except in class 7c, where it filled up more quickly).

The door to the subject-based classroom was always kept open by the teacher, allowing students from other classes to enter and use the room for their own work if there was space available and they did not cause any disturbance, as many students appeared to prefer the subject-based classroom over other traditional classrooms.

Hypothesis 5: The subject-based classroom, with an interior design that supports the subject and has a clear identity, enables teachers and students to enjoy better well-being than in a traditional classroom with regular individual desks and chairs

– WELL-BEING, INDIVIDUALIZATION & SAFETY

This hypothesis could not be inferred from the observations.

Observation conclusion

Data from the observations showed that the above-mentioned hypotheses were met, indicating a successful interior design and initial assessment. However, there were some minor issues observed that we decided to address in the second phase:

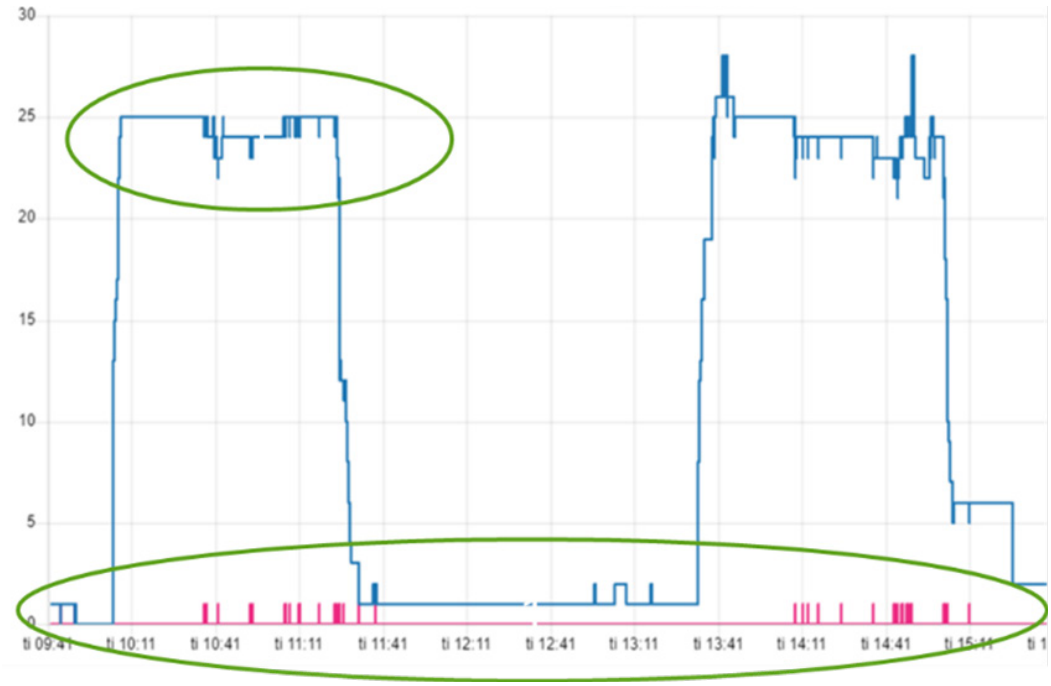
- 4 students could not see the whiteboard, and since its usage was more frequent than anticipated, we needed to address this issue.
- Students remained seated at the window tables during group work, even though it was not optimal.
- Students continued to sit in a row on the red sofas during group work instead of moving to the intended poufs opposite side of the tables.

During the observations, two positive behaviours which we had not anticipated were also noted. Firstly, students arrived early for classes to secure their favourite spots. This resulted in very few or no students arriving late for Joakim's lessons. Secondly, many students preferred the room over the common areas in the school and used the subject-based classroom during other class periods to study, as the teacher Joakim allowed them to do so.

Results of physical parameters (Phase 1)

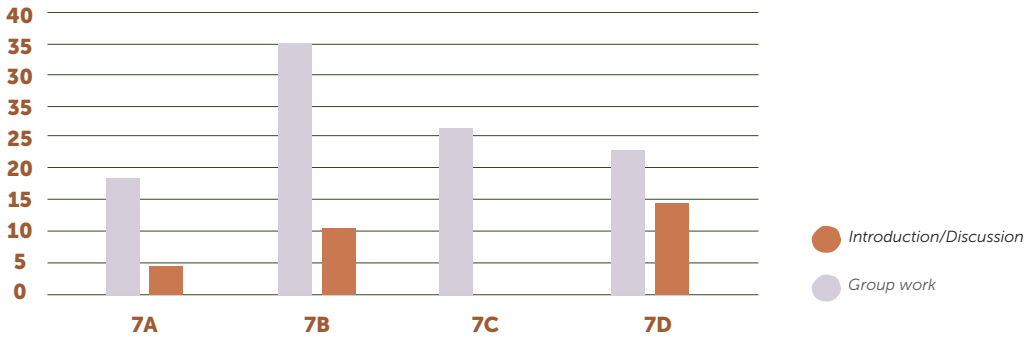
Aggregated data was used for data analysis, and samples were used to analyse trends when it was not feasible to include all data points in the visualizations.

PERSON COUNTER. The person counter worked satisfactorily in the large classroom, while in the small room, the data was presented in a way that complicated our analysis. Analysing the data was time-consuming because an automated solution was not available due to time, resources, and cost constraints. During the first measurement period, 131 data points were extracted for analysis. The average number of students in the large classroom was 22.



The upper left circle shows that students mostly stayed in the classroom. The bottom oval circle represents the small room, where each "stick" indicates when a student enters or exits the small room.

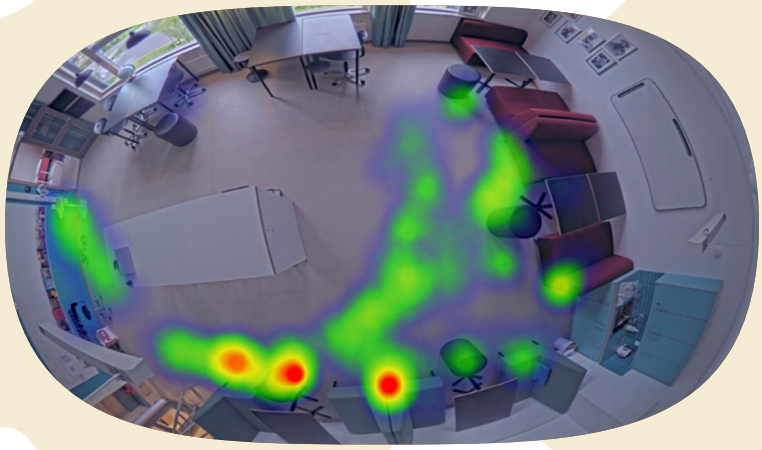
The small room



The small room is used by 2–3 people at a time and the average time they stayed was about 20 minutes.

The graph above shows that students mostly stayed in the classroom. Some students entered the small room, but there was significant variability in the teacher's instruction and the type of activity, which made it difficult to determine if students left because the chosen activity was not suitable for the learning environment. According to observational data, the teacher often kept the door open, and students moved freely in and out during class time. Additionally, students from other classes occasionally entered the classroom to talk to the teacher. This made it difficult to accurately determine how many students from the specific class entered or exited the classroom during a lesson. According to the person counter, an average of 5-10 students entered and exited the classroom during each lesson.

