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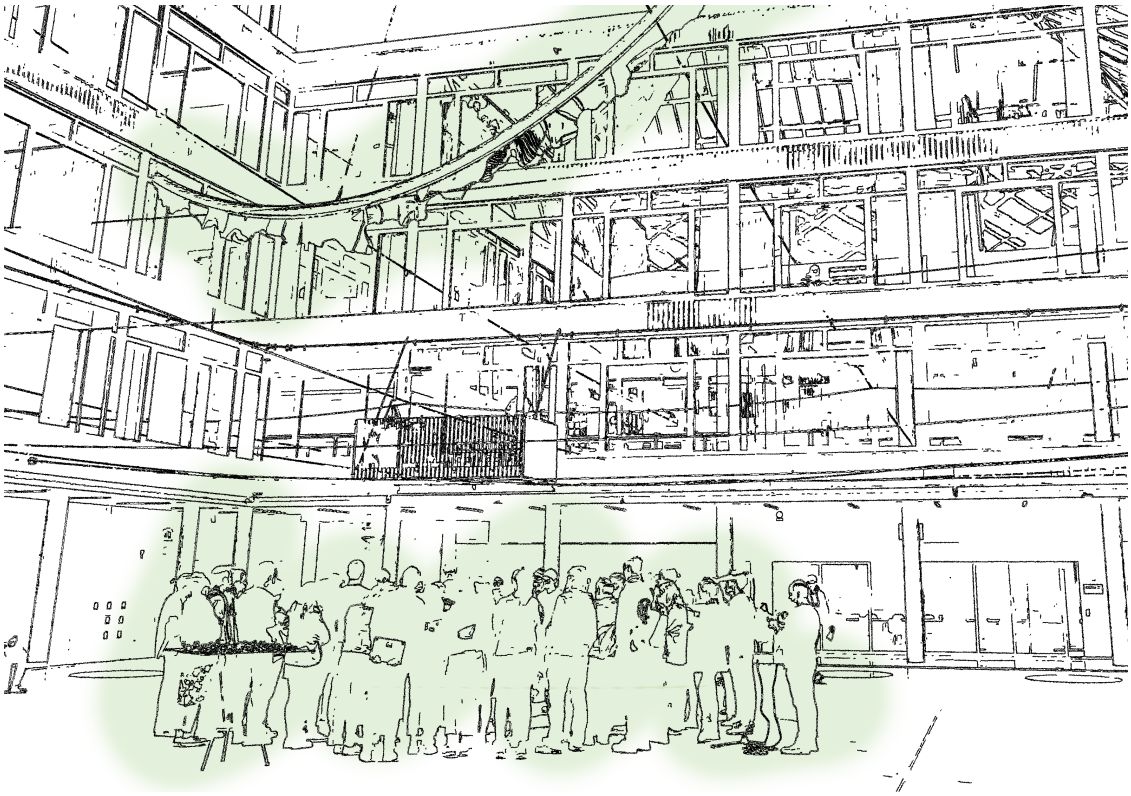

Architecture and Learning

The role of physical space in educational settings

Master's thesis in Master Programme Learning and Leadership

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Department of Communication and Learning in Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020

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Cover: Image of a group of people standing in the physical learning space.

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Abstract

The engineering education is in the midst of transformation, and with that, a need for new learning environments arises. This study investigates the impact of the physical space on perceived learning, through the perspective of engineering students in higher education. It uses the lens of Challenge-based Learning in the strive to give recommendations for the future design of learning environments. To accomplish this goal, an engineering course was followed and assessed using direct observations, student and instructor surveys, and a student focus group interview. The questions were designed around planning and execution for the instructor surveys, and identified environmental factors of the physical space as well as defined learning for the student surveys and interview. The observations were used to document the factors of the physical space and the use of, and activities taking place within, the physical learning environment. The results of the study indicated an effect of physical space on perceived learning, where specific factors showed to influence specific parts of the defined learning. It was concluded that the physical space was one of three actors with power to influence learning, with the other two being identified as pedagogy and instructor. This study emphasises the importance of considering what type of learning is intended for the physical learning spaces, both in architectural design and evaluation, as the interaction between pedagogy and space was the focal point of the conclusion.

Keywords: space, perceived learning, engineering, education, CBL, learning environment, pedagogy, instructor, architecture, design.

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Jonas Bergström & Angelica Lindberg, Gothenburg, May 2020

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Acronyms

ALC active learning classroom.

CBL Challenge-Based Learning.
CELE the Centre for Effective Learning Environments.

LEEP Learning Environments Evaluation Programme.

OECD the Organisation for Economic Co-operation and Development.

POE Post-Occupancy Evaluation.

Glossary of Terms

learning environment The result of interactions between the physical space and the social world consisting of learners, educators, content and policy.

physical learning environment The part of the learning environment which consists of the physical space.

physical space The physical room that is defined through elements such as walls, lighting, geometry and materials.

traditional classroom A learning space where the standard configuration is seats arranged in rows, facing a teacher desk and whiteboard/chalkboard/projector screen at the front of the room.

workshop Has a specific theme and typically involves a number of activities such as lectures, discussions, presentations and group assignments where the theme is explored.

Zoom A cloud-based online chat and video meeting service used for telecommuting and distance education.

1

Introduction

1.1 Background

During the past century, the role of the engineer as well as the demands from companies and employers have changed tremendously, while the engineering education more or less has stayed the same (Rugarcia, Felder, Woods, & Stice, 2000). It has been called outdated and unfit for producing engineering graduates that possess the skills and abilities required. According to Rugarcia et al. (2000), the engineer of the 21st century is not only required to obtain independence, learning, creative thinking and problem-solving skills, but also interdependence, teamwork, communication and self-assessment skills. These skills are not easily learned by studying them theoretically. Instead, engineering students should be put into contexts where they can practice these skills and gain the experience sought by their future employers. Rugarcia et al. consider the only solution for this issue to be a rewrite of the engineering education curriculum. One way of doing this is by introducing Challenge-Based Learning (CBL); a practice-oriented educational model developed during the last decade and derived from the concept of Problem-based learning (Malmqvist, Kohn Rådberg, & Lundqvist, 2015).

The CBL model emerged as the result of a project initiated by Apple in 2008, called Apple Classrooms of Tomorrow - Today, which had the purpose of developing design principles for the 21st-century learning environments (Nichols, Cator, & Torres, 2016). Malmqvist et al. (2015) define a CBL experience as "a learning experience where the learning takes places through the identification, analysis and design of a solution to a sociotechnical problem. It is typically multidisciplinary, takes place in an international context and aims to find a solution, which is environmentally, socially and economically sustainable".

In the spring of 2020, a project called Tracks has been launched at the Chalmers University of Technology, which aims to implement CBL into the engineering education. As part of the Tracks initiative, new learning environments will be created to meet the needs of Tracks courses (*Tracks – learning and teaching environment | Chalmers studentportal*, n.d.). However, these were not yet finished by the time the first courses started.

As the CBL education model is a rather new concept, there is a need for additional research to help understand how to design appropriate learning environments. For that reason, this master's thesis could provide valuable information about how

students and teachers are likely to use different learning environments. Just as Cleveland and Fisher (2014) state that the feedback from learning environment investigations could help designers to make informed decisions when creating new facilities, this study might aid the design of new spaces suitable for Challenge-Based Learning (CBL).

Apart from Tracks, there are other similar projects which aim to develop contemporary learning environments which meet the needs of a more practice-oriented pedagogy. In general, universities across the world are moving towards developing learning environments that better promote interaction between students and teachers as well as flexibility, and thus moving away from a more traditional approach that is teacher-centred and primarily promotes lecture mode. According to Borch et al. (2016), most of recent research is pointing towards an understanding of the learning facilities as an arena for collaboration, problem-solving, creativity and application rather than a place for students to obtain knowledge through merely listening to teacher-led lectures.

Three projects were identified as particularly interesting to investigate:

- the active learning classroom (ALC) at the University of Gothenburg, since the earlier phase of this investigation showed that ALC is a term that is often occurring in the context of practice-oriented learning environments.
- the DTU Skylab, as it was named by Tracks themselves as a source of inspiration in the upcoming design work.
- the Learning Lab, an innovation project run by Akademiska Hus, since it was located in close proximity and would be one of the most contemporary projects looking to investigate the relationship between physical space and learning.

These projects were investigated to understand the context of contemporary learning environments and also to get an understanding of what motivates their design. The two projects located in Gothenburg were visited as part of this study, however due to prevailing circumstances, the planned visit to DTU instead turned into an online meeting. The respective learning environment is described below.

1.1.1 The University of Gothenburg

At the University of Gothenburg, ALCs have been implemented for education since the beginning of 2016, inspired mainly by the University of Minnesota (Alfredsson, 2017). An example of such a classroom can be seen in figure 1.1, showing how the classroom is designed to be student-centred through the use of round tables. Beside each table there is a digital screen and whiteboard, enabling groups to present their work to each other.

Figure (1.1) ALC at the University of Gothenburg.

After implementing the first ALC, at the University of Gothenburg, interviews with focus groups were carried out to get an understanding of how the teachers and students experienced the learning environment. The teachers stated that there was a notable increase in the activity level in the ALC, both for the students and themselves, compared to the activity level when teaching in other classrooms. The students experienced that the learning space had a relaxing effect, and at the same time demanded engagement. Earlier research show how the round tables and the position of the teacher in the centre of the ALCs increase the level of engagement as well as the level of interaction, both between students and between students and teachers. Apart from the impact of the physical space itself, several studies show that the design of learning activities and task content is of great importance for the learning experience and activity of the students in ALCs. (Alfredsson, 2017)

1.1.2 DTU Skylab

DTU Skylab is a 2500 m^2 living lab for innovation and entrepreneurship and was established 2013 as part of the Technical University of Denmark. Here, "students, researchers, and corporate partners meet to exchange knowledge and develop visionary solutions for real-world challenges" (DTU Skylab, 2019).

DTU Skylab strives for openness, where people can meet across disciplines to share and learn from each other. The idea is that the place would be filled with people all the time, accommodating student-driven courses, start-up support and collaboration area with actors from the industry. The facilities contain spaces such as wood and machine workshops, open co-creation space, the auditorium in the form of a large flexible floor, electronic lab, incubator project rooms and other rooms for meetings and group work, see figure 1.2. According to Hussmann (Personal communication, 2020-04-22), team leader at DTU Skylab, the space is very important for the activities as some courses are more or less designed to be there. The space is seen as an actor, influencing teachers to lecture less, promoting group work and more of a student-driven approach in curricular courses.

Figure (1.2) Learning spaces at DTU Skylab. (Stamer, 2015). Reprinted with permission.

1.1.3 Learning Lab

Learning Lab is an innovation project run by Akademiska Hus at the campus area of Chalmers University of Technology. The lab was opened in the spring of 2020 and is part of the work to develop learning environments of the future, together with its users (Akademiska Hus, 2018). People from a large range of professions have been involved in the process of creating the lab, including architects, teachers, light designers, brain experts, IT-specialists and scenographers. Together they have designed an arena open for teachers, researchers and other stakeholders who want to explore the relationship between physical space and learning. The goal of the project is to create an evidence base for how environmental factors such as light, digital tools, furnishings and sound can affect learning, creativity and health (Akademiska Hus, 2018).

Learning Lab consists of three different rooms: a makerspace; a flexroom; and a studio. The furnishings in the different spaces are movable and flexible. In the makerspace, new ideas can be tested through building, prototyping and workshops. In the flexroom, writable glass boards and movable touch screens promote active learning. The largest room is the studio space, shown in figure 1.3. It is equipped with tools that enhance the learning conditions of the room, enabling different types of workshops and meetings. For example, there are box stools which can be used as a stage, to sit on or as tables by stacking them. Furthermore, entire walls of the room can be used for projecting images that together with light and sound equipment create a unique ambience for the learning activity taking place (Tengbom, n.d.).

Figure (1.3) The Studio in Learning Lab, a large flexible room which is to be used for exploring the impacts of environmental factors on learning.

1.1.4 The Learning Spaces Studied

The learning spaces that were part of this study is presented below. A description of details and specifications for each learning space can be found in Appendix A.1. The information about each space is derived from observations and complemented through floor plans and section drawings of the spaces, received from the property owner Akademiska hus.

The Acoustics Lecture room: a traditional classroom, featuring dual chalkboards stacked on top of each other, and a projector screen in the corner. It has one window facing the corridor.

Ljusgården: an indoor courtyard with balconies hanging from the above floors. It has a glass ceiling shaped like a pyramid, which lets in much daylight. The space is often used as a place to display and show off creative creations made by students. It is positioned in direct contact to the entrance area of the building, as well as classrooms on all floors.

Ateljén: an art studio, which is partly open through two floors, with a mezzanine at one side. The idea for the space is to be flexible, which is why furniture is folded and stored in the storage area below the mezzanine. It has an industrial appearance and much open space.

1.2 Aim

By examining which factors of the physical space affect the learning, as experienced by the students, the project aims to give recommendations for future development of the physical learning environment for Challenge-Based Learning.

As the learning environments assessed in this study are not designed specifically for the type of learning intended for CBL, the project provides a foundation for future assessment studies of the new learning environments once they are completed, as they can be compared with the findings of this study.

1.3 Research Questions

Based on the aim of the study, the questions that were to be answered in this project are as follows:

1. How does the physical space impact Challenge-Based Learning?
2. Which specific factors of the physical space might affect perceived learning, and to what extent do they affect it?
3. What can be done in the design of the physical space to increase Challenge-Based Learning?
4. How can this study help subsequent studies to further investigate the impact of physical space on learning in newly designed facilities?

1.4 Limitations

The learning environment referred to in this study includes fixed factors such as light, space type and space dimensions, but also how these factors affect the social interactions and movements within the classroom. The study includes the physical learning environment on campus, more specifically the individual rooms for lectures and workshops. It does not include aspects of accessibility. Other spaces for learning such as cafes, students' residences and public libraries are not included in the study. The data collected in the study is limited to the time frame of normal working hours, thus learning activities taking place on evenings and weekends are not included.

Due to the effects of a pandemic outbreak, a decision was made by the Swedish government in the spring semester of 2020 to continue all education at Swedish universities through online platforms. The limitations of this study were therefore slightly adjusted, meaning that the impacts of digital space on learning is included in the study.

The concept of CBL is used both for primary and secondary school, as well as at the university level (Malmqvist et al., 2015). However, this study only looks at the physical learning environment of CBL in the context of higher education.

Data is collected from one course, taught at two levels, namely: TRA100 Tracks Projects Basics and TRA105 Tracks Projects Advanced. The different levels are directed towards bachelor students and master students respectively.

The reliability of the result is affected by the difficulty to isolate the interaction between the physical space and the learning taking place. There could be social and psychological factors affecting the learning which are not highlighted in the study.

Another limitation is to what extent students and educators are aware of the diverse aspects of their physical surroundings while using the space. There is a possibility that the study created a non-neutral process for the students, thus affecting the way they reasoned when participating in the study. Additionally, the validity of the result could be limited due to the educators' unfamiliarity with the concept of CBL and learning outcomes of the new Tracks courses. It was the first time they carried out this type of course spanning over different disciplines.

2

Theory

This chapter aims to create an understanding of the impact of physical space on learning, which is done in a three-step process. The first step investigates what learning means within the context of engineering education. The second, which factors of the physical space that need to be considered when designing the study. The last part of the chapter then investigates how physical learning spaces are evaluated and how this type of data is collected.

2.1 Desired Learning

To examine how the physical space impacts learning, the desired learning outcomes need to be defined. Tracks aims to meet the demands set by society (*Tracks – learning and teaching environment | Chalmers studentportal*, n.d.), but what do their students then need to learn? This question was explored through first understanding what is wanted from society of an engineering graduate, in what way this is met by higher education and how Tracks as a project expresses the goals of their courses.

2.1.1 Required Competences for Engineering Graduates

According to Binkley et al. (2014) and Rugarcia et al.(2000), the competence engineering graduates should possess can be divided into *knowledge*; the fundamental information and strategies the student needs to learn, *skills*; abilities which the education should enable them to pick up from tasks and challenges, and *attitudes and values*; the culture around what it means to be an engineer. Rugarcia et al. (2000) acknowledge that, even though it is no longer possible to present the students with everything they might need to know in their later careers, they still need to be presented a core set of engineering fundamentals. Beyond this core information, Binkley et al. (2014) believes that engineering students should learn strategies for reasoning, evaluating and reevaluating when presented with new or unfamiliar information. They should be taught how to become life-long learners (Rugarcia et al., 2000) by learning how to identify gaps in knowledge, and learn what questions to ask (Binkley et al., 2014).

Rugarcia et al. (2000) divide the skills engineering students need to obtain during their education into seven categories:

1. independent, interdependent and life-long learning skills

2. problem solving, critical thinking and creative thinking skills
3. interpersonal and teamwork skills
4. communication skills
5. self-assessment skills
6. integrative and global thinking skills
7. and change management skills

Binkley et al. (2014) mention the same ideas, but instead make the division between effective reasoning and systems thinking.

According to Rugarcia et al. (2000) it is the values, attitudes and ethics that stay with the student the longest after they completed their education. The engineering graduates should leave university with a willingness to participate (Rugarcia et al., 2000), an openness to unfamiliar or different views and to reconsider their own views (Binkley et al., 2014). They should be involved in the service of others and have a concern for environmental, social and economical sustainability (Rugarcia et al., 2000).

2.1.2 The Definition of CBL and Learning in a Social Context

The pursuit to move away from the presenting of information and towards the obtaining of skills that in many cases are hard to learn theoretically through traditional lectures means that different institutions have started to create new methods for teaching. The method Tracks originates from is CBL. CBL is a practice-oriented educational model, which focuses on real-world problems and challenges (Nichols et al., 2016; Malmqvist et al., 2015). Students learn by identifying, analysing and designing solutions. It is value-driven, the context is typically global and the solution should be environmentally, socially and economically sustainable (Malmqvist et al., 2015). Both multidisciplinary and interdisciplinary are terms used in the context of CBL, however Richter and Paretti (2009) differentiates them. They define a multidisciplinary team as one where people from different areas work on a common problem, yet still separately, without much information being exchanged. They leave the collaboration unchanged. In an interdisciplinary team, however, the participants work closely together. Their knowledge is integrated and they leave the collaboration all having evolved.

