SCIENCE CENTER AS COMPLEMENTARY LEARNING ENVIRONMENT TOWARDS INCLUSIVE MATHEMATICS EDUCATION

An exploratory case field study

Master´s thesis in Learning and Leadership

ELIN BRYNE & MICHAEL PERSSON

Department of Communication and Learning in Science

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MASTER`S THESIS 2025

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Supervisor: Lena Pareto, Department of Education, Communication and Learning, University of Gothenburg

Examiner: Philip Gerlee, Department of Mathematical Sciences, Chalmers University of Technology

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Department of Communication and Learning in Science

Chalmers University of Technology

SE-412 96 GOTHENBURG

Telephone +46 31 772 1000

Gothenburg, Sweden 2025

Abstract

Universeum is the national science center of Sweden and is located in Gothenburg. The role of a science center in the society is to inspire people to learn and engage with science and the subjects in STEM. Mathrix is a newly developed experience-based learning environment at Universeum that focuses on exploring mathematics in a relaxed manner to improve attitude towards the subject and challenge the perception of the subject being difficult in order to lower the common barriers to the subject.

Several indications have been received by visiting teachers since the opening of Mathrix, that Mathrix could be a favourable learning environment for students that do not fit into the neurotypical part of the neurodiversity spectrum, which led us to investigating these indications further.

The study was an exploratory case field study conducted in Mathrix with the aim to examine if and how Mathrix can function as a complementary learning environment to the traditional classroom environment. The study consisted of a series of interviews with the participating teachers and observation sessions with the teacher/student groups performing learning activities in Mathrix at two occasions. 5 teachers and 14 students participated in the study. A thematic analysis was used to categorise the data production in three parts: categorisation by students' strengths and challenges, categorisation by learning situation_theme and categorisation by learning theory.

The findings shows that the learning environment in Mathrix together with the teaching organisation during the sessions can increase student engagement and interest in mathematics, contribute to higher self-efficacy in mathematics, and create favourable possibilities for scaffolding both by the teacher and between peers. The strong positive results regarding student engagement, self-efficacy and math performance may however partly be explained by the novelty of the environment, the situation, and beneficial small-group settings. Nevertheless, the Mathrix learning environment show high potential to function as a more productive learning environment than the classroom for this group of students.

The conclusion of this study is that the learning environment in Mathrix together with the teaching organisation result in beneficial learning opportunities that can support the students in their mathematical learning in the classroom, thus making Mathrix a complement to the classroom environment in mathematics.

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Elin Bryne & Michael Persson

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Thesis outline

Chapter 1	*Presents the introduction of this master thesis, including background relevant to the work, purpose and aims, the research question, and the delimitations for the thesis.*
Chapter 2	*Presents the theoretical framework used in the study to help understand the empirical findings.*
Chapter 3	*Presents previous research in this field to emphasise the purpose of the study and to compare with in the discussion.*
Chapter 4	*Presents and describes the methodology in this exploratory case field study including the empirical setting in the exhibition Mathrix, the research approach, data production, data analysis and a description of the thematic categorisation.*
Chapter 5	*Presents the findings of the study, including descriptions of the sessions, the participants and the characteristic strengths and challenges of the student group. Followed by the results from the sessions and the interviews.*
Chapter 6	*Analyses the data production in relation to the categories that emerged and the theoretical framework.*
Chapter 7	*Discusses the findings in relation to the characteristics of the participating students and problematises the validation of the results. Followed by our suggestions of future work.*
Chapter 8	*Presents the conclusions of this exploratory case field study.*

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1 Introduction

1.1 Background

In the modern society of today basic mathematical knowledge is essential both for the individual and for the society. Mathematics is crucial for every individual in many areas of life and is an important tool for problem-solving, logical thinking and reasoning, and for communication between individuals (1). As the society becomes more and more technological the numerical ability and problem-solving skills will be even more essential (2) and "[c]ompetent performance in mathematics is widely recognized as a necessity for participation in the 21st-century economy" (3, p.306). Typical daily tasks such as budgeting and time management are linked to being able to use basic mathematical knowledge and the ability to understand and work with numbers (4). If individuals lack the opportunity to acquire basic mathematical knowledge and abilities, they have a greater risk of being unemployed, engaged in criminal activity, and report poorer mental and physical health (4).