MOVEMENT PATTERNS. Movement pattern data was difficult to interpret as the motion sensor could not differentiate between individual students and the teacher's movement patterns. Therefore, the data analysis for this variable was limited, providing just a few examples to illustrate general movement pattern trends in the classroom. The collected data indicated that students, regardless of class, had similar movement patterns at the entrance, during class time, and at the exit.



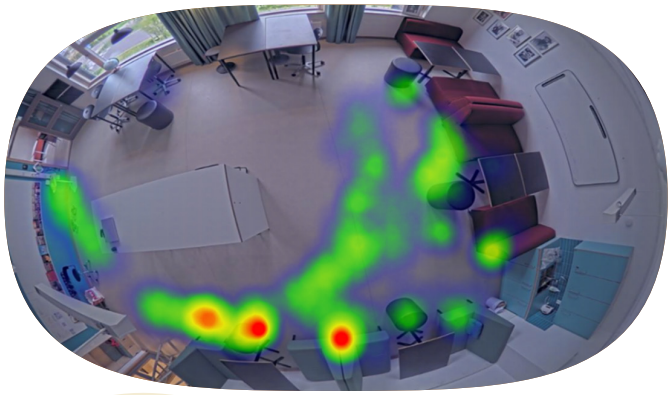
Examples of movement pattern data showing when students enter the classroom for a lesson.

Movement pattern data and activity logging were measured against specific questions that were important for the success of the case study. The questions were as follows:

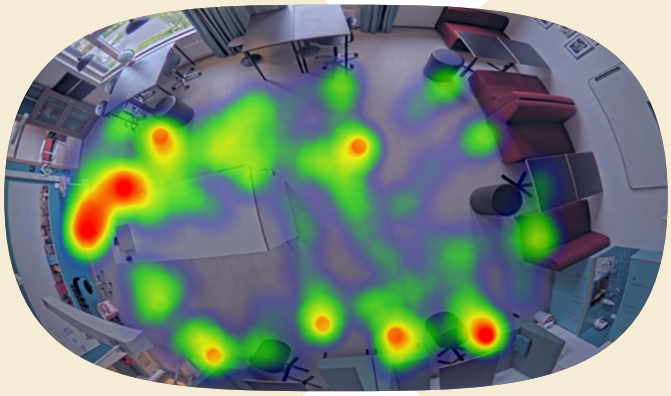
1. **Do students stay in the classroom during the lesson?**
2. **Are certain furniture groups more popular than others?**
3. **Does the teacher use the classroom as expected based on the activity?**
4. **Do students use the entire classroom?**
5. **Do students move around the classroom between different types of activities?**
6. **Do students choose furniture based on the activity?**
7. **How does the teacher move during the class?**

The third and final physical value, sound quality, was measured against hypothesis number 2:

2. The placement of furniture in the subject room facilitated easier movement between activities for students and teachers, without causing disturbances and thus creating a better sound environment.



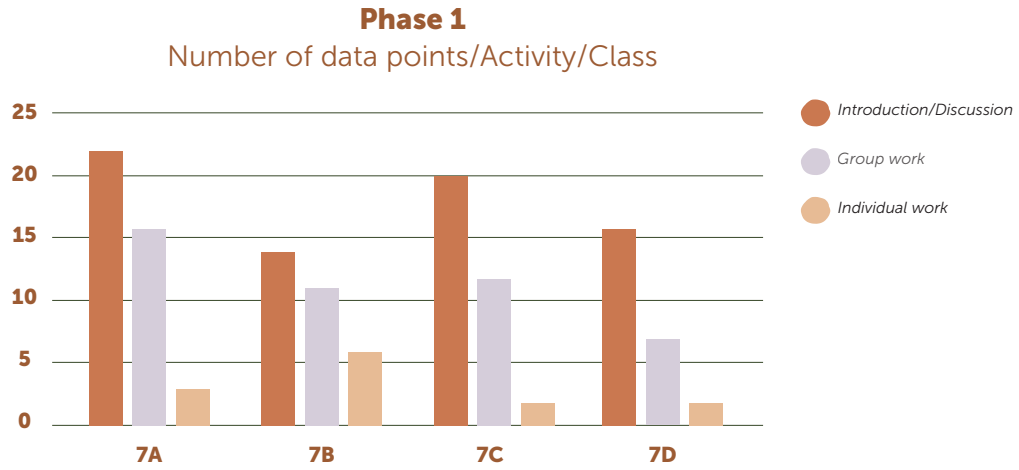
Examples of movement pattern data showing when students enter the classroom for a lesson.



Examples of movement pattern data showing the movement patterns of students and the teacher during the lesson.

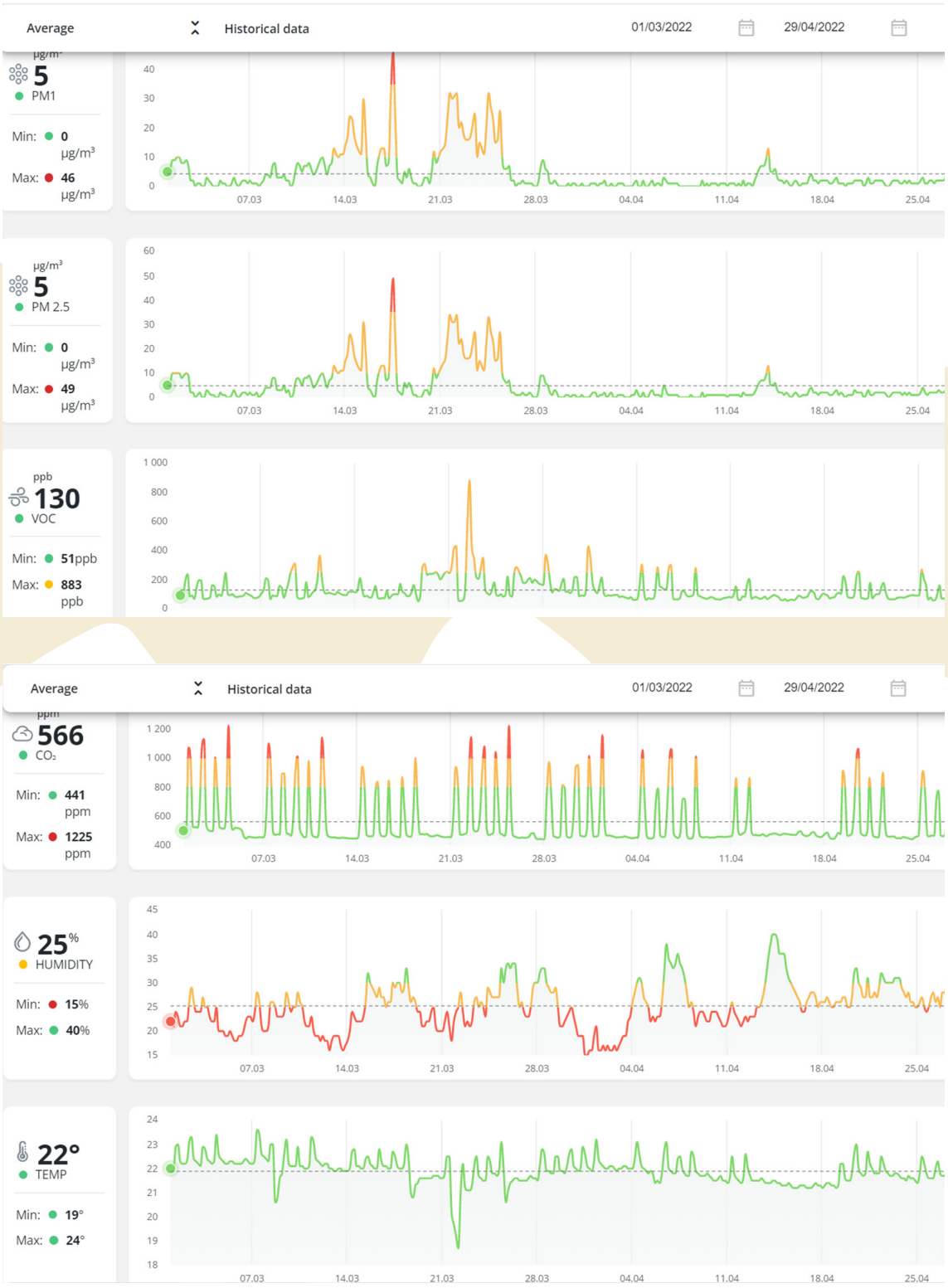
Examples of movement pattern data showing the movement patterns of students and the teacher during group work.