With the focus on teams, the social aspect of learning should be considered as well. There is a clear social nature of learning. The Soviet psychologist and educationalist Lev Vygotskij (1896-1934) stressed that much of what we learn we learn from others (Phillips & Soltis, 2014). John Dewey (1859-1952), philosopher and educationalist, described the school as a community where purposeful activity in a social setting was essential for effective learning. To avoid learning by rote, according to Dewey, instructors should not merely tell the students about new concepts. Such an approach is considered ineffective if the goal is to help students understand the relevance of a new idea and its connections to other ideas. Instead,

the role of the instructor should be to participate in collective learning experiences with the students, investigating common interests (Phillips & Soltis, 2014). This is something that differentiates CBL from traditional teaching approaches, as with a CBL approach, teachers move from merely being information experts to also becoming co-learners, who seek new knowledge and new ways of thinking together with the students (Nichols et al., 2016). This was considered the optimal way of understanding new concepts when learning takes place through interaction and engagement among learners in social contexts. Learning is then perceived to be more meaningful as the learner practices their problem-solving ability and easier can transfer the knowledge to new contexts and other types of future problems (Phillips & Soltis, 2014).

2.1.3 Learning Outcomes of Tracks

The Tracks courses aim to provide a "platform to work and solve challenging multidisciplinary authentic problems in teams and to learn to function efficiently in global teams" (Chalmers University, 2020a, 2020b). The general learning outcomes stated in the syllabi of Tracks courses have been retrieved from the student portal of Chalmers University and are summarised in Appendix A.2. The learning outcomes state the skills the students should possess after the completion of the course, and these were taken into consideration when investigating the meaning of learning in the context of this study.

2.2 Environmental Impacts on Learning

The term 'learning environment' has not always been primarily referring to the physical rooms for learning, but rather to social and psychological factors such as the 'interpersonal climate' in learning spaces (Weinstein, 1979; Cleveland & Fisher, 2014). Up until the 1970s, the general idea was that students' learning merely was affected by social, pedagogical and psychological factors as long as minimum requirements for the building conditions were met (Weinstein, 1979). However, as Weinstein explains, from the 1970s educators began questioning if there possibly could be other factors of the physical space that could have an impact on learning. Since then, research within the field has been developed, and the discussion continues regarding the relationship between physical space and learning (OECD, 2019). Still, the research and literature in the area is quite limited (Hunley & Schaller, 2009). Furthermore, there is an evident complexity for researchers attempting to find causal relationships; the difficulty of isolating the impacts of physical space from other factors that may influence learning (Weinstein, 1979; Cleveland & Fisher, 2014).

Regardless of the direct impacts of the physical environment on learning, there exists a mutual interaction between the physical space and its users, as it can either encourage or inhibit behaviour. According to Hunley and Schaller (2009), the physical space can support the needs of its users, or cause difficulties to fulfil their needs.

The physical learning environment is seen to provide conditions that improve students' learning, for example through supporting cognitive and physical health, as well as mediate social relations (OECD, 2017; Cleveland & Fisher, 2014).

Radcliffe, Wilson, Powell, and Tibbetts (2008) propose that pedagogy, technology and the design of learning spaces are closely interlinked and explain how the design of learning spaces can either inhibit or support the intended pedagogy. According to Radcliffe et al. (2008), the pedagogy is influenced by the way the space is arranged regardless of its intended use. The design of a lecture hall for instance, in terms of seating layout and equipment, promotes a teacher-centred pedagogy, creating difficulties for active learning and interactions among the learners.

Radcliffe et al. (2008) further list a number of important principles, collected from different prominent authors in the field, which should be considered when designing contemporary spaces that are to promote active and collaborative learning. However, there is limited empirical evidence to support these principles. Jamieson, Fisher, Gilding, Taylor, and Trevitt (2000), for instance, assembled guiding principles based on the idea of student-centred, flexible learning. These involve designing learning spaces that enable: multiple use of the space; maximised flexibility within the space; making use of the vertical dimensions of the space; maximising teacher and student control of features and functions in the space; and maximising student use and ownership of their physical learning environment.

2.2.1 Critical Factors of Physical Learning Environments

There are a lot of factors that together make up the holistic conditions of a physical learning environment. A lead figure in the area is the Dutch architect Hertzberger, who discusses what factors the architect needs to consider when designing spaces for learning. According to Hertzberger (2008), "the space should be articulated so as to ensure conditions that strike balance between collective and individual actions". Hence, the spatial design and the way the physical space is articulated directly affects how the space can be used and is perceived. It determines whether the space will be used by a single large group of people or if it is more suitable for work in separate smaller groups, where several activities can take place simultaneously.

Hertzberger (2008) further states that the following factors need to be considered by architects when designing spaces for learning: admission of daylight, views, level of enclosedness (the right balance between cover and views out), sight lines, room dimensions such as floor-to-ceiling height, acoustics (the level of audibility and noise) and aesthetics (materials for articulation and identification of the space). Several studies that have been made in school environments show the importance of daylight and views, both regarding people's health and their performance (Public Health Agency of Sweden, 2017). Daylight is valued much higher in comparison to electric light when it comes to physical comfort, colour reproduction and work performance, as well as alertness, well-being and mood. Furthermore, views can have a psychological impact on mood, where a positive mood, in turn, can stimulate creativity, a theory that has been questioned (Public Health Agency of Sweden, 2017).

Another important factor in physical learning environments is indoor air quality, which is directly linked to the outdoor-air ventilation rate. High concentrations of air pollutants have shown to impair work performance and increase health symptoms (Satish et al., 2012). Indoor carbon dioxide levels can be used as an indicator of air quality in indoor working environments such as schools and halls, as humans are the main source of carbon dioxide indoors. Outdoor carbon dioxide levels are normally 300-400 ppm while indoors 600-800 ppm indicates a well ventilated space. Mean values above 1000 ppm indicate poor ventilation (Public Health Agency of Sweden, 2019). This value should not be exceeded during longer periods. The value of 1000 ppm does not mean that there are health risks for people using the space, however, it indicates that the function of the ventilation is not sufficient to ventilate out contaminated air (The Swedish Work Environment Agency, 2009; Public Health Agency of Sweden, 2019). Furthermore, researchers note that a carbon dioxide-level of 1000 ppm or higher entails adverse effects on human decision making performance (Satish et al., 2012).

2.2.2 Examples from Case Studies

In 2004, a multiyear study was initiated at the University of Dayton, with a particular aim to explore the relationship between physical learning spaces, pedagogy and learning (Hunley & Schaller, 2009). Learning was evaluated through measuring engagement among the students. Four differently designed rooms were used for the study, where four classes rotated among these. Interactions were measured through observations, while focus groups and surveys were used as tools to grasp how the students and faculty members perceived and experienced the different spaces. The study revealed that there was a higher engagement level in spaces that were "comfortable, open, flexible, and appealing to the emotions" (Hunley & Schaller, 2009). Environmental factors such as air quality, lighting, temperature, seating layout and aesthetics all showed to have an impact on engagement. An interesting finding was how the rooms were perceived differently depending on which space type the students had experienced first. Students who had started in a traditional classroom found this room to be okay, while students who first had experienced a flexible room with movable and comfortable furniture found the traditional room to affect their engagement negatively (Hunley & Schaller, 2009).

At the University of Minnesota, there was an experimental study carried out 2008 where researchers partnered with an instructor who taught the same section of a course in two different learning spaces. They were able to control other factors and thereby isolate the impact of the physical environment on student learning (Brooks, 2011). The results of the study show that the physical environment has a significant impact on student learning outcomes. The students who were taught in an active learning classroom (ALC) achieved better study performances compared to those taught in a traditional classroom. ALCs are characterised as technology-rich and student-centred classrooms. The seating and equipment configuration of an ALC is typically round tables with 6-8 movable seats and by each table, there is a microphone, a whiteboard and a flat-screen monitor enabling students to display their work to each other. The teacher has a station in the middle of the classroom

from where the student screens can be controlled (University of Minnesota, 2020). The Minnesota study concludes the need for further empirical studies to examine the relationship between the formal physical learning spaces and learning, to answer questions such as (1) how the learning space affects students' perceptions of their learning experiences and (2) how the space constrains or enables teaching practices (Brooks, 2011).

A final example is from a recent pilot study at Umeå University with the purpose to increase the knowledge of the relationship between space, learning and teaching in higher education. The study clearly showed how the physical space impacts learning. 2012, before the pilot study started, 14 % of the students passed a certain course, while in 2016, after the implementation of a flexible classroom that enabled more active learning, 71 % of the students passed the course. The 'flex room' used for the study was large enough and furnished in a way that made it easy to shift from large-group lecturing to teaching in smaller groups without crowding and noise. Furthermore, the flexible room was equipped with technical equipment and movable screens which enabled students and teachers to communicate and present. Educational methods were also tested in more traditional classrooms. However, the traditional classrooms were crowded, had less writing surfaces and the shift between different teaching settings were not as time-efficient (Akademiska hus, 2019).

2.3 Evaluation of Physical Learning Environments

When assessing the usability of a physical space, Cleveland and Fisher (2014) advocate the use of Post-Occupancy Evaluation (POE). As the name implies, POE is a process performed in buildings after they have been in use for some time. The non-domestic POEs have been carried out since the 1960s, however, in the last 20 years, the bottom-up approach has been established, which values the opinion of the users (Cleveland & Fisher, 2014). The reason is the realisation of the importance of what Hunley and Schaller (2006) refers to as the 'person-environment interaction'. It is important to consider this relationship since the space, as mentioned earlier in section 2.2, according to Hunley and Schaller either can encourage or constrain a behaviour. The result of a POE is a validation of the real needs of the users, and a better fit between occupant and space. Then, future buildings can be based on this information, instead of making assumptions about what the users might need (Cleveland & Fisher, 2014). Trying to connect physical space to academic performance and learning is a complex task, but Lackney(1999) states that the way to manage is to adapt the approach of action research. It is a process, which combines the goal of generating theories with the goal of establishing change within education.

According to Lackney (1999), assessing a building can be done at three levels. The first level, the building condition assessment, focuses on the safety and health of the occupants, and how these are ensured by the building. The second, educational adequacy assessment, is done by evaluating the space according to predetermined

requirements, which are found by experts to be necessary for learning. This level is, according to Lackney, more controversial, since it is subjective what educational adequacy means. The third level is referred to as environmental quality assessment. It aims to evaluate how factors of the physical space impacts educational outcomes. At this level, general answers cannot be sought. Instead, the question becomes: How does this specific space affect this specific group of learners? (Lackney, 1999).

The latter two levels both raise a complex issue regarding assessment of physical learning environments. Namely, how to define environmental quality, as it is a subjective matter, based on each individual's perception of the space. From the year of 2005, the Organisation for Economic Co-operation and Development (OECD) began developing a framework for evaluations of educational environments with the main goal to "assist education authorities, schools and others to maximise the use of and investment in educational spaces" (Cleveland & Fisher, 2014). This project was carried out by the Centre for Effective Learning Environments (CELE) who recognised the need for defining a set of 'criteria of quality' based on certain principles such as the improvement of educational effectiveness and the optimisation of building performance. To define the criteria for evaluating environmental quality, researchers involve all stakeholders in the process through interviews, student surveys, and behavioural observations. From the data collected, a series of environmental concerns are grouped into categories with specific attributes of environmental quality (Lackney, 1999).

Once the level for assessment has been chosen, Lackney (1999) goes on to explain that methods can be indicative, investigative or diagnostic, each increasing in depth and number of perspectives. Hunley and Schaller (2006) state that the methods most useful when evaluating a physical learning environment is focus groups and interviews, surveys and photographic studies, while Cleveland and Fisher (2014) beyond these also recommend data collection methods such as systematic observation and participant observation. These methods help investigate how people actually use and perceive the space. Cleveland and Fisher point out that multiple methods is required when evaluating buildings to "ensure that the weakness of some methods can be compensated for by the strength of others".

2.3.1 Existing Models for Evaluating Physical Learning Environments

Several attempts have been made to design an evaluation model which successfully assess the physical learning environment. Below follows an overview of models of interest.

The *Facilities Performance Profile* was developed in California in 1978, as a tool for evaluating school facilities. The performance rating wheel was used to inform architects and school planners of performance standards for educational facilities. It consists of a so-called radar chart, an example of which can be seen in figure 2.1.

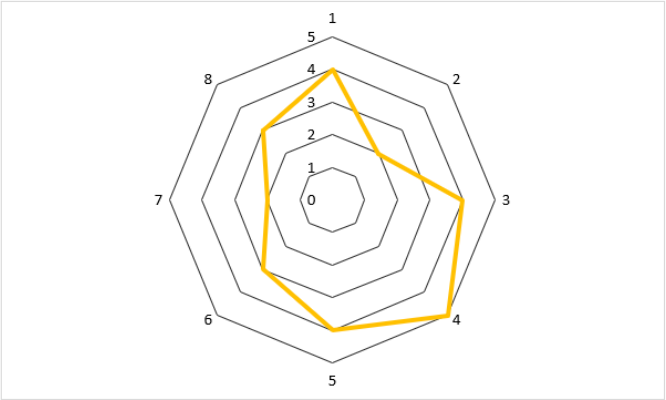

Figure (2.1) An example of a radar chart, with eight polarities and a scale 0-5

The radar chart of the profile rating wheel had ten polarities, which were: planning; finance; site; space; light; heat and air; sound; aesthetics; equipment; and maintenance. These factors were then rated on a scale from 0-10, from not acceptable to excellent. However, the tool did not consider the suitability of the physical space in relation to activities of teaching and learning or the experiences of the users occupying the space (Cleveland & Fisher, 2014).

As previously described under section 2.2.2, the *Learning Living Assessment Project* was a multiyear study initiated in 2004 to explore the relationship between physical space and learning. Hunley and Schaller (2006) state that an important issue to be considered in the evaluation design is whether the assessment focuses on teaching or learning. They further conclude that a model describing engagement is useful when assessing the impact of physical space on learning, partly since engagement is generally seen as a credible indicator of learning, and partly since assessing specific learning outcomes is a complex task. Factors of the physical environment that impact engagement can be identified through direct methods such as observations and indirect through surveys and focus group interviews, measuring frequency and how the space is used (Hunley & Schaller, 2006).

In 2008, Radcliffe et al. presented the *Pedagogy-Space-Technology (PST) Framework*. Radcliffe et al. mean that "the three elements, pedagogy, space, and technology influence each other in a reciprocal fashion" and should, therefore, be evaluated and developed in relation to each other. Although the authors propose starting with pedagogy and then continue through space followed by technology in a circular iteration, Radcliffe et al. clarify that the order is no indication of hierarchy. All three parts should be valued equally. A lesson learned from the PST framework was that when a physical learning environment is evaluated, the types of learning activities taking place in the space should be in focus. Whether the space encourages the desired type of learning needs to be considered (Cleveland & Fisher, 2014).

The *JELS evaluation framework* was the result of a study published in 2009. It aimed to provide a common vocabulary for the evaluation of physical learning environments. The framework was created around five key factors: intentions, context, practice, designs, and procedures. The study also highlighted a need for evaluations of physical learning environments to assess whether the space satisfies the

intentions of the design, and the needs of both instructors and learners (Cleveland & Fisher, 2014).

In 2011, a study called *A Comprehensive Learning Space Evaluation Model* stated that the field of physical learning environment evaluation needed further development. Again, the highly contextual nature of the learning environment was named as the reason why one model can not be comprehensive enough. However, the authors suggested a baseline around the three stages design, build, and occupation. The study concluded that more evaluation projects and studies are needed, to mature the field and to find how evaluation models should be developed further (Cleveland & Fisher, 2014).

Starting 2012, researchers at the University of Minnesota developed different data collection instruments for the *Science Teaching and Student Services Center (STSS)* research project, which was a study designed to better understand students' perceptions and experiences in active learning classrooms. Among these instruments were a student survey and a classroom observation form. The student survey presented the students with statements about the physical learning environment, while the observation form was used to take notes of how the occupants were using the space (University of Minnesota, n.d.).

The *Learning Environments Evaluation Programme (LEEP)* was started in 2013 and is part of OECD's work on effective learning environments. LEEP informs policymakers, school leaders and designers about how investments in learning environments lead to improved health and education outcomes. Through the development and implementation of the OECD School User Survey, the programme aims to collect evidence of how the physical learning environment impacts learning. The survey is meant to be used for collecting evidence of how physical spaces are used in schools and consists of questionnaires for students, teachers and school leaders. It also serves as a tool to collect users' perceptions of their learning environments (OECD, 2017).

Cleveland and Fisher (2014) conclude that the majority of the assessment methods previously used primarily focused on the physical conditions of the environment and not on the relationships between the physical space and how it is used and affects the behaviour of its occupants.

Several theories and models suggesting different relevant assessment targets, yet as evaluations of learning environments are highly contextual, an evaluation model should be developed and adapted for the specific context (Cleveland & Fisher, 2014).

3

Method

The following chapter explains the methods used in this study and consists of data collection methods, how the learning was defined in the context of the study, environmental factors that were considered, and a description of the data analysis process.

By following one of the initial Tracks courses the spring semester of 2020, hereafter referred to as 'the course', the existing learning environments were assessed with respect to the desired learning outcomes. The course consisted of four workshops, each with separate themes where students got an introduction and overall understanding of the current subject. The four workshops were divided on a total of eight occasions. In between these occasions, the students were to complete certain group assignments related to each workshop. The results of the assignments were to be presented at the latter session of each workshop.

The data in this project was collected by (1) observing the workshops of the course, (2) conducting surveys and interviews, (3) visiting and observing other facilities already designed with CBL in mind. As shown in figure 3.1 there were three phases of the data collection: the planning phase; the data collection phase; and the analysing phase.

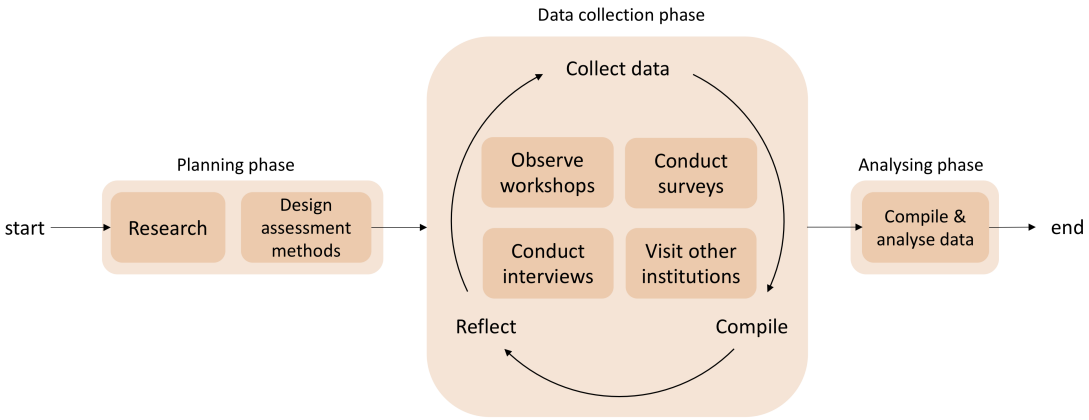

Figure (3.1) Workflow chart describing the three phases of the data collection.

The data was compiled and reflected upon continuously while collected, as recommended by Esaiasson, Gilljam, Oscarsson, Towns, and Wängnerud (2017). This was done as a mean to increase the validity of the investigation and made the analysing phase more effective and fruitful.

3.1 Defined Categories of Learning

All aspects of desired learning, described in chapter 2.1, were taken into consideration when trying to understand what was the intended learning in the context of the course and by extension, learning as identified for this study. As can be seen in table 3.1 the different parts of desired learning were therefore sorted by content, creating five categories of learning. These were named: communication; creativity; collaboration; self-assessment and; ethics and sustainability.

Categories of learning	Bullets from 2.1 Desired Learning
Communication	- communication (Rugarcia et al., 2000) - orally and in writing explain and discuss (Chalmers University, 2020b)
Creativity	- problem solving, critical and creative thinking (Rugarcia et al., 2000) - identifying, analysing and designing solutions (Malmqvist et al., 2015) - critically and creatively identify and formulate advanced problems (Chalmers University, 2020b)
Collaboration	- interdependent learning, interpersonal and teamwork skills (Rugarcia et al., 2000) - work in multidisciplinary and interdisciplinary teams (Malmqvist et al., 2015; Chalmers University, 2020b)
Self-assessment	- independent learning and self-assessment skills (Rugarcia et al., 2000)
Ethics and sustainability	- integrative and global thinking skills (Rugarcia et al., 2000) - value driven, global context, with solutions which are environmentally, socially and economically sustainable (Malmqvist et al., 2015) - show insights about cultural and ethnic differences, show insights about solutions in a global, economic, environment and societal context, and identify ethical aspects and their consequences (Chalmers University, 2020b)

Table (3.1) Categories of learning

The category of self-assessment were deemed as internal processes for each student, and therefore difficult to investigate using the chosen data collection method of observation. The same decision was made for ethics and sustainability, as this would most likely not be explored in the workshops, but rather in the later group projects of the course, which were not included in this study. The definition of learning, within the context of this study, was therefore defined as: to learn and develop the skills of *Communication*, *Creativity* and *Collaboration*. In addition to

these skills, *Engagement* among the students was measured in the study, since the level of engagement is admitted as a credible indicator of learning, described under sections 2.1.2 and 2.3.1.

3.2 Environmental Factors

The physical factors considered in this study are: light; temperature; acoustics; air quality; aesthetics; space type; geometry; views; seating layout; furniture; and equipment. Previous studies often refer to initial surveys and interviews with key stakeholders as the selection method of which factors to consider for the evaluation of physical learning environments. However, due to the limited time before the start of the data collection phase, these eleven factors were instead carefully chosen and compiled using the information received through the literature study. These factors and what aspects of environmental quality they represent, as well as references that were found to include the factors as significant, are shown in table A.5, and can be found in Appendix A.3.

Inspired by Lackney's (1999) evaluation levels, the factors were divided into three categories: building conditions; space design; and space configurations, as displayed in figure 3.2.

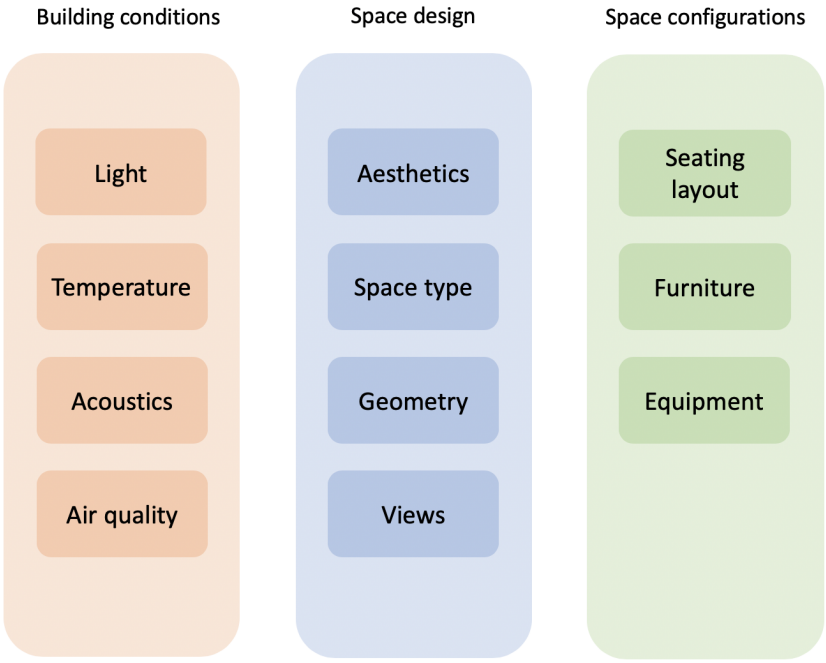

Figure (3.2) Environmental factors: the eleven factors identified and grouped together.

The building conditions category consists of well-being factors, provided by the building in which the space is located. The space design includes factors which are more specific for the space, rather than the whole building. It is what the space

looks like when unoccupied. Lastly, the space configurations are factors determining the set-up of the space, the spatial arrangements and the use.

This division was made to understand to what degree a change of a given factor was possible with given resources. It also influenced the radar charts used in chapter 4 as they were designed to simplify the analysis of the benefits of the space, or the type of changes that might be necessary.

3.3 Observation

By attending the workshops of the course, the physical space and how it is used by its occupants was observed. Observation was used as a mean to measure the level of engagement and to understand the person-environment interaction. The observations were carried out using the two protocols found in Appendix A.4. The first protocol focused on the fixed variables of the environment, such as geometry, light and layout. This was filled out once per space, the first time it was being used by the course. However, it was decided that if a space went under any major changes between uses, it should be considered a new space and thus a new protocol was to be filled out. The second protocol was a version of the STSS observation form, reworked to fit this study (University of Minnesota, n.d.). It was filled out continuously through each lesson in intervals of ten minutes. It focused on student participation and how the space was being used throughout the lesson. The observers were seated behind the students in each room studied, in order to get a good overview of the activity, such as movement and students on-task. Students were counted as on-task as long as they were not occupied with out-of-task activities. The second protocol was also used to document the changing variables of the physical environment. An indoor air quality meter was used to measure temperature, CO2-levels and relative humidity. The measuring device was placed in breathing height, but not closer than 2 meters from the nearest person, as far as this was possible. Intervals of noise levels within each room were captured through the use of a sound level meter. Both the air quality meter and the sound level meter were manually read, once per ten minute-interval. In order to be able to refer back to the environments, photographs of each learning space were taken before the participants arrived. Some photographs were also taken during the time the participants occupied the space, to illustrate how the space was being used.

According to Esaiasson et al. (2017), achieving validity is a typical problem when conducting observational studies. Therefore, in order to increase the validity, there were two observers participating simultaneously, aside from the first workshop where one observer could not attend. As recommended by Esaiasson et al. (2017), the observers collected the data using separate protocols during the teaching sessions. This method meant both that what was observed could only count as data if perceived by both observers, and that the observers were forced to strengthen the argument of their respective interpretations.

Furthermore, the following important steps mentioned by Esaiasson et al. (2017), was considered in the observation process:

- **The selection of environment.** As the learning outcomes of the Tracks courses have much in common with the CBL model such as collaboration, communication and problem-solving skills in interdisciplinary teams, one of the pioneer courses of Tracks was observed as the main instrument to answer the issues under investigation in this study.
- **Gaining access.** Access to the course and trust for the study was made possible through initial meetings with the instructors before the course started, to explain the aim and methods of the study.
- **Early and focused observations.** An early observation was carried out before the start of the Tracks course, for the observers to get familiarised to the observation protocols. This early observation was carried out at a seminar for master students, held in a traditional classroom. Notes were taken to capture as many aspects as possible for the early phase of the Tracks course.

3.4 Survey

Two surveys, found in Appendix A.5, was designed for this study. The first one, A.5.2, was answered by the participating students at the end of each teaching occasion and aimed to investigate the perceived effect of the learning space on the students' ability to learn and develop within the four identified categories of learning. The second, A.5.3, was answered by the instructor and focused on the influence of the learning space on the planning and implementation of the workshops. Each time the surveys were handed out, the participants were encouraged to answer based on their own experience of how the space enabled or inhibited their learning. They were informed to consider the particular space and the workshop sessions of that specific day. Additionally, at the top of the student survey, the students were reminded of the intended learning.

The student survey consisted of two sets of standardised questions with fixed answers. The first set, hereafter referred to as question 1, asked the students to consider how the factors of the physical learning environment, identified in 3.2, affected their learning. The answer was given on a four-degree scale, ranging from *Enables* to *Inhibits* with the additional option of *Does not affect me*. The last option is deliberately not a middle option, but put aside to act as a bigger of a choice not to answer on the four-degree scale. The second set, referred to as question 2, consists of ten statements, for which the participants again answered on a four-degree scale, but this time ranging from *Strongly agree* to *Strongly disagree*. This part of the survey and the statements were chosen, and in some cases slightly reworked, from the STSS student survey, to fit the particular setting of this study. The statements were chosen and assembled with the defined learning in mind, and each statement was linked to a category of defined learning, shown in table 3.2.

Category of defined learning	**Statement: The learning space I'm currently in...**
Engagement	*- increases my excitement to learn and enriches my learning experience.* *- deepens my understanding of the subject taught.* *- encourages my active participation.*
Communication	*- promotes discussion and enables me to communicate effectively.* *- helps enable connection with classmates.* *- helps enable connection with instructor.*
Creativity	*- helps me define issues or challenges.* *- encourages me to create or generate new ideas or products.*
Collaboration	*- helps me develop confidence in working in small groups.* *- helps me work in interdisciplinary and international teams.*

Table (3.2) Statements from question 2 of the student survey, linked to category of defined learning.

Something that had to be taken into consideration was that the participants likely perceived the scaling of the answers differently. That's why it was decided to collect the data with their names attached to it, to be able to follow each student through the study. The integrity of the participants was considered through identifying each person with a code, for which the key was stored locally on a USB. The handling of the students' personal data was approved of by each individual participant with signatures. The form used is found in Appendix A.5.1.

3.5 Transition from physical space to digital space

As the study progressed, there was a transition from the physical space to the digital space, meaning the two last workshop occasions had to be conducted distance-based, online through Zoom. For these off-campus sessions, the type of data that was collected was adapted and updated. Here, it was not feasible to include the environmental factors of the physical space, since these could not be observed. Instead the observations focused on participation frequency, and how the participants made use of the digital space, while the student surveys only took into account the answers of question 2, as the answers of question 1 was not useful without observation data to compare it with.

3.6 Interview

As a complement to the observations and surveys, a student focus group interview was carried out as a mean to (1) get a deeper understanding of the students' perceptions and experiences of how the physical space affected their learning, and (2) to evaluate and compare the different learning spaces in relation to each other.

The focus group interview format was chosen as it is a tool for exploring perceptions, feelings and experiences (Krueger & Casey, 2015). It was decided to have the interview online, as a pandemic outbreak made it unsuitable to meet in person. Based on a review of the literature in the area, a small group size was chosen, for the online interview to function smoothly, with a minimum of e.g. technology issues (Kite & Phongsavan, 2017; Daniels, Gillen, Casson, & Wilson, 2019). Students were first invited to volunteer to participate through e-mail, as well as through the online chat of workshops 3.3 and 4.1. Due to the lack of response, six participants were picked out from the group of students enrolled in the course and recruited via e-mail. The participants were chosen by random to avoid bias. Four out of the six approached agreed to the interview.

The focus group was conducted with n=4 participants and ran for 45 minutes. The online platform used for the interview was the online video meeting service Zoom. It was considered suitable since Zoom had been used during the online workshops of the course, and therefore the participants were comfortable using it. As a preparation for the focus group, an interview guide was created, which can be found in Appendix A.6. The interview was recorded and later transcribed.

3.7 Data Analysis

When entering the analysing phase of this study, some analysis had already been made through the continuous reflection mentioned earlier in this chapter. After each workshop, the multivariate data from each student survey was compiled and visualised, and put into the context of the corresponding observations. By recommendation of Esaiasson et al. (2017) these weekly discussions and reflections were carefully recorded and then brought into the analysing phase.

After the focus group interview had been transcribed, a quantitative content analysis was carried out in a three-step process, using measures described by Graneheim and Lundman (2004). Firstly the interview was read through several times by both researchers to get a deep understanding of the whole. Secondly, keywords and illustrative quotes were highlighted as a measure to analyse the explicit content and distinguish possible underlying meanings in what the interviewees were telling. Thirdly, the illustrative quotes were discussed and reflected upon by the two researchers, and put into relation to the research questions under investigation with the goal to make out themes that specified the students' perceptions and experiences.

During the analysing phase, the eight occasions were reflected upon all together at first, and later divided into groups, first by space, second by activities. This was done to detect and identify phenomenons. The mapping method described by

Esaiasson et al. (2017) was then used to identify possible causes for each phenomena. However, given the limited amount of data, causes in this particular situation was regarded as trends and tendencies, rather than truths. Finally, the identified trends were supported using statements from the student group interview.

4

Results

The results of this study were collected from four different learning spaces, with the help of 5 instructors and 24 participating students representing different disciplines, of which there were 10 bachelor and 14 master students. It consists of data from observations, survey responses and interview summary. The observations and survey responses are presented chronologically by workshop, and the interview summary follow below.

For the observations, how the CO2-levels, temperature, participation frequency and noise levels changed over the time of the workshop sessions are presented visually in graphs, where vertical lines mark the start and end of each session. In addition to the data presented in these graphs, all activities taking place within the scope of the workshop sessions were documented. This documentation was partly used to calculate the proportion of time spent on each type of activity, shown in table 4.1, and partly summarised under 'Observations' in this chapter describing how the learning spaces were used. Activities such as group work happening outside of class were not observed and therefore not taken into account for the proportions of time spent on each type of activity displayed in table 4.1.

Activity	**Description**	**Time (%)**
Lecture	*Instructor presenting, students listening*	64.7%
Presentation	*Students presenting results of assignments*	14.7%
Discussion	*The instructors and students discussing together*	12.8%
Group work	*Students working in groups*	2.5%
Individual work	*Students working individually*	3.1%
Other activity	*The use of interactive presentation software*	2.2%

Table (4.1) Proportion of time spent on each type of activity throughout the eight workshops. The activity recorded does not include any time spent outside of the observed occasions.

The student survey consisted of three questions. The first asked the students to rate the eleven environmental factors on a scale from enabling to inhibiting learning. The results are presented in radar charts, stretching from inhibits in the centre, to enables

at the edge. The transition between the two polarities is marked by a coloured line. For the second question, the students indicated whether they agreed or disagreed to the ten statements regarding learning. The result is presented below with pie charts, one for each part of the identified learning. The proportion of strongly agree and agree answers are marked with green, while disagree and strongly disagree are marked with orange, as shown in figure 4.1.

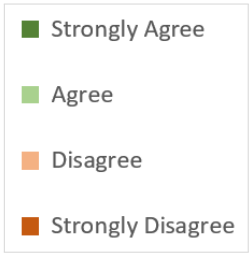

Figure (4.1) Colours of question 2 results

Finally, the interview is presented with summaries and quotes, sorted by interview question.

4.1 Workshop 1.1

Part one of the first workshop was conducted in the Acoustics Lecture Room. There were five sessions during the day, where each session lasted between 40 min up to 1 hour. The instructor was lecturing from the front of the classroom, while the students were sitting down and listening. The observations were performed by one observer and the student survey was answered by 21 students in the break between session 4 and 5.