ACTIVITY LOGGING. To compare movement patterns with activities, the teacher logged the activities in the app. He mostly recorded them promptly but sometimes forgot (overall, there are fewer registrations than the planned schedule and lessons for the entire measurement period). The students mostly had the same activity throughout the lesson and usually stayed in the same place even during activity transitions.



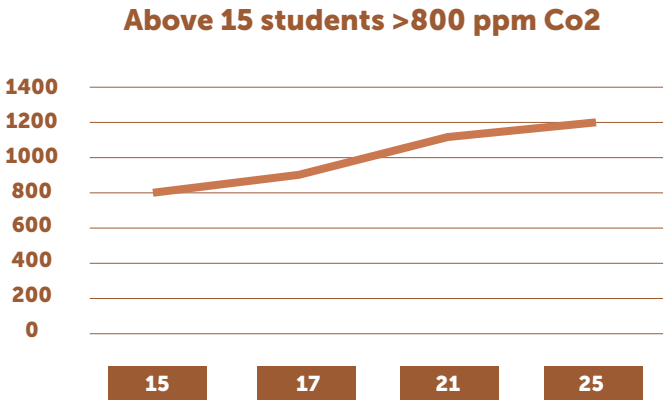
A total of 131 data points were recorded for Phase 1. The activity "Presentation - Discussion" was the most frequent, while "Individual work - Concentration" was the least frequent.

TEMPERATURE, AIR QUALITY, AND LIGHT QUALITY. The graphs below show the results from measurements of noise level, temperature, air quality, and light quality for Phase 1, with an average for each parameter in the left hand side column.

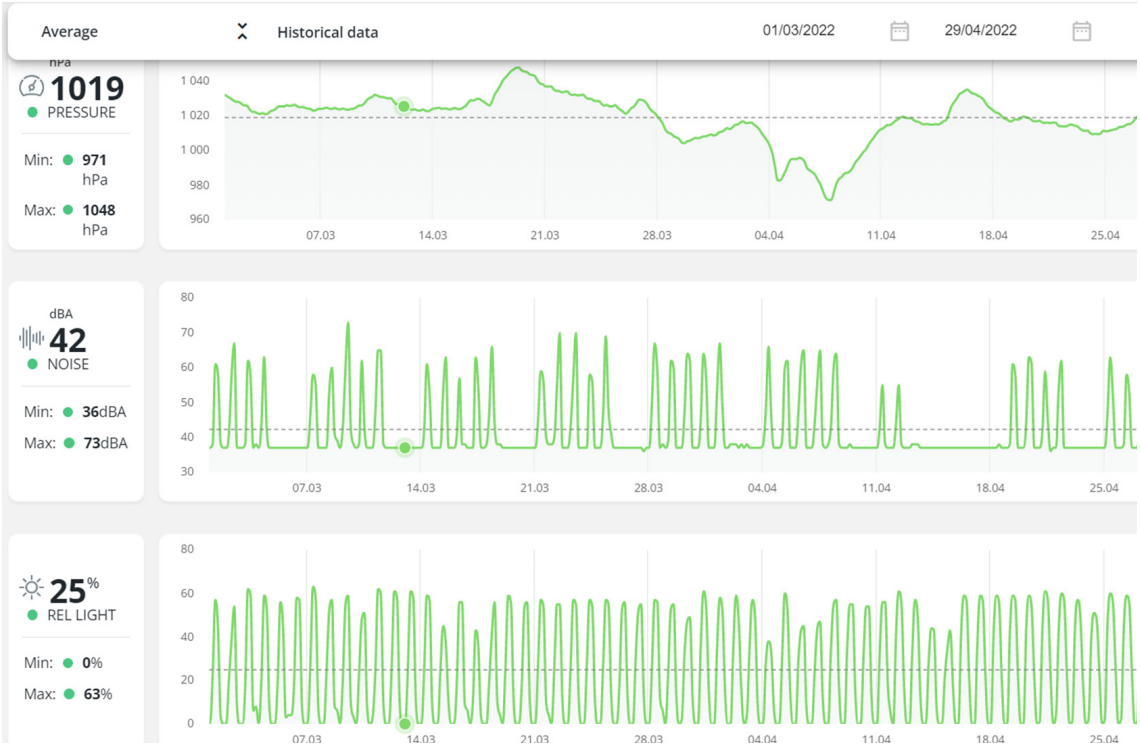


The air quality parameters mostly remained within the limits, except for the carbon dioxide levels and humidity.

A deeper analysis of the carbon dioxide levels showed that in a full class (more than 15 students), the carbon dioxide levels exceeded 800 ppm, indicating poorly ventilated air, which could lead to headaches and difficulties in concentration for the students. Both humidity and carbon dioxide levels should be addressed for the well-being of both students and teachers. A relatively simple solution is to open a few windows and systematically ventilate the classroom throughout the day.



SOUND. All classes had a similar and acceptable sound environment during all three types of activities. The average sound level was 42dB, which falls within the recommended range for educational spaces (30-45dB).



CONCLUSIONS TO THE SPECIFIC QUESTIONS

1. Do students stay in the classroom?

✓ The people counter showed that only a few students left the subject room during class time.

2. Is there a tendency for different furniture groups to be more popular?

✓ Movement pattern data showed that the first students entering the room often chose the green and red sofa groups.

3. Does the teacher use the classroom as expected depending on the activity or stay at the whiteboard?

✗ This could not be conclusively answered based on the physical parameters data, but data from observations indicated that the teacher spent more time at the whiteboard than expected during logged activities such as Introduction/Discussion.

4. Do students use the entire classroom?

✓ The data showed that the entire room was used.

5. Are students static or mobile within or between activity types?

✓ The data showed that students were mobile within and between activities.

6. Do students choose furniture based on the activity?

✗ This could not be answered based on the physical parameters data.

7. How does the teacher move during the class?

✗ This could not be conclusively answered based on the physical parameters data since the teacher could not be distinguished from the students in the movement pattern data analysis.

Physical parameters conclusion

The control variables of temperature and light levels fell within acceptable ranges and could therefore be excluded from having a negative impact on the students' and teacher's experience of the classroom. Most of the air quality parameters also fell within acceptable ranges, except for carbon dioxide levels and humidity, which generally fell outside acceptable ranges during class time. The sound level was also within an acceptable range, indicating a successful design implementation as the project's second hypothesis aimed to reduce the sound level in the subject-based classroom.

The activity logging measurement was not consistent as the teacher sometimes forgot to log an activity during class time. However, the activity logging that was performed showed that students spent less time in group work than what the teacher had estimated at the start of the project.

The movement pattern data was difficult to interpret in a useful way as it was not possible to distinguish students from each other, or the teacher from the students. The usability of data from this parameter was therefore limited. The people counter allowed for monitoring the number of students leaving the classroom during class, which was important to understand in relation to the project's first hypothesis regarding whether students stayed or left the classroom during group work.

Evaluation after the first phase

As all three data collection methods produced overwhelmingly positive results; we could conclude that the case study was a success and confirm all hypotheses:

CASE STUDY HYPOTHESES

1. The subject-based classroom facilitates group work activity, with at least 5 groups remaining in the rooms (including group rooms). Data from both observations and the people counter, combined with activity logging, showed that most students stayed in the classroom even during group work.

2. The placement of furniture in the subject-based classroom facilitates movement between activities for students and teachers without causing disruptions, thus creating a better acoustic environment. Data from both teacher and student surveys, as well as observations, indicated that both students and teachers found it easy to move around the classroom. The sound level measurement confirmed that the acoustics in the classroom were good.

3. The subject-based classroom provides an interior that supports and inspires students to participate in discussions and debates. Data from both surveys and observations showed that students felt the subject room worked well for participating in discussions and debates. The sound level parameter confirmed that the acoustics in the classroom were good.

4. The interior design of the subject-based classroom provides students with more seating options and different furniture to choose from, thereby increasing the sense of autonomy and well-being. Student surveys showed that the overwhelming majority enjoyed the classroom and felt that there were enough seating options to choose from. Observations also revealed that students intentionally chose different furniture without conflicts, had different preferences, and arrived early to secure their preferred seating.

5. The subject-based classroom, through an interior design that supports the subject and has a clear identity, makes both teachers and students feel more comfortable than in a traditional classroom with regular individual desks and chairs. Both students and teachers confirmed that they felt much more comfortable in the subject-based classroom compared to other classroom with regular individual desks and chairs.

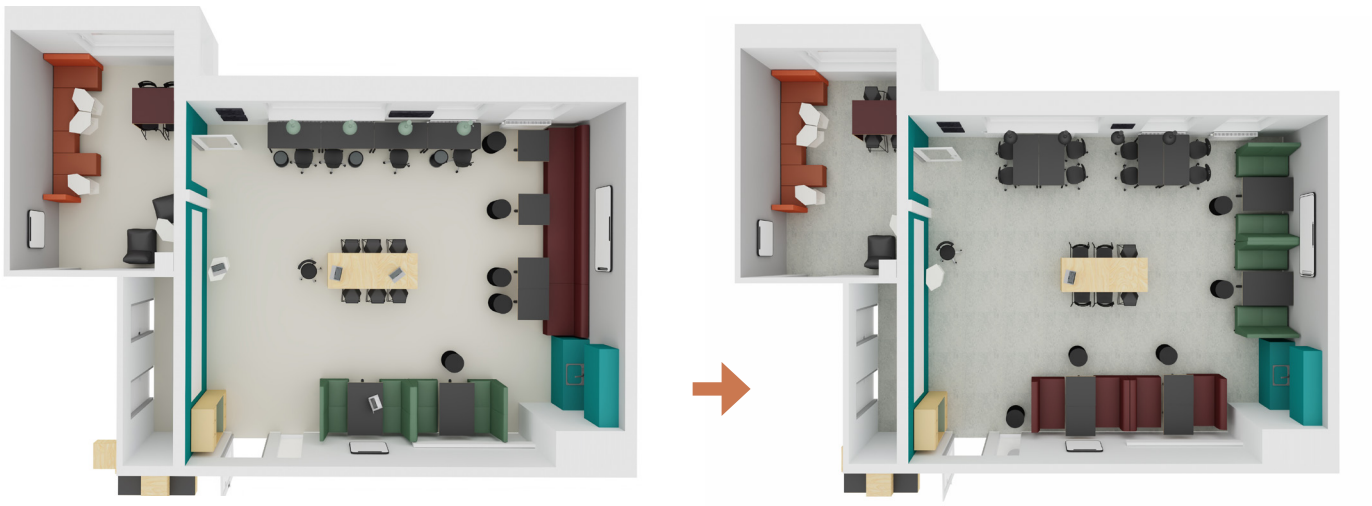
CONTROL VARIABLES

- **Temperature -** The collected data was within an acceptable range. ✓
- **Light quality -** The collected data was within an acceptable range. ✓
- **Air quality -** The collected data of carbon dioxide levels and humidity fell outside acceptable ranges. ✗
- **Class -** Did not negatively impact the results of the student survey. ✓
- **Gender -** Did not negatively impact the results of the student survey. ✓
- **Interest in the subject -** Did not negatively impact the results of the student survey. ✓
- **Opinion of the teacher -** Did not negatively impact the results of the student survey. ✓
- **Opinion of the school -** Did not negatively impact the results of the student survey. ✓

Phase 2: 3 May 2022 - 5 June 2022

As described in Phase 1, all data collection methods produced overwhelmingly positive results, validating the success of the case study, and confirming all our hypotheses. However, two out of our three data collection methods (survey and observation) identified some minor issues with the furniture arrangement in the classroom. We therefore decided to make the following four design changes in the subjective-specific classroom and allow the students and teacher to use the new furniture configuration for a month to see if the changes could contribute to even better results.

1. Move the green booth sofas to the back wall so that all students can see the whiteboard.
2. Move the red sofas to the right wall and position them facing each other to create two booth setups, facilitating group work and limiting the number of students per sofa.
3. Arrange the four window tables facing each other in two groups to facilitate group work.
4. Replace the four chairs from the small room (with backrests) with the four chairs from the central conference table (without backrests).



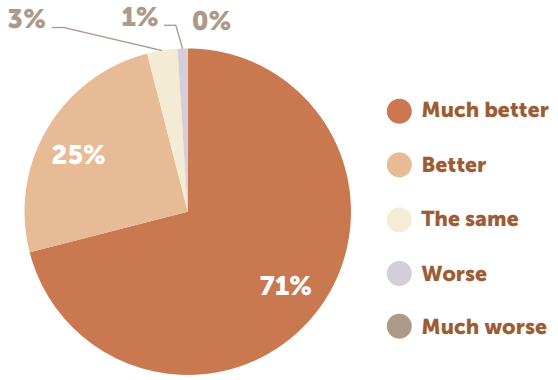
Since we only made minor adjustments to the existing furniture and used the same methods as in Phase 1, we will only briefly present the results of Phase 2.

Student survey results (Phase 2)

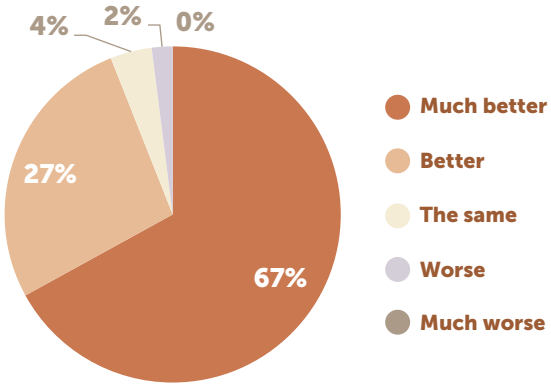
The same number of students participated in the second survey (92), with a similar distribution of girls, boys, and non-binary gender identities. The other control variables, such as students' opinions of the teacher, subject, and school, also yielded similar responses with no significant difference between the results of the two surveys. There was no significant difference in the answers to the three main questions (T1, T2, and T3) between the first and second survey either.