4.1.1 Observations

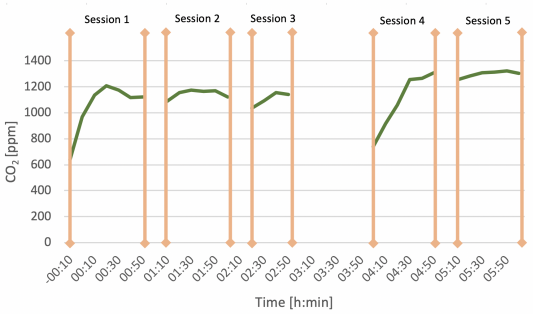

Figure (4.2) Workshop 1.1. CO2-levels [ppm]

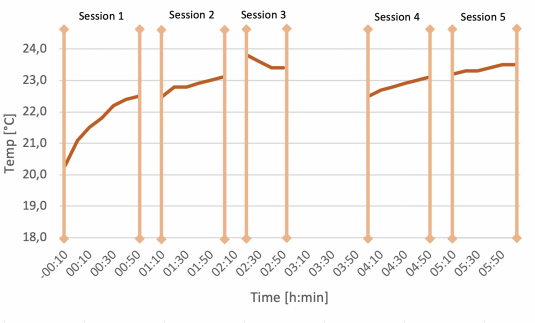

Figure (4.3) Workshop 1.1. Temperature [°C]

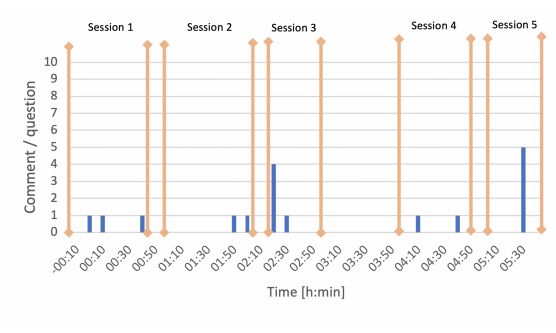

Figure (4.4) Workshop 1.1. Participation frequency

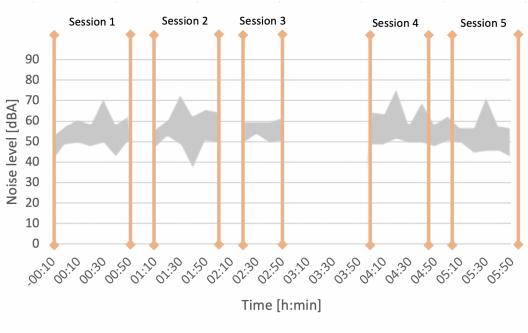

Figure (4.5) Workshop 1.1. Noise level [dBA]

As seen in figure 4.2, the CO2-levels quickly increased and exceeded 1000 ppm. One student commented that he found the air quality bad when entering the classroom before the start of session 3. The temperature in the classroom, displayed in figure 4.3, ranged from 20.3-23.8 °C. The participation frequency displayed in figure 4.4, shows the amount of comments or questions from the students, where the highest participation rate was during session 3 and 5, with 5 questions or comments per session respectively. 90-100% of the students were actively listening during the lectures, 1-2 students were occasionally occupied with other things. Figure 4.5 shows how the min- and max noise level varied throughout the day, spanning from 36-77 dBA. The relative humidity (RH) ranged from 30.6-37.1%. The instructor had brought some equipment to the lesson such as musical instruments and their computer. Moreover, the instructor used the projector, speakers and chalkboard while lecturing. During the lectures, the instructor occasionally posed short answer questions to the students. The room was crowded as there were only three free seats and no extra space to move between each table row.

4.1.2 Student Survey

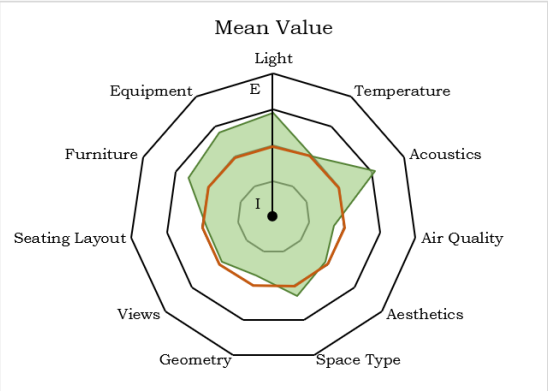

Figure (4.6) Workshop 1.1. Radar chart showing mean values for each factor, the result of question 1 of the student survey.

According to the result, presented in figure 4.6, furniture, equipment, and light were all factors which were perceived as partially enabling the students' learning. Acoustics just barely reached to enabling. The space type was close to neutral while still being perceived as enabling, while the temperature received a completely neutral grade. The aesthetics, views, and seating layout were perceived as just barely inhibiting. The lowest score was given to air quality and geometry respectively.

Both aesthetics and geometry each had 38% of the students saying that the factor 'Does not affect me'.

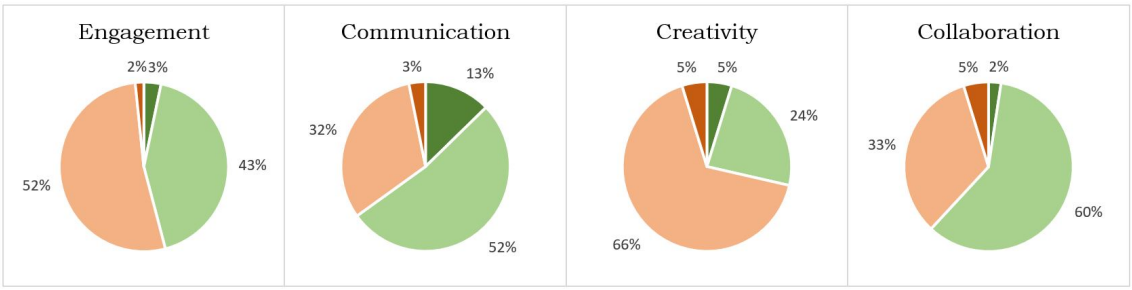

Figure (4.7) Workshop 1.1. The result of question 2 of the student survey.

As seen in 4.7 the space was perceived to have a positive impact on communication as well as collaboration, by 65% and 62% of the students respectively. The type of learning most negatively affected by the space was creativity, as only 29% of the students agreed that the space encouraged it.

The need for better ventilation and more windows was repeatedly mentioned by the students. The space was said to be too crowded or too small. The space was referred to as “depressing”.

4.1.3 Instructor Survey

The instructor stated that the planning was affected a lot by the space in the form of an adaptation to the number of students. The space completely matched up with the expectations the instructor had, although they expressed a wish for the ventilation to be better.

4.2 Workshop 1.2

Part two of the first workshop was conducted at Ljusgården, the indoor courtyard. The workshop session consisted of group presentations in groups of three students, where one group at a time had a three-minute music performance to show off the instruments they’ve built. The observations were performed by one observer and the student survey was answered by 19 out of the 22 students participating in the workshop session.

4.2.1 Observations

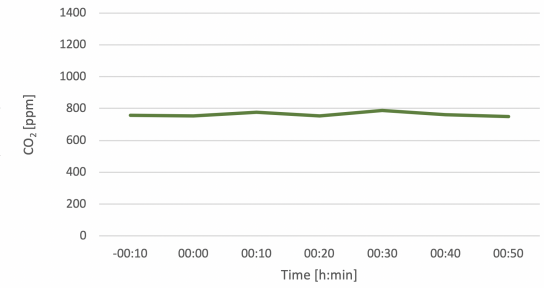

Figure (4.8) Workshop 1.2. CO2-levels [ppm]

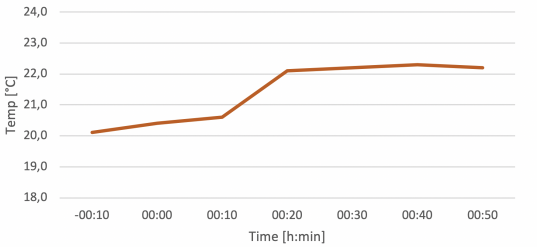

Figure (4.9) Workshop 1.2. Temperature [°C]

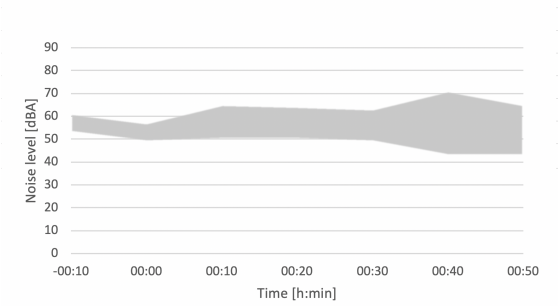

Figure (4.10) Workshop 1.2. Noise level [dBA]

As there was no furniture in the indoor courtyard, the participants were all standing up during the whole session. The group of students and teachers were first gathered in one of the corners of the indoor courtyard, where the instructors introduced the workshop session to the ones present before the group presentations began. Soon they moved into the centre of the space, where the group presentations continued. There, they gathered in a big circle and the group performing were standing in the centre. In the audience, there were four instructors, students enrolled in the course as well as other interested students and a camera crew who documented the session. In total there were 50-60 people present. There were also some students observing the performances from above, standing on one of the balconies at the highest floor. Each group performance was followed by an applause and then an explanation from the group about their work as well as feedback from fellow students and instructors. As Ljusgården is a large open circulation space, background noise from other activities was tangible which affected the audibility of speech to some extent. The clear blue sky was seen above the space, which lit up the indoor courtyard with a rich flow of daylight.

The RH ranged from 28.2-32.5%, which is normal. The level of CO2 seen in figure 4.8 was stable during the entire session, varying between 749-777 ppm, which indicates a good ventilation rate. During the session, the temperature rose from 20.1-22.3 °C,

shown in figure 4.9. Figure 4.10 displays the noise level varying from 43-71 dBA throughout the session. The participation frequency was not counted during this session since there was such a mix of people participating apart from the students and instructors of the course. This made it difficult to discern the exact engagement level of the students enrolled in the course. However, as the main activity was student group presentations followed by feedback from tutors and fellow students, there was always something happening where the students were actively involved, either through presenting or through giving feedback.

4.2.2 Student Survey

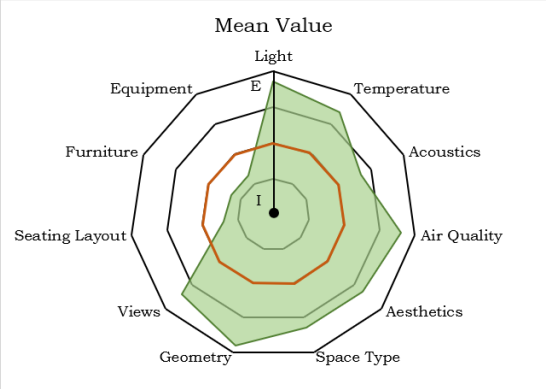

Figure (4.11) Workshop 1.2. Radar chart showing mean values for each factor, the result of question 1 of the student survey.

Figure 4.11 shows that light, temperature, air quality, aesthetics, space type, geometry and views were all perceived by the participating students as enabling, while acoustics was seen as partially enabling. The factors seating layout, furniture, and equipment, all received the grade of partially inhibits.

37% of the students stated that equipment 'Does not affect me', and 32% said the same thing about furniture. 16% was not affected by the seating layout.

According to the results presented in figure 4.12 the space is perceived to have a positive impact on all four parts of learning. Around 70% of students are agreeing or strongly agreeing to the statements having to do with communication, creativity and collaboration.

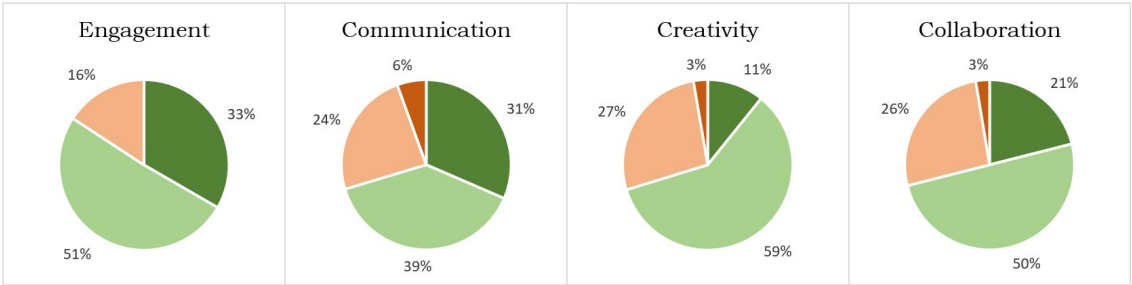

Figure (4.12) Workshop 1.2. The result of question 2 of the student survey.

As seen in figure 4.12 engagement received an agreement of 84%. Notice the high proportion of 'Strongly Agree' answers. A few students comments on the lack of seating. But the noise and distraction of non-participants moving in and around the space seems to be the primary problem.

4.2.3 Instructor Survey

According to the instructor, the space affected the planning of the lecture a lot. Although, the comment suggests that it was rather a matter of choosing a space for its properties, as it was stated that the room was chosen for its strong acoustics and sufficient size to hold an audience.

The space partially lived up to the expectations of the instructor, and what diverged was the amount of background noise, which was higher than anticipated.

4.3 Workshop 2.1

Part 1 of the second workshop was conducted in Ateljén, the art studio. There were four sessions during the day, where the time length for each session varied between 45-90 minutes. The main part of the workshop sessions the instructor was lecturing, except for the last session were the students got some time to experiment with their computers on their own. The observations were performed by two observers and the student survey was answered by 19 out of the 21 participating students towards the end of the fourth session.

4.3.1 Observations

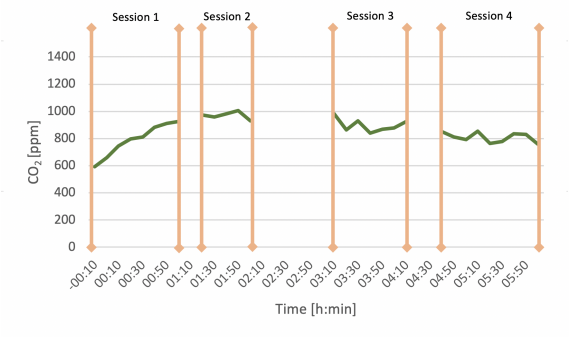

Figure (4.13) Workshop 2.1. CO2-levels [ppm]

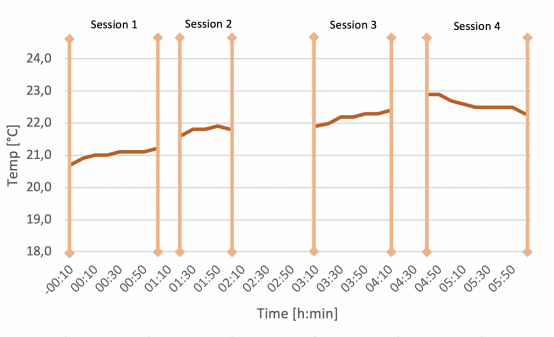

Figure (4.14) Workshop 2.1. Temperature [°C]

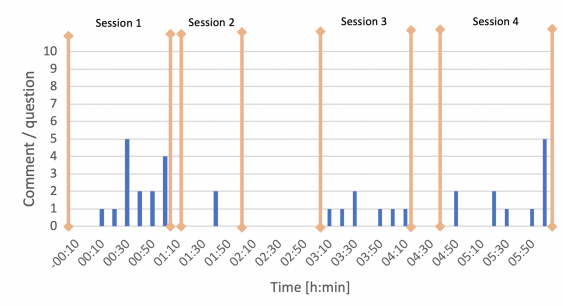

Figure (4.15) Workshop 2.1. Participation frequency

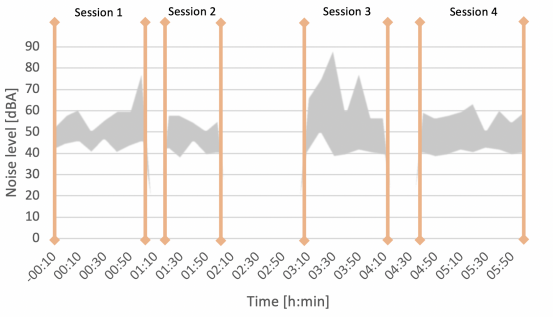

Figure (4.16) Workshop 2.1. Noise level [dBA]

The instructor had a table with a computer set up as well as a projector, projector screen and sound system in front of three rows of portable chairs arranged in a traditional lecture layout. During sessions 1-3 the instructor was lecturing and played several video and audio clips, and occasionally asked if the students had any thoughts, comments or questions. The instructor was moving around a little at the front, while the students were seated during all of the sessions. The observers noted the use of cellphones by some of the students occasionally, due to waiting time. The comments and questions from the students were generally quite sparse as seen in figure 4.15 as the students were mostly listening to the instructor lecturing. The participation frequency was highest in the first session. The final five comments during session 4 were regarding the upcoming home assignment.

In the break between session 3 and 4, there was a rearrangement as the seating layout was changed from the lecture setting to a group work layout. Tables were assembled and the students were spread out into sitting in groups of 2-4 people at each table. In this last session, the students were working individually, but were also discussing among themselves in each group. They listened to the instructor giving a demonstration in the front of the room and tried out different features of an editing program simultaneously. The instructor walked among the groups and supervised the students.

The CO2-level in the room varied from 594-1003 ppm, as seen in figure 4.13, indicating that the room was well ventilated. The temperature measured, displayed in figure 4.14 rose from 20,7 up to 22,9 °C throughout the day. The RH-level was normal and ranged from 33,5-38,4%. The noise level mostly varied between 40-60 dBA, however sometimes peaked with a maximum of 90 dBA due to high volume when the instructor was playing audio, causing some students to cover their ears. During session 3 one student asked if the instructor could lower the volume.

4.3.2 Student Survey

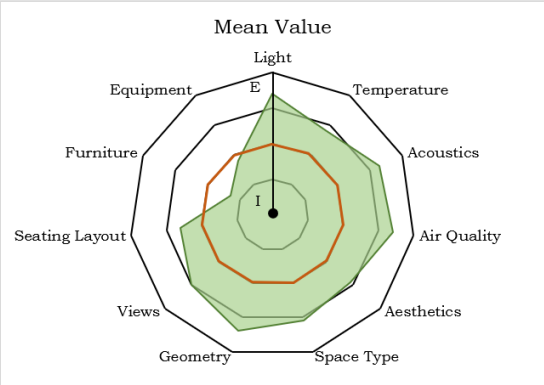

Figure (4.17) Workshop 2.1. Radar chart showing mean values for each factor, the result of question 1 of the student survey.