Difference between phase 1 and 2

Phase 1. Compared to your other traditional classrooms with regular individual desks and chairs, do you feel better or worse in Joakim's classroom?



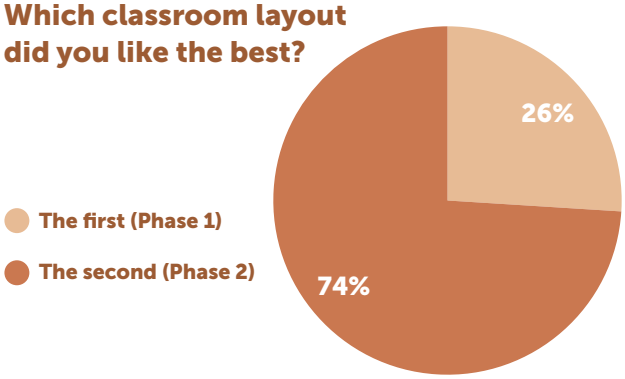
Phase 2. Compared to your other traditional classrooms with regular individual desks and chairs, do you feel better or worse in Joakim's classroom?



There was also no significant difference between the two survey results regarding where students chose to sit in the classroom and how often they changed seats. Most of the answers to the survey questions, which were identical to the questions in Phase 1, were not significantly different, which we did not expect since the changes we made to the room between the two phases were minimal.

However, when we asked the students which classroom layout they preferred, the second classroom layout was the clear favourite; 74% of the students liked it the most.

Which classroom layout did you like the best?



Students had different opinions on why they preferred the second classroom layout but better visibility of the whiteboard and improved space for group work were recurring answers.

"Because there is more space for group work, and that's what we mostly do."

"It is easier to see from all seats and it is easier to work when it comes to the tables."

"Because now you can see when sitting in the green sofas, and it was difficult to concentrate when sitting in the red sofas at the back. However, there are almost no places where you can work individually now."

"You can see the whiteboard better from the red sofas, the chairs in the middle are shorter so it's easier to see the whiteboard, and it's easy to work in groups by the windows."

"Because there is space for four people everywhere and we always have group work, and there is a better overview from all places."

Teacher survey results (Phase 2)

The teacher felt that both classroom layouts worked equally well, but that the first classroom layout worked best for individual work and presentations. The teacher was also convinced that the students preferred the first classroom layout, based on what he had heard from the students, and he argued that children generally do not like changes.

Survey conclusion

As expected, the surveys in phase 2 generally produced similar responses to the surveys in phase 1. Since we made only minor furniture changes between the phases, both the students' and the teacher's survey responses were generally positive and indicated that they were very happy in the classroom.

The only difference between the surveys was the added question about which classroom layout both the students and the teacher preferred. While the teacher was happy with both layouts but was convinced that the students preferred the first layout, it turned out that an overwhelming majority (74%) of the students preferred the second classroom layout.

Classroom observation results (Phase 2)

The observations took place in the following classes:

CLASS 7A Date 2 June 2022. Lesson duration and time: 80 minutes, 10:35-11:55. Number of students: 28. 7a primarily had individual work, and the lesson consisted of Introduction 10% and Individual work 90%.

CLASS 7C Date 1 June 2022. Lesson duration and time: 80 minutes, 13:50-15:10. Number of students: 28. 7c primarily had individual work, and the lesson consisted of 10% group work, 70% individual work (watching a film), and 20% discussion.

CLASS 7D Date: 1 June 2022. Lesson duration and time: 80 minutes, 10:25-11:55. Number of students: 26. 7d primarily had individual work, and the lesson consisted of Introduction/ Quiz 30% and Individual work 70%.

Just like for the first phase, the observation summary is written against the five hypotheses.

Hypothesis 1: The subject-based classroom facilitates group work, with at least 5 groups staying in the rooms (including group rooms) – WELLBEING, VARIATION

Based on the observations, it was evident that, like in Phase 1, virtually all students chose to stay in the classrooms. The seating groups (including the red ones) worked excellently for group work and were used by 4 groups. The central tables also worked well and were used by one group. The window tables, which were now turned towards each other, functioned excellently for 2 groups. In the small room, both the table and the sofa served as a group activity area and were used by both classes (except 7c, who watched a film).

Hypothesis 2: The placement of furniture in the subjective-specific classroom facilitates movement between activities for students and teachers, reducing disruption and creating better acoustics – WELLBEING, VARIATION

The observations yielded the same results as in Phase 1. Transitions between activities were quick and smooth. There was no chaos or noise in the classroom during activity changes since the furniture did not need to be moved. The acoustics in the room were generally good, and it was easy and convenient to rearrange. Joakim also moved around the room effortlessly and could easily reach the different groups.

Hypothesis 3: The classroom provides an interior that supports and inspires students to engage in discussions and debates – VARIATION, INDIVIDUALIZATION & SAFETY

The observations showed that the interior worked excellently for discussions in all classes. The students actively participated in the discussions from their seats. All students could also see each other, and the room had good acoustics. As more students sat at the central table in this observation phase (as fewer could fit in the red sofas), Joakim spent more time by the whiteboard. The four students who now had their backs to the whiteboard in the red sofas could easily turn around and face that direction when required. The students sitting around the window tables could also easily turn their chairs to have a clear view. However, as more students now sat at the central table, they slightly obstructed the view for the students in the green sofas when Joakim as standing by the whiteboard.

Hypothesis 4: The classroom's interior provides students with more seating options and different furniture to choose from, thereby increasing the sense of autonomy and comfort – VARIATION, INDIVIDUALIZATION & SAFETY

Based on the observations, it was evident that in all classes, like in phase 1, students had their favourite spots. The students waited patiently outside before start of class and then distributed themselves purposefully and evenly in the classroom. The lesson could start on time as very few students arrived late. The students distributed themselves relatively evenly, first between the sofas and then the window tables. The central table was taken last. Since the red sofas were now facing each other, only 8 students could sit in them (compared to 10-12 students in the previous phase), which led to a few discussions among the students about these seats. The teacher did not intervene in deciding who would sit where but intervened and resolved the seating discussion in two of the classes.

Hypothesis 5: The classroom, through an interior that supports the subject and has a clear identity, enhances the well-being of teachers and students compared to a traditional classroom with regular individual desks and chairs – WELLBEING, INDIVIDUALIZATION & SAFETY

This hypothesis could not be inferred from the observations.

Observation conclusion

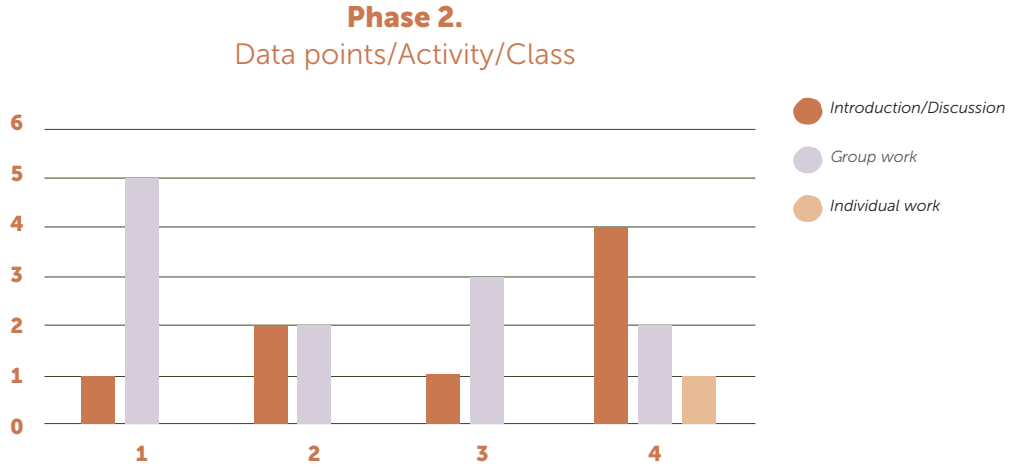
The second observation phase showed that the interior design again confirmed all our hypotheses and validated the success of the case study project. However, a few new minor issues were noted because of the design changes made after the first phase.