Figure 4.17 shows that the factors light, acoustics, air quality, space type, geometry and views was all perceived by the students as enabling their learning. Temperature, aesthetics and seating layout was perceived as partially enabling. Equipment and furniture were both perceived as partially inhibiting, with the lowest score given to the furniture.

16% of students stated aesthetics and space type, respectively, did not affect them.

According to the results shown in figure 4.18, the students perceived the space as having a positive effect on all four identified parts of learning. The statements

regarding engagement, creativity and collaboration all received an agreement of over 80%, while the statements regarding communication received an agreement of 72%. Once again the high level of 'Strongly agree' answers is interesting, as well as the complete lack of any 'Strongly disagree' answers.

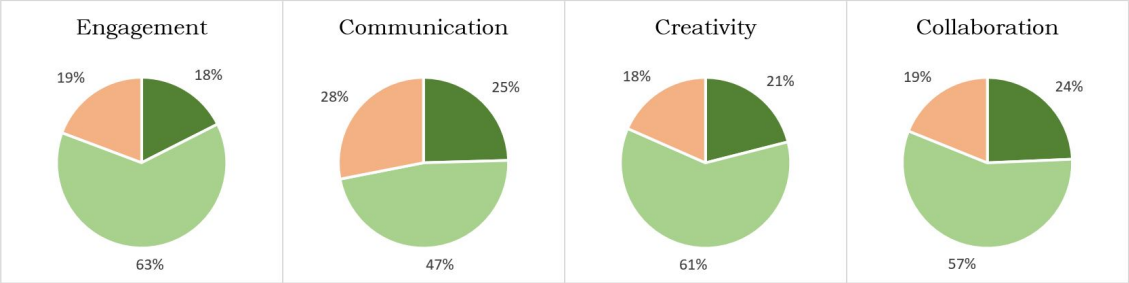

Figure (4.18) Workshop 2.1. The result of question 2 of the student survey.

The air quality was mentioned as something that was appreciated in the space, while the temperature was mentioned as too cold. The seating arrangement was said to impede note taking. The most mentioned problem, however, was the uncomfortable chairs.

4.3.3 Instructor Survey

The planning of the lecture was partially affected by the space, and the instructor stated that it was mainly the available equipment that was taken into consideration. That the room was spacious was something that was mentioned as nice, even though it didn't have a direct effect on the planning.

The space, and the equipment, completely lived up to the expectations of the instructor.

4.4 Workshop 2.2

Part 2 of the second workshop was held in Ateljén, the same place as for part 1. There were three sessions during the day, which lasted between 45-60 minutes each and there was a lunch break between session 2 and 3. In workshop 2, part 1, the students were handed an assignment to individually create music pieces. This second part was dedicated for the students to individually present their music pieces to each other and the instructors of the course. The observations were performed by two observers and the student survey was answered by 16 out of 16 students in the third session.

4.4.1 Observations

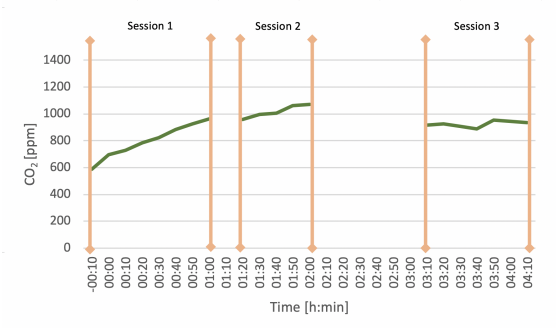

Figure (4.19) Workshop 2.2. CO2-levels [ppm]

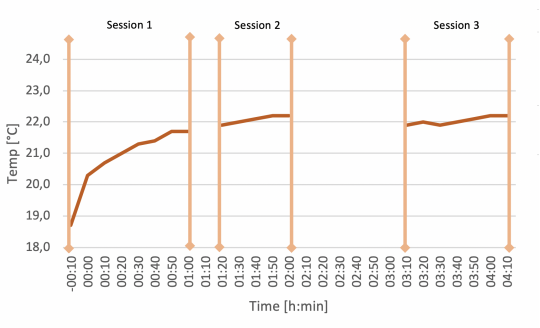

Figure (4.20) Workshop 2.2. Temperature [°C]

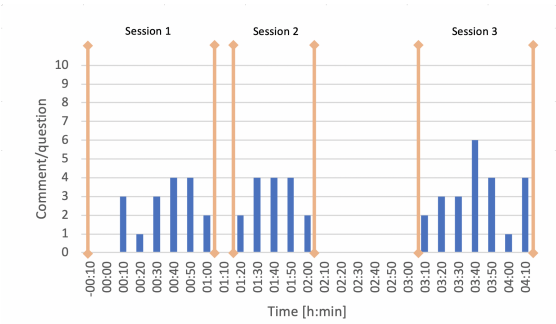

Figure (4.21) Workshop 2.2. Participation frequency

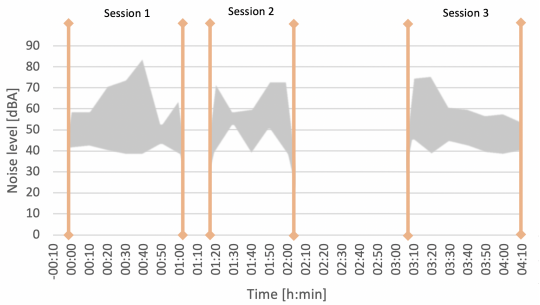

Figure (4.22) Workshop 2.2. Noise level [dBA]

Before the start of the first session, the students rearranged the furniture. From one big table, to first a group tables-layout, but then setting the tables aside completely. Instead they arranged chairs in a semicircle facing the projector screen at the front of the room. Just as in part 1 of workshop 2, the instructor had a table set up with a computer, projector and sound system. The projector was however not used, as only the sound system was needed for the presentations of the students' music pieces.

The students were seated in the semicircle of chairs and one by one walked to the front to present their work. The instructor walked to the back of the class while listening. Each presentation was followed by an applause as well as comments, questions and feedback from fellow students, the instructor and the other participating teachers. The participation frequency was relatively high throughout all three sessions, shown in 4.21. In between the presentations, the instructor held short explications, inspired by the former student presentation. The last session was wrapped up with reflections on the week, the assignment and the workshop.

As for the well-being parameters, the CO2-levels in the room shown in figure 4.19 increased from 588-1071 ppm and then stayed around 900 ppm after the lunch break. There was a relatively quick rise of the temperature, starting at 18,7 °C and reaching

22,2 °C at its peak. The noise level displayed in figure 4.22 varied from 38-85 dBA, where the high values were due to the volume of audio playing. The volume was lowered as it was requested from a student in the third session. The RH-level varied between 32,5-36,2%.

4.4.2 Student Survey

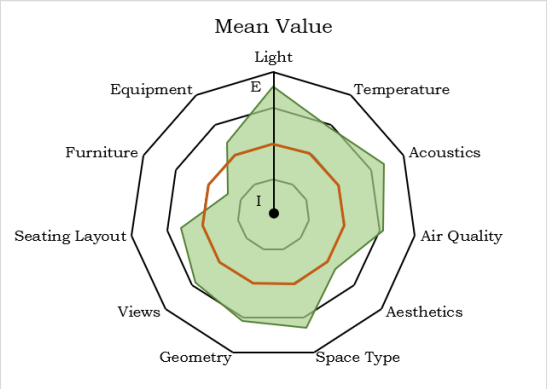

Figure (4.23) Workshop 2.2. Radar chart showing mean values for each factor, the result of question 1 of the student survey.

As seen in figure 4.23, light was the factor perceived as the most enabling in this space, but acoustics, air quality, space type, and geometry were all perceived as enabling as well. Temperature, views, seating layout, aesthetics, and equipment were all perceived as partially enabling, and furniture was the only factor to be perceived as partially inhibiting.

None of the factors stood out as not affecting learning in this space, with the factor receiving the most being equipment which had two students answering it 'Does not affect me'.

Figure 4.24 shows that the space was perceived to have a positive impact on learning, with engagement receiving an agreement of 81%, communication and collaboration both receiving 69% agreement and creativity 62%. Again, no one is strongly disagreeing with any of the statements.

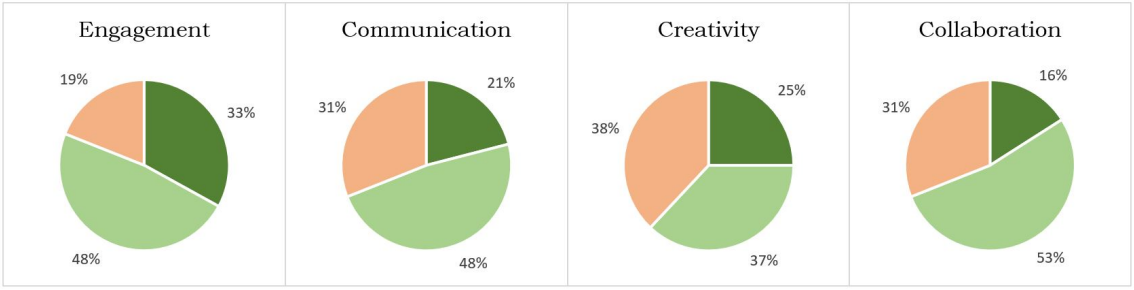

Figure (4.24) Workshop 2.2. The result of question 2 of the student survey.

Temperature and uncomfortable chairs are both mentioned again. But also the fact that the participants had to knock on the door to get into the space is mentioned as hindering.

4.4.3 Instructor Survey

The instructor did not fill out a survey at this time as it was the same instructor in the same space as a few days before. Instead, they stated that the experience was the same as the whole workshop was planned together and for the same space.

4.5 Workshop 3.1

Part 1 of the third workshop was conducted in the Acoustics Lecture Room, the same space as for workshop 1, part 1. It consisted of a lecture, divided into three sessions, where each session lasted between 40-60 minutes. The observations were performed by two observers and the student survey received 13 replies, out of the 16 students participating in the third session.

4.5.1 Observations

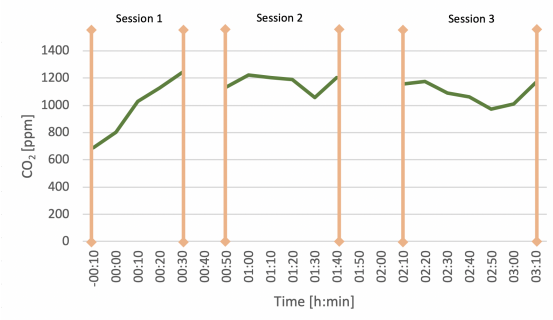

Figure (4.25) Workshop 3.1. CO2-levels [ppm]

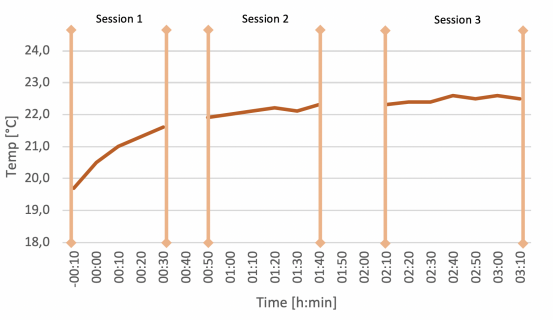

Figure (4.26) Workshop 3.1. Temperature [°C]

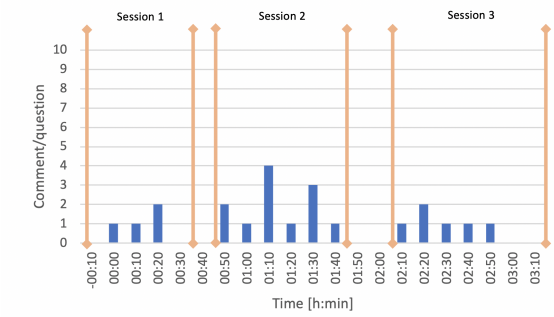

Figure (4.27) Workshop 3.1. Participation frequency

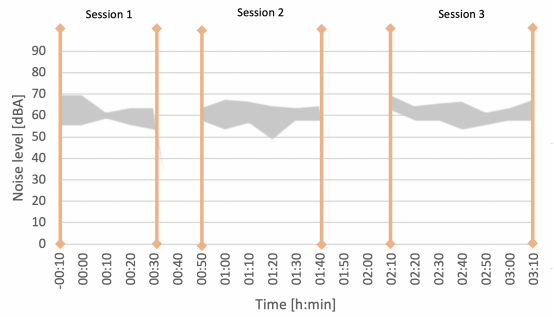

Figure (4.28) Workshop 3.1. Noise level [dBA]

In the start of session one, there were only 11 students present. Some students and another teacher showed up late, interrupting the instructor. There was also a cameraman who entered late to set up a camera tripod in the back of the room.

The instructor stood in the front of the room and used a projector, chalkboard and speakers as well as a musical instrument while lecturing. They showed several video and audio clips and there were some questions occasionally coming from the students who were sitting down in the table rows with limited space to move around. The students were invited to be actively involved during session 2, by turning their heads to notice an effect while listening to audio samples, but beyond that, they were mostly passively listening to the lecturer. The participation frequency can be

seen in figure 4.27. Towards the end of session 3 the students seemed to be getting tired and unfocused, someone picked up their mobile phone, the lecture was running late and went over time 15 minutes.

As shown in figure 4.25, the CO2-level increased from 689-1239 ppm in a time frame of 40 minutes. The CO2-level then stayed above 1000 ppm during both session 2 and 3. The temperature in the room was rose from 19,7-22,6 °C, displayed in figure 4.26. The relative humidity in the room varied between 35,6-41,3% and the noise level from 48-70 dBA, shown in figure 4.28.

4.5.2 Student Survey

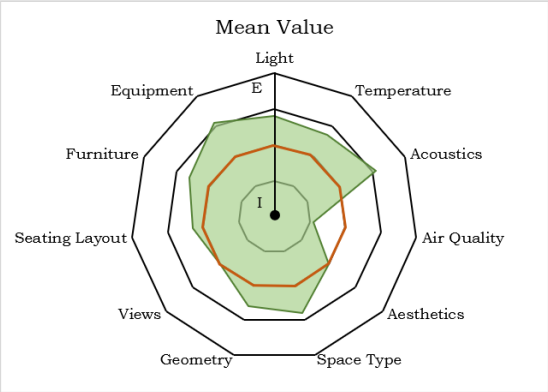

Figure (4.29) Workshop 3.1. Radar chart showing mean values for each factor, the result of question 1 of the student survey.

According to the results presented in figure 4.29, acoustics and equipment were both perceived as enabling, while light, temperature, space type, geometry, seating layout, and furniture were partially enabling. Aesthetics and views were both perceived as neither enabling nor inhibiting, but received a neutral grading. Air quality was the only factor which was perceived as inhibiting.

As seen in figure 4.30 engagement and communication both received a majority of agreement, 67% and 69% respectively. Neither had any students strongly disagreeing to any of the statements. On the other hand, collaboration, and creativity especially, received a lot of disagreement. And while 4% of the answers were strongly disagree, no student strongly agreed to any statements.

The need for more windows was the only problem to be raised in this lecture.

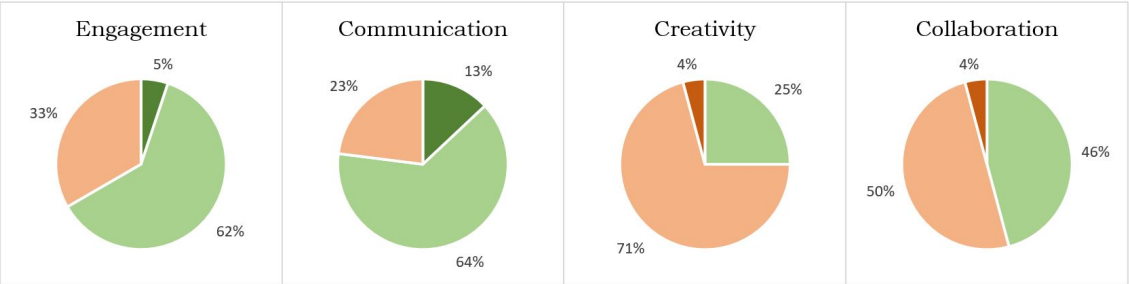

Figure (4.30) Workshop 3.1. The result of question 2 of the student survey.

4.5.3 Instructor Survey

The space had a lot of influence on the planning of the lecture according to the instructor. It was the quality of the sound system that was the most appealing part of the space.

The space only partially lived up to the expectations of the instructor, as the sound system was described as having “a few funny properties”.

4.6 Workshop 3.2

The venue for the second part of workshop 3 was Ateljén, making it the third lesson in this learning space. This time however there were only five students present, due to the effects of a pandemic. The other students were participating online via Zoom. Two instructors were leading the sessions together. The student survey was answered by 4 out of 5 students present and the observations were performed by two observers. The time length for each session was between 30-60 minutes.