- A couple of students in the green sofas now had difficulty seeing the whiteboard as the students at the central table obstructed the view.
- With fewer students fitting in the red sofas, a few discussions about seating arrangements arose among students that were not observed during Phase 1.

Results of physical parameters (Phase 2)

Since we were able to conclude that the case study was a success already after the first phase and only made minor adjustments to the furniture arrangement, we opted for a shorter testing period in Phase 2, resulting in fewer recorded data points and activities. As expected, the physical parameters in the second phase showed no significant differences compared to the first phase.

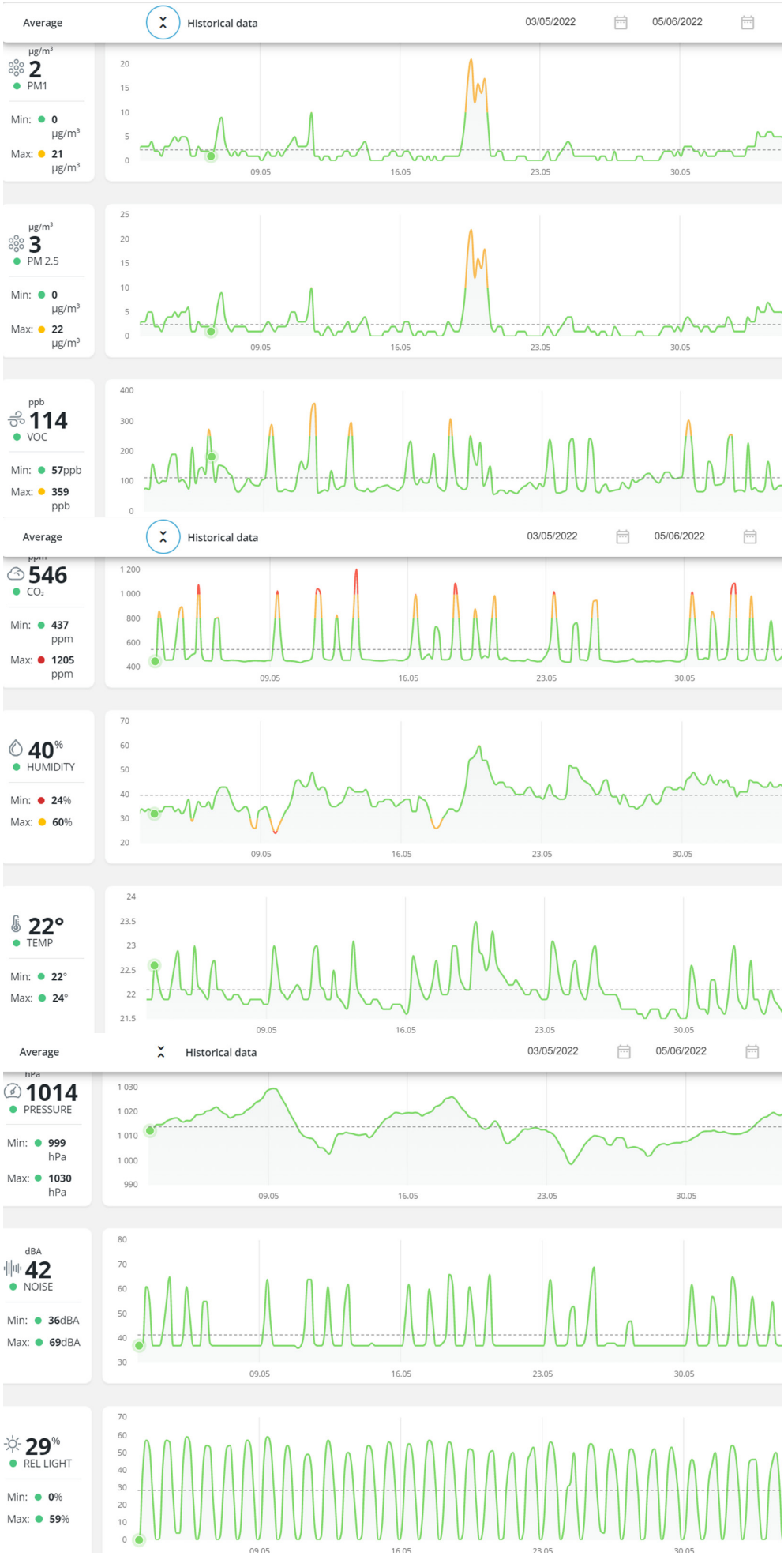
PEOPLE COUNTER. The people counter and activity logging also functioned satisfactorily in the second phase, with 21 activities recorded and a slightly higher average number of 24 students.



Phase 2: 9 May - 2 June 2022, (21 data points, average number of students 24).
The activity 'Group work' was the most frequent during this measurement period, while 'Individual work' hardly occurred at all.

MOVEMENT PATTERNS. The movement pattern parameter had the same limitations as in phase 1 and could therefore only be used to provide an overview of general movement pattern trends in the classroom. No noticeable difference between movement pattern data from phase 1 and phase 2 could be discerned, and the data showed that students, regardless of class, had similar movement patterns at entry, during class time, and at exit.

TEMPERATURE, AIR QUALITY, AND LIGHT. The graphs below show the results from the data collection of temperature, air quality, and light quality for phase 2, with an average for each parameter in the left column.



As the graphs show, all parameters generally remained within acceptable levels, including humidity in this phase, except for the carbon dioxide value, which still exceeded the acceptable level. The carbon dioxide concentration went above the recommended 800 ppm, resulting in poorly oxygenated air.

SOUND. As per phase 1, all classes had a similar acceptable sound level with an average of 42 dB during all three different types of activities, as illustrated in the graph below.

Physical parameters conclusion (Phase 2)

The control variables of temperature and light level remained within acceptable levels in phase 2 and subsequently any negative impact on the students' and teachers' experience of the subject-based classroom could be excluded. The sound level also remained within an acceptable range, indicating a continued successful design implementation as the project's second hypothesis aimed to reduce the sound level in the classroom. As in phase 1, the carbon dioxide level was too high, indicating the need for occasional ventilation.

The activity logging in phase 2 showed a higher frequency of group work, which was more consistent with the teacher's initial estimation at the start of the project.

As in phase 1, the movement pattern measurement was difficult to interpret in a useful way as it was not possible to distinguish individual students from each other or the teacher from the students. The usability of data from this parameter was therefore limited.

Final conclusion

Even though the observation method in the second phase still identified a few situations where a small number of students wanted to sit in the same areas, nearly three-quarters (74%) of the students preferred the improved furniture configuration in phase 2.

We can subsequently conclude that the subject-based classroom we designed met the criteria of the case study in creating a classroom that aligned with the learning environment and pedagogy, as well as increased the students' and teachers' well-being, security, variation, and individualization. We can also confirm that our method of collecting data in two phases contributed to implementing improvements based on our data analysis after phase 1, which could be further analysed and evaluated in the second data analysis following the completion of phase 2.

CHAPTER 6

Evaluation of the data collection method

How well did the method triangulation work?

Confirmation of results

As expected, the method triangulation allowed the results from each individual data collection method to be supported by the results from one or both other data collection methods. Generally, the method triangulation worked well and provided confirmation for all our hypotheses with relative certainty as the results from at least two data collection methods aligned.

OBSERVATION = PHYSICAL PARAMETERS

Hypothesis 1 could be confirmed with relative certainty as data from the observations and the person counter combined with the activity logs both confirmed that students mostly stayed in the classroom during the lesson.

Hypothesis 2 could also be confirmed with relative certainty as data from the observations and the noise level measurement both confirmed that the acoustics in the classroom remained objectively acceptable and subjectively pleasant.

STUDENT SURVEY = TEACHER SURVEY = OBSERVATION

Hypotheses 3, 4, and 5 could all be confirmed with relative certainty as the results from both the student survey and teacher survey, as well as the observations, all confirmed that the students enjoyed the classroom, and that it contributed to increased well-being, safety, individualization, and variation.

Refutation of results

The strength of method triangulation is not only that different data collection methods can affirm each other's results, but also that different data collection methods can refute each other's results. In our case study, the method triangulation resulted in the identification of several results in individual data collection methods that were misleading.

STUDENT SURVEY ≠ TEACHER SURVEY

The teacher was convinced that the students preferred the first layout of the subject-based classroom because they had become accustomed to it, and he argued that children generally do not like sudden changes. However, the student survey showed the opposite to be true; the students preferred the second layout of the classroom with an overwhelming majority of almost three-quarters. If we had only relied on the teacher's perspective, we would have based our conclusions on incorrect information.

MOVEMENT PATTERNS ≠ SURVEY + OBSERVATION

According to the data from the movement pattern monitoring, the small room was rarely used. However, data from both the observations and surveys painted a different picture. According to both these data collection methods, the small room was generally used by at least one group of students in each class. In other words, the small room served its intended purpose. If we had solely based our evaluation on the movement pattern data, we would have likely drawn incorrect conclusions.

Conclusion

The method triangulation worked well generally, but a few measures could have been taken to improve its effectiveness and precision.

1. Develop hypotheses that align with the project's specific criteria and goals and allow the hypotheses to guide the selected the data collection methods.

This was mostly done in our project but could have been improved further. A specific hypothesis focusing on students' comfort in the classroom should have been included, and a more specific and accurate way of interpreting movement patterns in the classroom would have been beneficial.

2. If the project consists of more than one phase, allocate proportional time to each phase.

The timeline of our case study meant that students and the teacher only had the opportunity to use the classroom layout for one month in the second phase, compared to four months in the first phase. In our case study, the difference between Phase 1 and 2 was small, only involving minor practical furniture adjustments, as we had already been successful in confirming all our hypotheses in Phase 1. It was therefore not a major issue in our case study, but it could theoretically have been a large potential problem. In future projects, each phase should be given proportional time.

3. Involve multiple teachers.

Only one teacher participated in our case study. This teacher was highly motivated and engaged, working in close collaboration with Lekolar and Atea throughout the project. Whilst this was invaluable, it meant that we could only gather data from one teacher's perspective of the classroom. In future projects, it would be advisable to involve more than one teacher using the relevant learning environment, to consolidate multiple teachers' individual perspectives.

How well did each individual method work?

HOW WELL DID THE SURVEY METHOD WORK?

The survey method was the most effective data collection method for evaluating goal 2 in the case study, which focused on understanding the subjective experience of students and the teacher in the subject-based classroom. Three out of five of our hypotheses were focused on this goal. The survey method generally worked well; it was easy to distribute, completed by most students, and collected a significant amount of quantitative data that allowed us to confirm several of our hypotheses with relative certainty.

However, a few weaknesses regarding how the survey questions were developed were identified. To improve the survey method and the quality of the data collected next time the method is used, the following should be addressed:

HOW WE MEASURED STUDENTS' EXPERIENCE OF THE CLASSROOM.

We asked students how they experienced the subject-based classroom "compared to a traditional classroom with regular individual tables and chairs." Asking this type of unspecific comparative question can be considered somewhat leading, and highly subjective. It is reasonable to assume that students' internal image of a "traditional classroom with regular individual tables and chairs" varied significantly based on their previous experiences. It would have been better to compare the subject-based classroom with another specific classroom in the same school that all students had also used to make for a more consistent and uniform comparison.

HOW WE DETERMINED IF THE PROJECT GOALS WERE MET. We considered that the project goals were met and that our hypotheses were confirmed based on the survey questions about well-being, safety, individualization, and variation, all of which received overwhelmingly positive responses (over 90% chose the most positive or second most positive response option for all questions). However, we had not established a baseline or a general level of success. For example, if we had included the same questions about another specific "regular" classroom in the survey, we could have used those responses to establish a baseline, and then make an informed and calculated decision on where the success level should be set. For instance, if 40% of students gave a positive answer regarding their well-being in a specific "regular" classroom in the school, we could say that 70% of students would need to give a positive answer regarding their well-being in our designed subject-based classroom for it to be considered a success.

HOW WELL DID THE OBSERVATION METHOD WORK?

The observation method was the most effective method for evaluating goal 1 in our case study, which focused on how well the designed learning environment aligned with pedagogy and how well the design of the classroom functioned practically and physically. Whilst the observation method was time-consuming and therefore relatively expensive, it resulted in rich and valuable data. However, a weakness regarding who performed the observations was identified:

WHO PERFORMED THE OBSERVATIONS. In our case study, all observations were conducted by a single person; the project's spatial designer. It is a good idea to assign the observation role to someone from the team who designed the room layout because that person knows the purpose behind every design choice and can therefore systematically and in precise detail conduct the observation. However, there is a risk that a person from the design team may have a natural bias and unconsciously focus on, and potentially exaggerate, aspects that can confirm the project's hypotheses, while aspects that could refute the hypotheses might be ignored. This problem can be addressed by using more than one observer. At least two observers should be used, one from the design team and one from the research team. This way, the observation results from each observer can be compared to identify unconscious bias and increase the objectivity of the measurement method.

HOW WELL DID THE PHYSICAL PARAMETERS WORK?

The physical parameters, including activity logging, people counter, movement patterns, noise level, and control parameters, functioned as an effective complementary method in the triangulation model. Since the surveys and observations were subjective measurement methods, the physical parameters served as an objective method that could corroborate the results of the other methods, primarily related to the first goal of matching the learning environment with the pedagogy.

The noise level measurement and control parameters worked well, and the students participated in the data collection method using their phones (QR code) to remind the teacher when it was time to open a window, for example. The people counter supported goal 1 in showing that most students stayed in the classroom during group work.

However, a few limitations in the data collection from the other measuring instruments were identified and should be addressed for future projects:

ACTIVITY LOGGING AND THE ROLE OF THE TEACHER. The teacher was the only one logging the activities through an app on a specific mobile phone provided solely for this purpose and not used otherwise. It was found that the teacher forgot to log activities (compared to the planned schedule) or logged them late (after the activity change), creating measurement uncertainty. This uncertainty could potentially have been avoided by logging activities in an easier way using already used technical equipment. The uncertainty could also have been reduced by involving more than one person to log activity changes (e.g., one or a few students in each class).

FUNCTION OF THE MOVEMENT PATTERN MEASUREMENT (HEAT MAP).