4.6.1 Observations

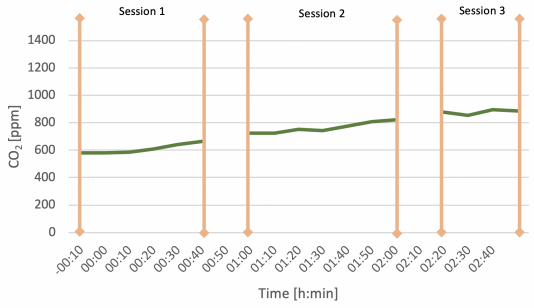

Figure (4.31) Workshop 3.2. CO2-levels [ppm]

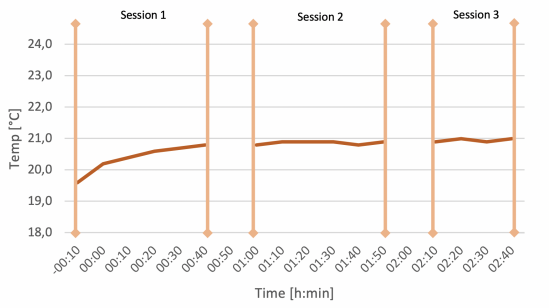

Figure (4.32) Workshop 3.2. Temperature [°C]

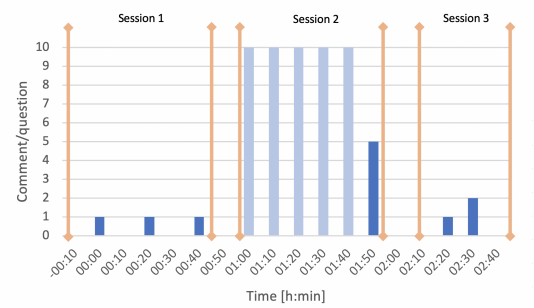

Figure (4.33) Workshop 3.2. Participation frequency

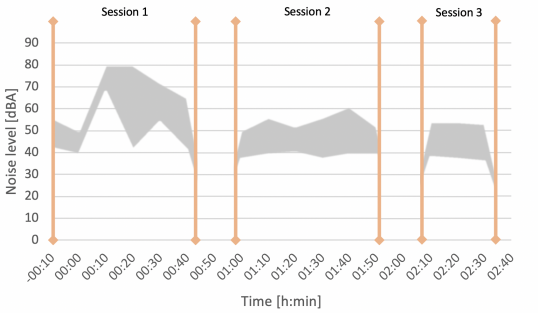

Figure (4.34) Workshop 3.2. Noise level [dBA]

Before the start of session 1, the students fetched foldable chairs and placed them on a line facing the projector screen. Since they were very few, there were a lot of extra space in the room. The instructor lowered the blackout curtains for the students to see the projector screen better. During the first session, the students were actively involved as the instructors made use of an interactive presentation software where

the students could vote using their mobile phones or computers. The engagement level of the students dropped a bit towards the end of the session.

In the second session, the students were first divided into small groups to discuss. The online participants were divided into breakout rooms in Zoom. Next, the chairs were moved to form a circle at the front, moving close to the microphone. This was done so that the students online could hear. There was a whole class discussion together with those online, where the participation frequency reached 10 or more comments/questions per 10-minute interval, displayed in figure 4.33. The equipment used was mainly a projector, speakers and video camera. The instructor turned the camera when needed, enabling the online participators to see the projector screen and whoever was talking. In the third and last session, the instructor was lecturing and the students were seated in a semi-circle at the front.

The noise levels measured during the workshop sessions varied between 36-80 dBA and are displayed in figure 4.34. The noise level reached 80 dBA during the first session when music examples were played, before the volume was lowered. Both the CO2-levels and temperature in the room were quite stable. The CO2-levels increased from 580-897 ppm, shown in figure 4.31 and the temperature rose from 19,6-21 °C, displayed in figure 4.32.

4.6.2 Student Survey

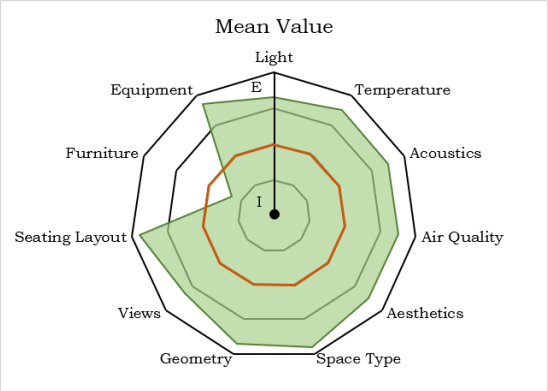

Figure (4.35) Workshop 3.2. Radar chart showing mean values for each factor, the result of question 1 of the student survey.

All factors, according to the result shown in figure 4.35, were perceived as enabling, except for furniture, which was seen as inhibiting. The number of people in the room, five students in total, was mentioned as a big positive contributing factor to this result. By following the present students through the different workshops, however, they were discovered to be positive to the space through all occasions.

The same could be seen in figure 4.36 and the four parts of learning. Only one of the statements, regarding engagement, was disagreed to by one student. The nuances between the parts can instead be found in to what extent the students agreed. There can be seen a greater percentage of strongly agree answers for the statements regarding communication, while the creativity was prominently agreed to.

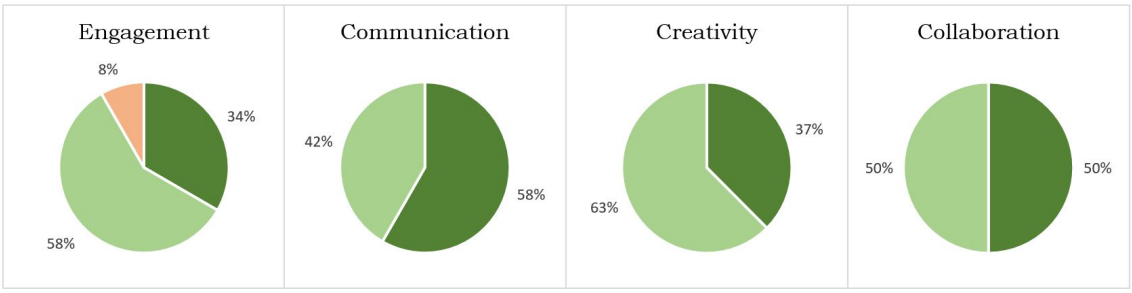

Figure (4.36) Workshop 3.2. The result of question 2 of the student survey.

The students commented that there was nothing about the space they would change to increase learning.

4.6.3 Instructor Survey

As this lecture was planned and conducted by two instructors, they both answered the survey. The instructors agreed that the space had a lot of influence on the planning, as it had to be combined with the use of digital tools such as Zoom and Mentimeter.

The answers diverge when asked about whether the space lived up to the expectations of the instructors, as one stated it mostly did, and the other stated it only partially did. According to the instructors, it was the hardware, mainly the projector, which turned out to be an unexpected issue.

4.7 Workshop 3.3

The third part of workshop 3 was conducted entirely distance-based, online via Zoom. Three of the instructors were gathered in a group room at campus, two other instructors joined in on their computers and the students participated from their homes. During sessions 1 and 2 there were student group presentations, followed by a summary of the content and whole-class discussion in session 3. This workshop part was divided into three sessions, spanning between 40-50 minutes respectively. 10 out of 16 participating students replied to the student survey after the end of session 3. The workshop sessions were observed by two observers.

4.7.1 Observations

CO2-, temperature- and noise levels were not able to be measured and is therefore not considered in this distance-based part of the workshop.

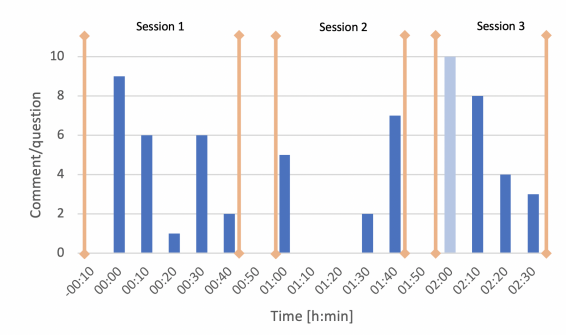

Figure (4.37) Workshop 3.3. Participation frequency.

During the sessions, the students could communicate either through using their microphones or by writing in an online chat. Participators could also share video from their web camera or share their screen. The presenting group shared their screen for others to see presented slideshows and videos. The instructors leading the workshop shared video from their camera. Non-presenting students had both microphone and camera turned off, however, some students turned on their microphones momentarily to ask a question or give a comment.

Each group presentation was followed by feedback through questions and comments from instructors and fellow students. Both comments stated vocally and written comments were considered for the estimation of participation frequency among the students, displayed in figure 4.37. The participation frequency was high, especially during session 1 and 3 with 6 or more comments/questions per 10-minute interval, some of which were short comments in the form of 'yes' and 'no'. Furthermore, the first 10-minute interval of session 3 had a participation frequency exceeding 10, shown in figure 4.37, as there was a whole class discussion.

There were some technical problems during the sessions, particularly regarding sound quality, the ability to hear each other speaking and to hear sound from shared video or audio. However, the technology worked well for the main part of the workshop sessions.

4.7.2 Student Survey

As shown in figure 4.38 the transition to the digital classroom seems to have had a negative effect on all identified parts of learning. Most affected was engagement, which received a highly negative score with only 24% agreement. The statements regarding communication and creativity received an agreement of 43% and 35% respectively, and the one only part which had a positive outcome was collaboration with an agreement of 55%.

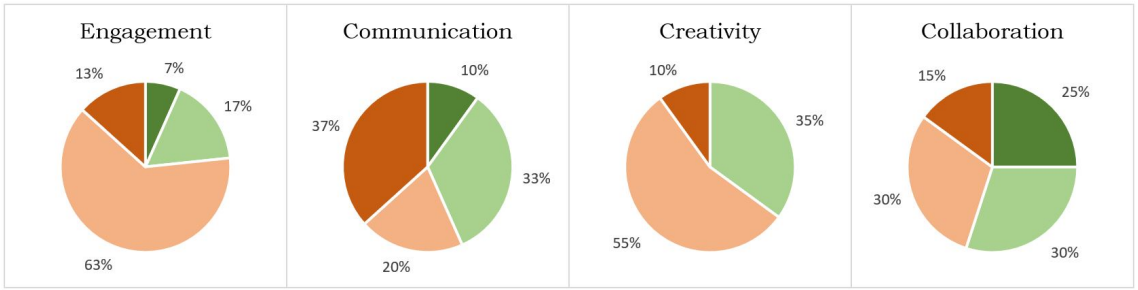

Figure (4.38) Workshop 3.3. The result of question 2 of the student survey.

The students state that the digital platform exceeded their expectations in many ways, but it also created a distance that made communication hard. On the other hand, it is also mentioned that the digital platform makes everyone more equal, which makes communication easier. The students also identify a need to get used to the new situation.

4.7.3 Instructor Survey

The digitisation of the classroom affected the planning of the lecture a lot. The instructor stated that an issue in planning was that it was hard to know how the presentation and comments were to be experienced by the students.

The reality of the digital classroom completely met the expectations of the instructor. They were impressed by the students patience, understanding, and above all, how problem-solving oriented they were.

4.8 Workshop 4.1

The fourth and final workshop was conducted online via Zoom, like the previous workshop 3.3. Both the instructors and the students were seated in their home environments and participated in the meeting via computers. The workshop was divided into four sessions, each with a duration between 40-100 minutes. The instructor was lecturing the main part of the sessions and there was also some time for individual work for the students. The workshop was observed by two observers and the student survey was answered by 12 out of 22 participating students.

4.8.1 Observations

CO2-, temperature- and noise levels were not measured during this workshop.

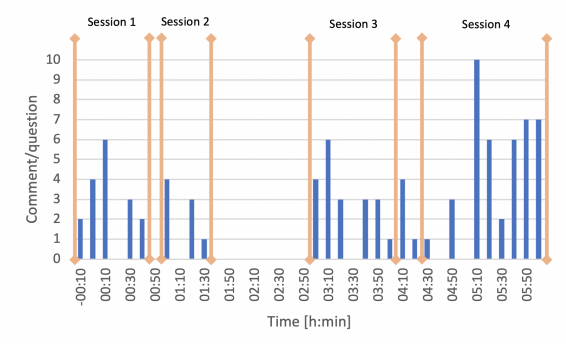

Figure (4.39) Workshop 4.1. Participation frequency.

The instructor shared their screen and video from their camera while lecturing. As one student had problems with their internet connection, the workshop sessions were recorded. The instructor strongly encouraged, and expected, the students to combine the breaks with individual work such as watching assigned videos to make well thought through comments afterwards or try out the software modular synthesizer. Furthermore, the students were given 40 minutes for individual work with the modular synthesizer-programme during the fourth session, followed by feedback and a whole-class discussion on the design and implementation of the workshop, including the upcoming group projects.

When it comes to student participation during the workshop, the students were asked to interrupt the instructor if they had any questions. Most of the time, the students had their microphones muted and cameras turned off, making it difficult for the instructor to know if they were following or not. The participation frequency is shown in figure 4.39, where both oral and written comments are taken into consideration. As in the previous online workshop 3.3, the participation frequency was relatively high, often reaching 6-10 comments per 10-minute interval. However, some were short comments or comments touching technical issues. During the individual work in session 4, the instructor asked how it was going and the students used the chat to help each other out.

4.8.2 Student Survey

Figure 4.40 shows that the statements regarding engagement received the greatest amount of agreement, with 55%, while communication and creativity received 53% and 50%, respectively. The least agreement was received by collaboration, with 42% agreement.

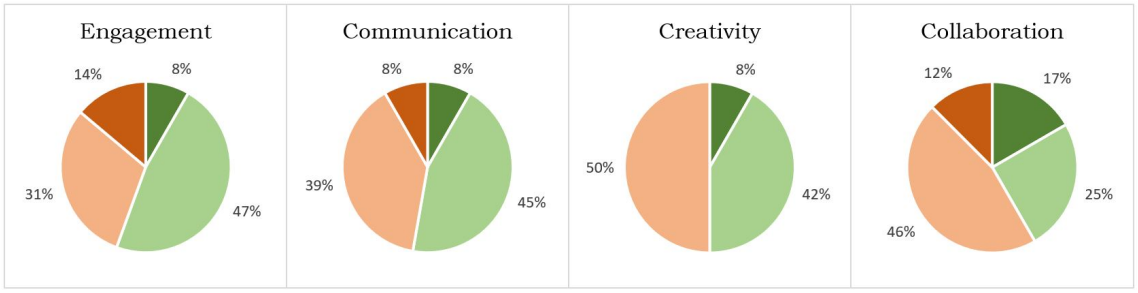

Figure (4.40) Workshop 4.1. The result of question 2 of the student survey.

The students commented about some technical issues, which inhibited learning. Other comments suggested enabled learning however, thanks to the ability to record the lecture and watch it later, either due to not being able to follow it live, or if the need of repetition emerged.

4.8.3 Instructor Survey

The transition to a digital classroom affected the planning a lot, since the instructor had to adapt to what hardware the students had access to at home. The activities had to be adapted as well, as the level of interactivity could not be kept as high as originally planned.

The platform, for the most part, lived up to the expectations of the instructor. Some audio issues were harder to solve than expected, but it was solved with feedback from the students. The instructor stated that it was harder to help the students than expected, and also to know whether they follow, as feedback during lecture portions is sparse.

4.9 Focus Group Interview

Found in this section are the results of the online focus group interview conducted in the study. After each question follows a summary of what was said during the interview. Four students were participating in the interview, of which three were studying at master level and one at bachelor level. Quotations from the students are listed below each question highlighting their perceptions and experiences. These quotes are numbered 1-34, to enable reference in chapter 5.

Q1: What are your thoughts on the course as a whole?

The course was described as a fun break from the rest of the studies, and a connection to the culture that was found to be previously missing from the students' respective programmes. It was not what they expected, but instead more basic, creative, and engaging. The lack of questions which had a right or wrong answer was appreciated, as well as the interdisciplinary group work.

1. "the course is really fun, it is more basic than I thought, but it's more creative than I thought too."

2. “the course was not what I expected at all. It was a lot more engaging, a lot more intuitive.”
3. “I felt like it was something like this missing”
4. “for a change there is no right and wrong answer, it’s more free and interactive.”

Q2: What are your thoughts about the different learning spaces?

To be somewhere new, in a space you are not used to, was described as stimulating and inspiring. The students expressed that the spaces that were considered not to be traditional classrooms were the most preferred ones. Ateljén was specifically named in this regard. The students enjoyed how they were seated in the room, as this gave an interactive and relaxed feeling to the lecture.

The chairs in Ateljén however, were described to be a big negative thing about the room, in combination with the fact that the students were seated for a long time. The students mentioned that they would have preferred moving around, and a variation of sitting and standing. They would have wanted more tactile experiences, which they were anticipating and looking forward to for the last workshop, which unfortunately had to adapt to the transition to the digital classroom.

5. “It’s a nice change to not be in a standard classroom where there is one teacher and a lot of students and it’s usually a one-way communication.”
6. “It’s something about sitting down like that, in front of a screen, that’s really relaxed. So that was nice.”
7. “when we moved to the Ateljén I was like ‘Wow - I think this is a good place to be creative’.”
8. “I would have wanted more of a variation, maybe get to move around in the room. Or at least more ergonomic chairs.”

Q3: How did the learning spaces relate to the aim of TRACKS and the identified learning?

The atmosphere of Ateljén was said to contribute to the communication. That they were seated in a semicircle was again mentioned, now as something that contributed to a feeling of not having a lecture, as the students were not seated behind a table. According to the students, the semicircle also made it easier to stay focused and engaged compared to in a traditional classroom. The students also talked about how they during the break had hung out in the space, without feeling a need to leave the room.

The acoustics lecture room was instead described as crammed, and the students mentioned the difficulty to get a visual connection, as they had to shift in their seats to see. It was a room they had to leave during breaks.

9. “we were at one point sitting in a semicircle, literary looking at each other.”
10. “in Ateljén we didn’t have to go out of the room, we just hung out there because it is such a spacious, well-lit room.”

11. “the little ring we made at the end of the third workshop was really special, because it was such an intimate experience to have a lecture that way”
12. “it does really make an impact if your lecturers are really passionate about what they’re teaching. If you can sense they are having fun, it rubs off and it influences how much you grasp a concept.”

Q4: How big part did the space play compared to lecturers and the themes of the lecture?

Initially, the students talk about the theme and instructors as the main contributors to their learning. But further into the conversation, they started to discuss a connection to the space as well. Connections mentioned were about how the instructors used the space, or how the space could encourage engagement and communication with both instructors and peers.