When analysing the data from the heat map, it was found that intense movement from a few students was marked as "red activity" on the heat map. The teacher allowed significant mobility of the students in the class and students from other classes to enter the classroom during class time, making it difficult to measure goal 1. As the room was also small relative to the number of students present in the classroom simultaneously, it was challenging to discern specific movement patterns in the classroom. Whilst this measurement method would likely be effective in a larger area of a school, such as measuring bottlenecks or dead spaces, this type of measurement instrument was not suitable for the physical size of the subject-based classroom in our case study.

LIMITATIONS IN DATA ANALYSIS. Aggregated data was used for data analysis, and trends were examined using a sample when it was not feasible to include all data points in the analysis. For a complete data analysis of all collected data, automation would be necessary. However, this would require a larger budget and more time.

CHAPTER 7

Next steps

How can this project be developed into a functional and effective service?

The goal of this report and the project ”Learning from Learning Environments” was to examine how we could develop an evidence-based service to optimize the learning environment in schools, increase well-being, safety, variation, and individualization through data collection of movement patterns, physical parameters, surveys, observations, and spatial understanding. This report, our first step towards developing an evidence-based service, aimed to test a method (triangulation) by measuring a specific learning environment (the Toftanässkolan case study) and evaluating the need for and usefulness of the collected data.

The method triangulation we used worked well for measuring and analysing our case study, confirming our hypotheses with relative certainty when the results from at least two data collection methods generally corresponded. However, the evaluation of individual measurement methods revealed that they ought to be further improved through standardization.

Standardization of measurement methods

Several standardization points that we will carry forward into the next step of developing ”Learning from Learning Environments” are listed below.

SURVEY

- Evaluate, improve, and standardize the survey questions for goal 2 (increasing well-being, safety, individualization, and variation), as well as the control questions.
- Establish a baseline for the survey questions related to goal 2. This could be achieved by conducting a large-scale student survey covering schools across Scandinavia to understand how students currently perceive their well-being in different types of classrooms. A cheaper and faster solution is to investigate if research on this topic has already been conducted and if so, use existing data to establish a baseline.

OBSERVATION

- Evaluate, improve, and standardize all observation points.
- Evaluate the optimal number of observations and observers depending on the project’s size.

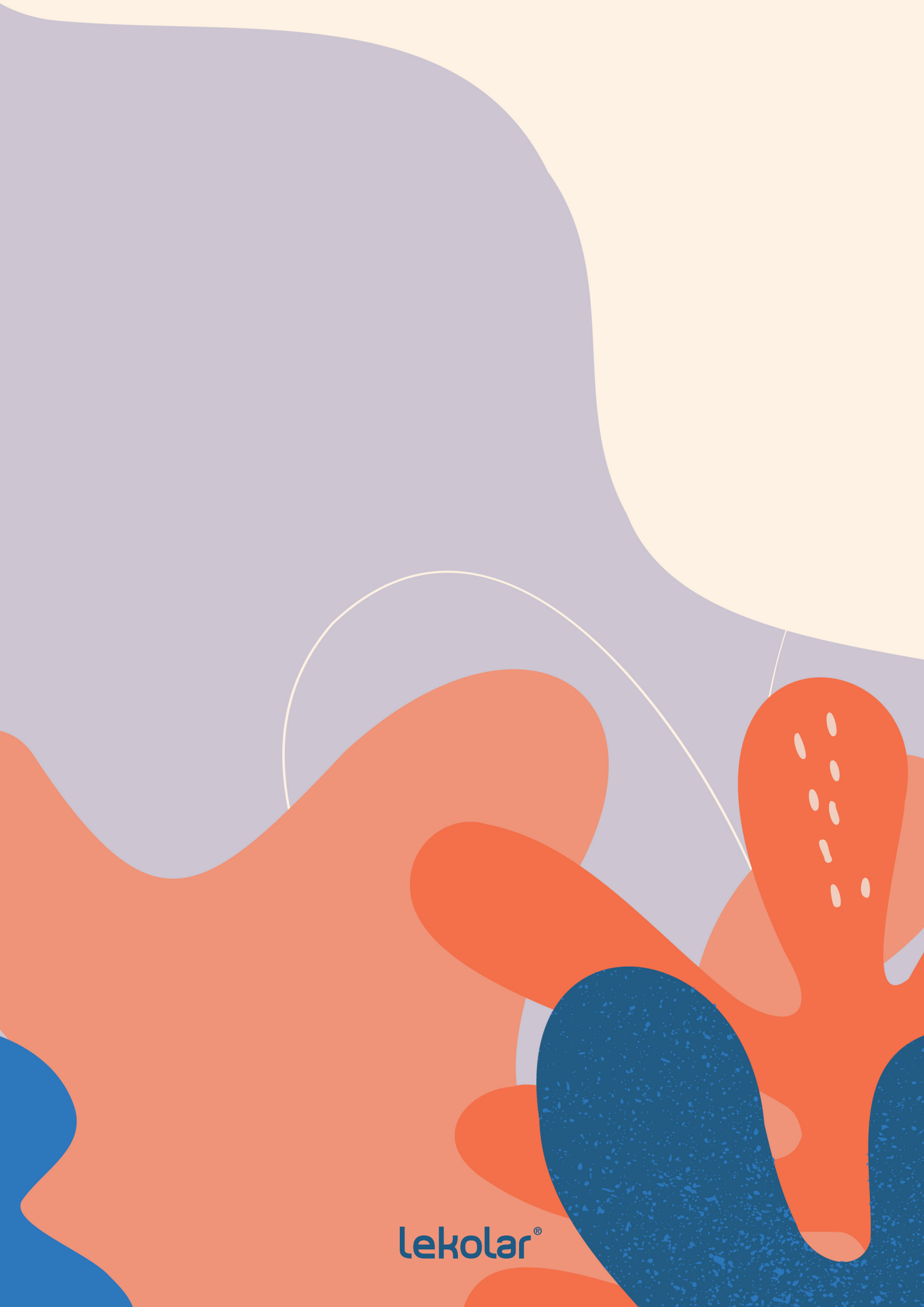
PHYSICAL PARAMETERS

- Evaluate, improve, and categorize all physical measurement methods.
- Determine the number of times each measurement method needs to be conducted to confidently confirm that the collected data provides a general picture of the physical parameters in the classroom. For example, should we measure sound, light, air quality, and temperature in different conditions (time of day, different weather, and different seasons)?
- Evaluate the precise need for movement pattern tracking. Does it potentially only work in larger spaces to measure for example bottlenecks or unwanted activity?
- Evaluate the need, optimization, and simplification of activity logging.
- Investigate standardizing schedule logging in relation to movement patterns (tracking) in larger spaces.
- Explore the automation (programmed) measurement analysis and its potential complexity and cost.

CASE STUDY

- Expand the case study to involve multiple schools with different locations and profiles.
- Involve a larger area of the schools with more general and subject-based classrooms.
- Engage more teachers using the same classroom layout.
- Measure any potential changes in student attendance and academic performance (well-being).
- Measure any potential increase in teachers' well-being.

Our next step is to standardize our method and apply it to a larger and more complex case study involving more schools, areas, students, and teachers. Ultimately, our goal is to develop an advanced data collection method that can evaluate and suggest adaptations for the entire school environment, ensuring that the learning environments we provide achieve the best possible outcomes in terms of well-being, safety, variation, and individualization, thereby creating an optimal workspace for both students and teachers according to their needs and creativity.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