13. “of course, it all comes down to what you’re being taught, if you have an interest in it or not. But I felt like it was easier to stay focused for longer, easier than in a regular classroom.”
14. “the lectures, for me, are a bigger factor than the actual classroom. If it was some other typical lecture it would really be uncomfortable and not a great experience.”
15. “[In the Acoustics Lecture room] it was more like - sit down and look at the lecturer giving the presentation - sort of a classroom feel.”
16. “I felt relaxed being in there [Ateljén], which simplifies just asking a question or turning to another student and talk to them about some specific questions.”

Q5: What are your thoughts about the different factors of the space? Which was most important?

Light, temperature, air quality, aesthetics were directly named as important factors by the students. But they also spoke in terms of views, geometry, openness, seating layout and space type.

17. “For me, I really need sunlight. I feel that, I don’t know, I just feel more happy, at peace. [...] It doesn’t have to be direct sunlight, but just that you get some connection to the outside world is really important.”
18. “Temperature and air quality. It is easier to concentrate when there is some oxygen in the room and it is not too warm or too cold.”
19. “It was a relief to come to the Atejlé, because it is such a big room [...] it is such an airy venue for the number of people that we were.”
20. “the air quality, temperature and sunlight were fine, but I think the aesthetics of that room played a big role as well. That it’s not a completely white classroom, there’s little things everywhere.”

Q6: What did the 'does not affect me' option mean to you?

The students agreed that the 'does not affect me' option was used primarily when the factor was nonexistent, or not too bad. They stated that for them to perceive something is inhibiting, it had to be really bad. The students also said this could be due to them being used to some things not being great, and it was implied that something one is used to becomes neutral and therefore it no longer has an impact.

Lastly, the students stated that it had to do with the fact that you need something to compare with. It was implied that the way they thought about what affected their learning changed throughout the study, as they became more aware.

21. "where I put 'does not affect me' I think it was the lack of that thing"
22. "when I came to a room with say great lighting, it was more clear that it did affect me in a positive way."
23. "most of us are used to classic classrooms, maybe we are accustomed to some things and we don't notice them. For example, if there is no natural light. I'm used to that."
24. "If you don't have anything to compare it with, it is easier to put 'does not affect me'."

Q7: How did you experience the digital lectures?

The students stated that primarily participation, focus and communication was negatively affected by the transition to the digital classroom. But they also mentioned that they were impressed by how well the instructors pulled it off and the adaptations that were made.

25. "because of the physical distance it is not the same feeling. You are more on your own. In that sense it was more difficult to engage and communicate with others."
26. "It is easy to just, even if you have a question, not ask it because you don't feel the connection in the same way you do live."

Q8: Is there anything in the learning spaces that could be changed to increase learning?

The students implied it came down to the duration of which they spent seated. Something should be done with the comfort of the furniture, without losing the flexibility of the space and seating.

27. "Again, the chairs. They made it really difficult to focus on what the lecturer was saying."
28. "the workshop duration"
29. "Do all the workshops with flexible seating and not a structured table chair setup."

Other quotes of interest

30. "you see that [Ateljén] is a room that's used for creative things. And just to be in that environment enhances your ability to be creative"
31. "The fact that you had to pull out your own chair, and just little things like that, made it more engaging."
32. "you see that something is going on even when you are not there, and someone is working. And then you go there the next day and something has moved. So, it's a bit more dynamic."
33. "if we redid the surveys from the first workshop, you would get some different answers"
34. "for participation reasons I think it is better to have a few rows that are stretched longer, than to have five people and then five people and then five people. It is a more engaging seating arrangement, I think."

5

Discussion

In the following chapter, the method used in this thesis is problematised and discussed. Thereafter follows reflections on how the physical space and its different environmental factors affect Challenge-Based Learning. These reflections are sorted into sections based on the categories of learning defined in section 3.1. Finally, the role of physical space in education is discussed through a comparison to learning taking place in digital space.

Following the discussion is a section listing recommendations for the development of future learning spaces, based on the outcomes of this study. Lastly, suggestions for further research are described.

5.1 Discussion of Research Methodology

This study had a relatively small number of participating students, which might be considered a disadvantage. More participants would have meant a greater certainty for the trends that have emerged from the results. However, the ability to measure engagement and person-environment interaction through observations was of great importance for the study. Since observations are restricted to a certain place and time, the population from which the participants could be chosen had to be limited. During the time of this study, there were two possible courses which could have been investigated, and only one was chosen. It must, therefore, be acknowledged that there is a possibility that the conclusions of this study could have varied if a different choice had been made. Another part of that, however, is that if the choice to follow both courses would have been made, the possibility of having two observers present during the workshops probably would have been eliminated. This would have been a problem, as having dual observers is an important part of the method to ensure the validity of observation data, described in section 3.3.

This study has focused on investigating the students' and instructors' perceptions of the space, and the perceived learning. This choice was made, due to the gap in research within the field, identified by Brooks (2011) and Cleveland and Fisher (2014), namely, the relationship between the space and the learning and teaching occupants within it. The perspective of occupants' perceptions was also indicated to be more modern, as it was used by the most recent evaluation models found. However, this perspective has the disadvantage of subjectivity, and also the uncertainty in to what extent the students understand or are aware of their own learning. Connecting to this is the fact that the process of participating in the study

likely changed the students perceptions, expectations, and views as it progressed. This was also attested by the students, with quote 33 from the interview. However, it could not clearly be detected in the data itself. The students can also have influenced each other, which is probably most prominent in the focus group.

5.2 Discussion of how Physical Space Impacts Learning

Below follows a discussion of how the physical spaces used in the course affected learning, divided into the different areas of defined learning for this context. It concludes with a discussion of the impact of the transition to the digital space.

5.2.1 Engagement

The factors of the space which seem to affect the engagement of the students are: air quality; temperature; and furniture comfort, as there is a clear correlation between high agreement in engagement and high enable-ratings of these factors. In other words when well-being is ensured, the students become more focused and engaged with learning. Consequently, the results from this study regarding the relationship between physical space and engagement, to a high degree confirm the findings from Hunley and Schaller (2009) presented in section 2.2.2. Such a conclusion might seem natural and unsurprising. More interesting, however, was the extent to which the seating layout seem to affect engagement. This can to some degree be seen in the survey responses, but was a lot more clear in the focus group interview. Quotes 6, 9, 15, 29, and 31 all suggests that how the students are seated in a space, or maybe rather the flexibility of the seating layout, is of great importance for engagement. It contributes to the space feeling dynamic and therefore encourages activity and involvement, a result comparable with findings from previous research (Radcliffe et al., 2008; Hunley & Schaller, 2009; Brooks, 2011; Alfredsson, 2017; Akademiska hus, 2019). As part of this, movement was something that was missed by students, and the lack of it was well documented in the observation forms. The observed movement of picking up and placing one's own chair at the start of workshop 2.2, was named by the students as a great example of flexibility with increased engagement as a result.

To state that engagement is closely linked to the participation rate might be considered redundant. By looking at all the workshops together this connection can be seen over and over. Spaces like Ateljén and Ljusgården, which are considered more engaging were also observed to have a higher participation frequency or involved more activity among the students. Furthermore, there is an interesting difference seen when comparing the survey results from workshop 1.1 and workshop 3.1. For these two occasions, even though they were in the same location, the space was perceived to contribute to the students' engagement and involvement at a higher extent in the latter of the two. The main difference between the two occasions were the students' participation frequency and the amount of active learning methodology used by the instructor. The similar tendency can to some extent also be seen

comparing workshop 2.1 and workshop 2.2. Again the two occasions took place in the same space, and even though they have the exact same level of agreement to the engagement statements, there is an apparent contrast between the level of strong agreement. The same sentiment was also implied in the interview, quote 14, which stated that the content of a lecture affects the experience and whether the space is perceived as comfortable or not. Hence, a more engaging room does not automatically imply a higher level of participation. Instead it seems like the amount of participation and type of activities in a space, in a way, can change how the space is perceived. This supports what Alfredsson (2017) pointed out from the findings of several studies performed in ALCs, described in section 1.1.1.

Important to note is that, even though the above connections can be found in both the survey and the interview result, the students agreed, when asked directly, that it was the instructors and the content, rather than the space itself that affected their engagement. The passion and engagement of the instructors was said, as per quote number 12, to rub off on the students. That it makes them more engaged when it was visible that the instructors not only wanted to teach, but also wanted them to learn.

5.2.2 Communication

The results from the student surveys show that, in general, the students perceived the different learning spaces as promoting discussion and enabling connection both to each other and to the instructors. Especially a combination of the environmental factors space type, seating layout and geometry were seen to have an impact on communication. This was not evident by merely looking at the radar charts from the student survey, as for example the Acoustics lecture room received high ratings in workshop 1.1 for how the space affected communication, despite low ratings for the environmental factors mentioned above. However, the impact of these factors on communication became clearer through the focus group interview. Firstly for space type, quote 5 from the interview shows how the students experienced it as a nice change to not be in a traditional classroom where there usually is a one-way communication. Secondly, quote 9 and 11 demonstrate that a change in seating layout from a row-layout to a circle-layout was said to create a more intimate experience, as the students were facing each other. The results from observations together with quote 34 from the interview confirm a higher participation frequency with wide, stretched out rows, compared to a traditional presentation seating layout. Thirdly, quote 10, 16 and 19 from the focus group interview illustrate how the geometry and volume of the space in relation to amount of occupants can influence the students to become relaxed, which in turn simplifies connection and discussion.

One interesting thing to note is how the answers from the student surveys differed from what was observed during the workshop sessions and what was said during the focus group interview. According to the survey results, the Acoustics lecture room was perceived as promoting communication, with 65% and 77% agreement respectively for the statements related to communication. The focus group instead

mentioned that the communication was negatively affected by the Acoustics Lecture room, as quote 15 implied that there was a feel of one-way communication, compared to in other spaces.

5.2.3 Creativity

The well being and the positive moods' effect on creativity, as described in chapter 2 was also observed in this study. Daylight and views were named by students as essential for their mood, displayed through quote 17 from the interview. This was confirmed with the survey results, where spaces receiving a rating of enabling on the factor views, also had a high level of agreement of the statements regarding creativity. The results further indicate that the dimensions of the space could affect creativity, since the Acoustics lecture room which was smaller than the other rooms and described by the students as cramped and confined, received a comparably high level of disagreement regarding its impact on creativity.

Another factor which the results suggest to be of importance for creativity is the aesthetics. In workshop 1.1, the Acoustics lecture room was described as depressing at the same time as 38% of the students answered that the aesthetics did not affect them. In contrast, the survey results from workshop 1.2 at Ljusgården show that all of the students found the aesthetics to affect the learning, this time almost exclusively in a positive way. Simultaneously, the perceived positive effect of the space on creativity increased from 29% to 70%. This was confirmed to apply to Ateljén as well, both from the survey result and the interview, with quote number 7 and 20. It was therefore theorised at the start of the analysis stage that the aesthetics was an elevating factor. That it either had a positive effect, or it did not have any effect at all. The results from the interview, however, indicate that it instead has to do with what the students are used to, similar to what Hunley and Schaller (2009) concluded from their multiyear study, described in section 2.2.2. Quotes 23 and 24 suggest that being accustomed to the conditions of the traditional classroom means that the students might not notice the negative effect of certain factors. Especially if there is nothing they can compare the space to. In the interview, the students also stated that just being in a new space, or to experience a big variation of space types, was inspiring and lead to more creativity.

So the results indicate that both aesthetics and space type are important for creativity. The question then becomes how these factors can be utilised to achieve a positive effect. Quotes 30 and 32 from the interview seem to provide an answer for this. They imply that Atéljen, being an art studio in which it is evident that creative work is constantly in progress, makes the students feel more creative. This can also help explain the positive effect that Ljusgården was perceived to have on creativity, as this is a space often used to display creative work. In other words, it seems like creativity sparks creativity.

5.2.4 Collaboration

As shown in table 4.1, 92,2% of the total workshop time was spent on lectures, presentations and discussions. Merely 2,5% of the total workshop time was spent on

group work. Almost all of the group work assignments were scheduled to take place outside of class, and as these activities were not observed, the results regarding how the physical space affected collaboration are limited.

5.2.5 Learning in Digital Space

The students expressed, both in the surveys and the interview, that the transition to the digital platform had a negative effect on engagement. Quote 25 and 26 from the interview demonstrate that because of the physical distance the students felt more isolated. It was more difficult for them to feel a connection and engage with each other compared to an in-person setting. This can be seen in the student survey results from workshop 3.3, where there was a disagreement of 76% for the statements related to engagement. The survey result of workshop 4.1, however, is a bit more ambiguous. Because while the agreement is higher than for workshop 1.1, workshop 4.1 shows the highest amount of strongly disagree out of all of the occasions.

Interesting to note is that if the parts that were conducted online would follow the same pattern as the rest, the low engagement would suggest the participation frequency to be low as well. On the contrary, participation in the online environment was much higher compared to the previous occasions conducted at campus. However, the type of communication also differed, as it in the digital classroom was a higher degree of short affirmative comments.

When it comes to workshop 3.3 and 4.1 which were conducted off-campus in an online setting, results from the student surveys as well as the focus group interview show a larger disagreement for the statements related to communication. Again quote 25 and 26 display how physical distance can make communication more difficult. Figure 4.38 and 4.40 display how the online environment had more of a negative effect on communication compared to the in-person workshop occasions on campus. According to the instructors, the inability to see the students made it harder to know whether they were following. At the same time, the digital platform was perceived to make everyone more equal, the hierarchy in the space was less prominent, and in that sense made communication easier. Moreover, apart from several technical issues with the equipment, the ability to record online workshops was positive for communication, as it enabled students who could not participate the scheduled time to take part of the lecture later.

5.3 Discussion of the Instructor Perspective

Even though the instructors when asked during the course, implied that the spaces were chosen according to whether they made the planned activities possible, the spaces had a considerable impact on the planning of all but one occasions according to the instructor surveys. When it comes to environmental factors, the instructor surveys indicate that mainly room size and technical equipment affected planning and teaching. Apart from the impacts of physical space on planning, the pedagogy of CBL seems to have affected the planning of the course as a whole, as the instructors several times pointed out that multidisciplinary teamwork was a central part of

the planning and execution. However, from the observations it is unclear to what degree the instructors were familiar with CBL. The observed workshop occasions seems to in many cases have been regarded as being outside of the CBL-approach, as the instructors were observed to a large extent taking the role of information experts, instead of expanding their role to becoming co-learners, which is desired within CBL according to Nichols et al. (2016). That the observed occasions were regarded as outside of CBL would also explain the lack of group work observed. Instead, the students were expected to carry out teamwork assignments between the workshop occasions and present their results at the end of each workshop. An offer of guidance during this in-between time was voiced during the occasions observed, but not scheduled, so whether this occurred and to what extent, is unknown. No patterns were detected when it came to whether the space lived up to the expectations of the instructors.

5.4 Recommendations for Development of Future Learning Spaces

In this section, an attempt is made to give recommendations for the design and development of future learning spaces that are to promote Challenge-Based Learning, based on the literature study and outcomes of this thesis.

- Acknowledge the physical space as an actor. The space can provide conditions that either encourages or discourages behaviour, such as the level of engagement, communication and creativity among the participants.
- The design of physical learning spaces needs to be informed by the intended learning. A specific type of pedagogy that involves certain types of activities, is only made possible by making sure the designers and decision-makers are well-informed about the intended pedagogy and learning.
- The space in itself is not the whole solution for success. It is important to consider providing further instruction for teachers regarding how to implement pedagogical strategies of CBL and how to best make use of the physical spaces to enhance learning.
- For the design of future learning spaces to effectively support CBL, a bottom-up approach that involves students and teachers is crucial, to understand the actual needs of the users.

5.5 Further Research

A general goal of this study was to provide eligible hypotheses for future research projects through implementing an initial exploratory research approach. Based on gathered knowledge from this study, what follows are suggestions for what kind of investigations that should be conducted in the future.

- **More samples from each space**

  This study did not have any influence over what spaces to use, how the spaces were configured nor how many times each space was used. This put severe restrictions on the investigation, and going forward it is therefore recommended that an investigation is conducted where respective space is observed a greater number of times. This to minimise the risk of coincidental results, or the false perception of the influence of one factor on another.

- **Different groups within each space**

  Each specific group is assumed, by researchers today, to have different perceptions of a space. It is therefore recommended that a greater number of different groups are observed within the same space, to approach the making of general assumptions.

- **Compare the effect of the space, to the effects of pedagogy and instructor**

  In chapter 6, this study concludes that the physical space is one of three actors which impacts learning, the others being pedagogy and instructor. It is however still interesting to investigate the respective importance of these actors.

- **The impact of acoustics**

  This study did not give a clear result of the effect of acoustics on learning. It is therefore relevant to continue to investigate whether, and how, acoustics affect learning, and also how it then can be evaluated successfully.

6

Conclusion

Because of what Lackney (1999) said about the third level of physical learning environment evaluation, that only the specific group in the specific space can be considered, the conclusions of this thesis should not be regarded universal facts, but rather trends. This study should neither be considered isolated, but rather as a part of the growing amount of data collected in this, still relatively unexplored, field of study. It should also be considered together with data collected through subsequent studies, as this study aimed to provide a foundation for these future studies.

The results of this study indicate that the physical space indeed has the power to impact learning. The data suggests that this power is shared with the pedagogy and the instructor. Here, pedagogy and instructor are considered two separate actors, as the instructor has the freedom to choose what aspects of the intended pedagogy, such as CBL, to use. Even though this study could not see any hierarchy or division in importance, as this was not sought, it was implied that all three factors interact closely with each other, as visualised in figure 6.1.

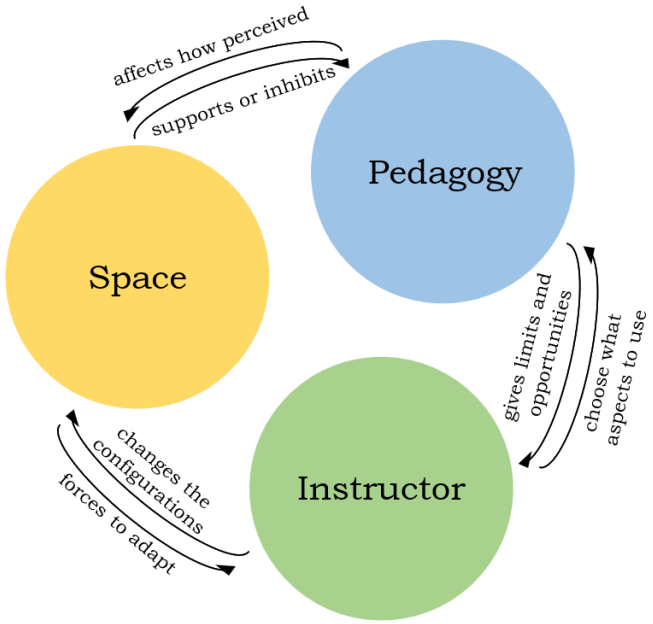

Figure (6.1) The interaction between the three actors of learning: Pedagogy, Space, and Instructor

The space forces the instructor to adapt, as shown by the instructor surveys, while the instructor can change the space configurations, which was observed by rearrangement of furniture and the equipment brought to the workshops. The instructor chooses what parts of the intended pedagogy and methods to use, observed in the proportion of the respective activity types, while the intended pedagogy and methods put limitations and opens up possibilities for the instructors. The space supports or inhibits the pedagogy, and what type of pedagogy is used can affect how the space is perceived, as shown by the students' perceived engagement. The last-mentioned interaction is the most prominent one in the result of this study. The theory suggested that the space should be designed for the intended learning (Hertzberger, 2008; Radcliffe et al., 2008), and the results of this investigation confirms this suggestion. If the intention is to encourage engagement the students' well-being should be prioritised, and the seating layout should be considered. The space type, seating layout, and geometry of a physical learning space can encourage intended communication. If creativity is wanted, the focus should be on views, light, space type, and aesthetics. The space should also showcase creativity.

This study concludes that when a new space is to be designed, or redesigned, the intended learning and pedagogy needs to be considered. The type of learning intended should be allowed to guide the design, to give the users the right learning conditions. If CBL is the wanted method, the results of this study suggest the need for comfort and well-being from the building conditions. That the space design focuses on openness in geometry, as well as views and a connection to the outside. The space should also be designed around the creativity of others. The space configurations, with focus on seating layout should enable eye contact between all occupants, but at the same time be used with flexibility and movement. To validate, or confirm any of these design suggestions however, they need to be tested in an action research matter, and they each need to be isolated from other factors that can have an impact on learning, to claim any causal links between each environmental factor and learning.

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A

Appendix

A.1 Learning Spaces

A.1.1 Acoustics Lecture Room

Figure (A.1) Acoustics Lecture Room. Photos and floor plans of the physical space.

Space design		
	Space type:	traditional classroom
	Geometry:	5.2 x 7.8 x 4.0 [m]
	Aesthetics:	White walls; blue chalk boards; hanging white acoustics dampers; steel ladder; wall-posters; ventilation steel pipes.
	Views:	A large machine 2 m outside the classroom; windows 10 m outside the classroom window; a parking lot; a big building in the background, 150 m away.
	Openness:	1-4% of walls; 0% of ceiling
	Light:	Indirect daylight; direct overhead homogeneous artificial light from fluorescent lamps.

Space configurations		
	Seating layout:	Presentation. Limited space between rows.
	Room capacity:	26 people.
	Furniture:	Wooden tables, 120x50 [cm], with metal legs, nonadjustable; chairs, nonadjustable.
	Equipment:	Projector; projector screen; chalk board; speakers.

Table (A.1) Key Characteristics of Acoustics Lecture Room

A.1.2 Ljusgården



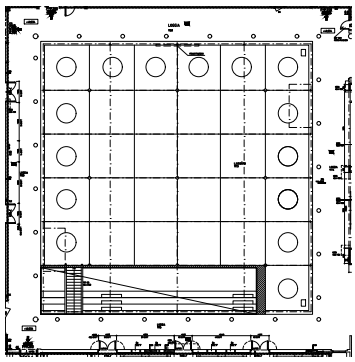


Figure (A.2) Ljusgården. Photos and floor plans of the physical space.

Space design	
Space type:	Indoor courtyard
Geometry:	25.3x25.3x19.5-28.5 [m]
Aesthetics:	Brown air bricks on first floor; oxidised copper on the second to the fourth floor; white walls on the top floor. Balconies hanging off the walls, facing the courtyard; white pillars surrounding the courtyard; ribbon windows and a pyramid shaped glass ceiling. A big sculpture, a semi-circle, is hanging from the ceiling.
Views:	The blue sky above; entrance area, wood workshop, library, and meeting room in the first floor; classrooms and other learning spaces facing the courtyard on the second to fifth floors.
Openness:	60% of walls; 100% of ceiling.
Light:	Daylight and artificial light; direct overhead and homogeneous.

Space configurations	
Seating layout:	None.
Room capacity:	Unknown.
Furniture:	None.
Equipment:	Pedestals and wires for exhibitions.

Table (A.2) Key Characteristics of Ljusgården

A.1.3 Ateljén

Figure (A.3) Ateljén: Photos and floor plans of the physical space.

Space design	
Space type:	Art studio.
Geometry:	10.2x13.5x6.0; 11.3x5.2x3.0 (mezzanine) [m]
Aesthetics:	Raw and industrial; white wood panels, concrete walls, and exposed wood details; a blue industrial bridge hanging from the ceiling; steel railings; concrete floor on lower level and exposed wood flooring on mezzanine; differently sized easels hanging off the walls.
Views:	The sky and the exterior of two other buildings approximately 50 meters away outside the windows; a corridor and Ljusgården outside the doors; a storage space underneath the mezzanine.
Openness:	15% of walls; 0% of ceiling.
Light:	Direct daylight, diagonal down from windows towards seating; overhead homogeneous artificial lights sometimes used.
Space configurations	
Seating layout:	Presentation, temporary; group work tables on mezzanine.
Room capacity:	Approx. 65 people
Furniture:	Plastic folding chairs; wooden folding tables.
Equipment:	Art materials; projector screen; portable projector; sound system; blackout curtains.

Table (A.3) Key characteristics of Ateljén

A.2 Learning Outcomes of TRA100 and TRA105

After completion of the course the student should be able to:

TRA100/TRA105
critically and creatively **handle/identify and formulate** advanced architectural or engineering problems.
tackle/master problems with open solutions spaces which includes to be able to handle uncertainties and limited information.
participate/lead and participate in the development of new products, processes and systems using a holistic approach by following a design process and/or a systematic development process.
work in multidisciplinary teams and collaborate in teams with different compositions.
show insights about cultural/ethnic differences and to be able to work sensitively with them.*
show insights about and deal with the impact of architecture or engineering solutions in a global, economic, environment and societal context.
identify ethical aspects and **discuss/discuss and judge** their consequences in relation to the specific problem.
orally and in writing explain and discuss information, problems, methods, design/development processes and solutions.
fulfill project specific learning outcomes.

Table (A.4) Learning outcomes, general for all Tracks courses

* exclusive for TRA105

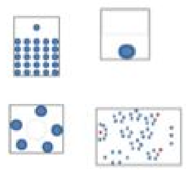
A.3 Environmental factors

Environmental factor	Aspects of environmental quality	References that include the factor
Light	Well-being/comfort	(Akademiska Hus, 2018; Hertzberger, 2008; Hunley & Schaller, 2009; OECD, 2018; Public Health Agency of Sweden, 2017; Weinstein, 1979)
Temperature	Well-being/comfort	(Hunley & Schaller, 2009; Lackney, 1999; OECD, 2018)
Acoustics	Well-being/hearability	(Akademiska Hus, 2018; Akademiska hus, 2019; Hertzberger, 2008; Lackney, 1999; OECD, 2018; Weinstein, 1979)
Air quality	Well-being/comfort	(Hunley & Schaller, 2009; Lackney, 1999; OECD, 2018; Public Health Agency of Sweden, 2019; Satish et al., 2012; The Swedish Work Environment Agency, 2009)
Aesthetics	Articulation of the space	(Akademiska Hus, 2018; Hertzberger, 2008; Hunley & Schaller, 2009; Lackney, 1999; OECD, 2018)
Space type	Usability of space	(Akademiska Hus, 2018; Akademiska hus, 2019; Alfredsson, 2017; Brooks, 2011; Hunley & Schaller, 2009; Lackney, 1999; OECD, 2018)
Geometry	Spaciousness/usability of space	(Akademiska Hus, 2018; Akademiska hus, 2019; Hertzberger, 2008; Jamieson et al., 2000; Lackney, 1999; Weinstein, 1979)
Views	Well-being/openness/sight lines	(Hertzberger, 2008; OECD, 2018; Public Health Agency of Sweden, 2017; Weinstein, 1979)
Seating layout	Flexibility/space configurations	(Akademiska Hus, 2018; Alfredsson, 2017; Hunley & Schaller, 2009; OECD, 2018; Radcliffe et al., 2008; Weinstein, 1979)
Furniture	Functionality/comfort	(Akademiska Hus, 2018; Akademiska hus, 2019; Alfredsson, 2017; Hertzberger, 2008; Hunley & Schaller, 2009; OECD, 2018)
Equipment	Functionality/space configurations	(Akademiska Hus, 2018; Akademiska hus, 2019; Alfredsson, 2017; Brooks, 2011; Hunley & Schaller, 2009; OECD, 2018; Radcliffe et al., 2008)

Table (A.5) The environmental factors considered in this study linked to references that include them as significant.

A.4 Observation Protocols

A.4.1 Protocol 1 - Fixed variables

Date	Spatial arrangments			Comfort/well-being	
	Space type	Seating layout	Aestetics	Light	Furniture
					

Openness/enclosedness			Usability of space/functionality			Comments
Openness [%]	Sight lines	Views	Room capacity	Geometry W ,L ,H [m]	Equipment	

Space type Trad. classroom, tech. workshop (wood, metal, plastics, robotics), hall/auditorium, studio space for art,music,design, other;

Aestetics: materials, colors, details; **Light**: daylight/artificial, direct/indirect, concentrated/homogenous, sidelight/overhead light;

Furniture: comfortable/adjustable/movable **Openness:** Percentage of the walls/roof that is open or has windows

Sight lines: interior-exterior, interior-interior, interior-interior-exterior; **Views:** description of what is seen outside the space;

Room capacity: the intended amount of people for the space

A.4.2 Protocol 2 - Changing Variables and Use of Space

Observation Form

Date and Time: ____ | ____ | 2020
Teachers:
Room:
Number of students: ________

Time	Activities							Students			Comfort/well-being				Comments
	Lecture	Discu-ssion	Ind. work (1)	Small Group (2-3)	Large Group (4-9)	Use of equipme nt	Rearran gement	Participation Frequency	On-task	Move-ment	Temp [°C]	Noise [dB]	CO2 [ppm]	RH [%]	
-00:10															
00:00															
00:10															
00:20															
00:30															
00:40															
00:50															
1:00															
1:10															
1:20															
1:30															

CODING KEY:
Lecture/Discussion: X = Event occurs during interval, **Individual Work, Small Group & Large Group:** 1 = First instance of group work; 2 = Second; 3 = Third; Etc.; **Use of equipment:** b=white or black board, p=projector, o=other (state which equipment as comment). **Rearrangement:** X = rearrangement of furniture or equipment; **Participation Frequency:** X = 1 question or 1 comment from a student; **On-task:** e.g. 13/20. number of students actively participating; **Movement:** S=sitting down, M=moving around; **Comments:** Open-ended description of classroom activities.

A.5 Surveys

A.5.1 Personal Data Form

Approval for the handling of personal data

The purpose of this study is to analyze the impact of the physical learning space in relation to the intended learning, to propose recommendations for the development of future learning spaces. To participate in the study by filling in surveys is voluntary. The only personal data that will be collected is your name. The personal data that is gathered will be used for this master's thesis exclusively.

The data will be anonymized continuously, within 48 hours after each survey is filled in, by replacing the name with a code to be used in the ongoing study. The personal data will be handled confidentially, it will only be available for the two master students carrying out the study. The personal data will be stored locally on a USB/PC.

Any communication regarding the study with persons outside the project group are based solely on anonymized material. The personal data will be deleted after the completion of the master's thesis, 2020-05-31.

As the data for the study is gathered from one specific course, complete anonymity at a group level is not possible. The results of this research project will be published as a master's thesis at Chalmers University and may also be used as a contribution to a conference. The name of the course will not be published. The personal data will not be published so that it is possible to relate the data with a specific individual.

The participation in the study can be cancelled at any time through a written email to the master students carrying out the project (see contact information below).

Data controllers/master students carrying out the study:
Angelica Lindberg, anglind@student.chalmers.se
Jonas Bergström, jonasber@student.chalmers.se

I hereby authorize my personal data to be used in the research project "Architecture and Learning" at Chalmers University.

Date	Signature
_____	_____
Place	Printed name
_____	_____

A.5.2 Student Survey

Survey – Learning Environments

The learning outcomes of the course focus on product development in interdisciplinary and international teams. The skills you should develop during this course are closely connected to ***collaboration***, ***communication*** and ***creativity***. We are investigating how the physical learning environments affect your ability to learn and develop these skills.

1. To what degree do the following factors enable or inhibit your learning in this learning environment?

	Enables	Partially enables	Partially inhibits	Inhibits	Does not affect me
Light: e.g. daylight, lighting and how well you can see	☐	☐	☐	☐	☐
Temperature: e.g. too hot, too cold or just right	☐	☐	☐	☐	☐
Acoustics: e.g. how well you hear or the presence of noise	☐	☐	☐	☐	☐
Air quality: e.g. presence of odor or oxygen level	☐	☐	☐	☐	☐
Aesthetics: e.g. color, materials or ornamentation	☐	☐	☐	☐	☐
Space type: e.g. classroom, workshop or other	☐	☐	☐	☐	☐
Seating layout: e.g. how the seating is arranged in the room	☐	☐	☐	☐	☐
Furniture: e.g. comfort or functionality	☐	☐	☐	☐	☐
Equipment: e.g. whiteboards, computers or tools	☐	☐	☐	☐	☐
Geometry: e.g. shape, ceiling height or openness	☐	☐	☐	☐	☐
Views: e.g. windows, openings or what you can see outside	☐	☐	☐	☐	☐
Other:	☐	☐	☐	☐	☐

2. For the next set of statements please indicate whether you Strongly agree, Agree, Disagree or Strongly disagree.

The learning environment I'm currently in…	Strongly agree	Agree	Disagree	Strongly disagree
increases my excitement to learn and enriches my learning experience.	☐	☐	☐	☐
deepens my understanding of the subject taught.	☐	☐	☐	☐
encourage my active participation.	☐	☐	☐	☐
promotes discussion and enable me to communicate effectively.	☐	☐	☐	☐
helps enable connection with classmates.	☐	☐	☐	☐
helps me define issues or challenges.	☐	☐	☐	☐
encourages me to create or generate new ideas or products.	☐	☐	☐	☐
helps me develop confidence in working in small groups.	☐	☐	☐	☐
helps me work in interdisciplinary and international teams.	☐	☐	☐	☐

Other comments or thoughts about how the current learning environment affects your learning and development of collaboration, communication and creativity skills:

A.5.3 Instructor Survey

Survey – Instructor perspective

In order for us to fully understand and be able to assess the learning spaces used in the course, we would be grateful if you – as the instructor – could answer a few questions.

Thank you,
Angelica & Jonas

Name of instructor: _____

1. To what extent did the design of the physical learning space affect your planning of the workshop?

Completely	A lot	Partially	Not at all

2. When planning, what possibilities and/or limitations did you expect the space to provide? (e.g. with respect to equipment, space layout, spatial conditions)

_____

_____

_____

3. Did the reality of the learning space match up to the expectations you had when planning?

Completely	A lot	Partially	Not at all

4. If it did not completely, what possibilities and/or limitations differed, and how did it affect your execution of the workshop?

_____

_____

_____

A.6 Interview Guide

Introduction: (5 min)
Some opening words about the purpose of the interview and how it will be conducted. Explain that we will be recording the interview for transcription purpose, that the recording will be deleted afterwards.

Warm up questions: (5 min)

- What are you studying right now? (For those enrolled in a MS-programme: What did you study before the Master?)
- How have you experienced the course so far?

Thematic questions/follow up questions: (20 min)

- What are your thoughts about the learning environments you have been in during the workshops?
    - Acoustics Lecture Room
    - Ljusgården
    - Ateljén

  (How perceived the rooms? How affected learning? Favourite room? Most disliked? - Why?)

Tracks aim/Challenge-based Learning. (Communication, Collaboration, Creativity, Active Learning)
TRACKS aim to be "a platform to work and solve challenging multidisciplinary authentic problems in teams and to learn to function efficiently in global teams."

- How did the rooms affect this type of learning?
    - How big of a part did the room play? In comparison to factors such as pedagogy or lecture theme, lecturer?

- The 11 factors: Light, Temperature, Acoustics, Geometry, Space Type, Seating Layout, Views, Furniture, Equipment, Air Quality, Aesthetics. Thoughts about them and their impact on learning?
    - Most/Least important? Why?
    - Thoughts about "Does not affect me." Did this differ between rooms?
    - Other factor we forgot?

- (How did you experience the digital workshop sessions?)

Question regarding development: (5 min)

- Is there anything in the learning environment that could be adjusted/changed to enhance learning?

Closing question: (5 min)

- Is there anything else you are thinking about that you would like to add?