Accordingly, it is very important that every child gets the opportunity to learn basic mathematics in school. It is also important that students do not develop an aversion to the subject as it is a core school curriculum that will follow them throughout the schooling. Like many other subjects in school the education in mathematics is cumulative and students who demonstrate low performance in mathematics early on "are more likely to perform poorly in math throughout their schooling" (4, p.248). So, for both low achieving students in general as for students with a neurodevelopmental variation it is important to address mathematic disabilities to prevent numerical skills incompetency that can in more serious cases develop to a deliberate avoidance of numbers (5). Typically, this can further increase the gap between high achieving and low achieving students in mathematics, and for low achieving students in mathematics, it is known that repeated failure and lagging behind in class can "decrease their motivation and sense of internal responsibility and make them more passive learners" (6, p.1094). Note that low achieving students are not equal to less capable, but rather those students who do not receive the support or encouragement they need to demonstrate their abilities.

Mathematics education and traditional teaching in school is often based on a lecture by the teacher to introduce a subject and followed by individual work focused on solving mathematical exercises and problems. Group discussions and working with peers to solve problems is also typical for mathematic education in school. Typical problems with traditional teaching in mathematics that affect the students learning process negatively is lectures that are based only on abstract examples and long verbal presentations, have a low degree of variation in lesson structure, and focus on static individual work and one-sided training in solving problems mainly using textbook exercises (7).

As described above difficulties in learning mathematics can be a result of both a neurodevelopment variation and low achievement in mathematics in general. To capture this variety in how we as humans learn, the more holistic view of *Neurodiversity* is used. Neurodiversity is an umbrella term that connects the difference in cognitive functioning with the natural variation in human development. “Under this umbrella are neurotypical individuals who´s cognitive functioning aligns with societal standards and neurodivergent individuals who´s brains function differently from societal norms” (8, p.9). It is easy to think of cognitive development as in black-and-white terms, however, one group often overlooked in this picture are the “gifted students” or “most able learners”. They may not stand out in the classroom – in fact, they downplay their abilities to fit in socially and as a result of that, their needs can go unnoticed and the students “fall between the cracks” of the traditional educational system (9).

Within the neurodivergent field one can find what is referred to as neurominorities including individuals with neurodevelopment variations such as ADHD, ADD, autism and learning disabilities. The main purpose of the neurodiversity movement is to remove the categorisation of people due to their difference in cognitive functioning and take away the stigma surrounding neurodevelopment variations and instead embrace different ways of being.

So, in what ways are the typical classroom environment not beneficial for neurodivergent students? Susy Forsmark described some of the problems that can be seen in traditional mathematics education in school (10). Typical challenges that are described are; teaching that focuses too much on results rather than the process to understand the mathematics, and a learning environment that is promoting less successful learning strategies which is characterised by memorising and reciting facts, solving problems in a specific way, and a focus on right and wrong thinking. For low achieving students this type of learning environment can lead to surface learning as it often focuses on memorising facts and solving problems that lacks relevance to the students. Forsmark argues that “on the other hand, if understanding and creativity are given greater space the student may experience that he/she understands and sees context and meaning in his/her work” (10, p.224).

The use of interactive media, computer-based play and augmented reality (AR) can be a way to increase understanding and enhance learning among neurodiverse, as well as neurotypical, students in the classroom environment. These types of technologies can help the students to visualise abstract concepts in different ways and let them experience different scientific phenomena that are difficult to create without technological assistance (11), “and thus, reinforcing the learning experience, increasing understanding, and enhancing student’s motivation, participation, and their engagement (12, p.568).

Universeum in Gothenburg is the national science center of Sweden where the visitors can explore the world through science, technology, and mathematics (13). The focus of the different exhibitions is that the visitors should be able to explore and experience science in different ways and Universeum wants to create forums “in which questions, thoughts and ideas about the world can flow freely” (13). Universeum is working within different areas and two of them are experience-based learning and lifelong learning in STEM (science, technology, engineering, and mathematics). Experience-based learning in mathematics is the foundation of Mathrix, which is one of the exhibitions in Universeum. Mathrix was established in 2023 with the goal to increase interest, motivation and learning in mathematics, mainly focused on students in the age between 13 and 18 years (14). The exhibition is built around different areas of mathematics and consists of exhibits where visitors can explore the concepts of mathematics through AR, interactive media, physical objects, and other artefacts in a playful way.

Even though Mathrix has only been open for two years, Universeum has received indications from visiting teachers that Mathrix could be a favourable learning environment for students that do not fit into the neurotypical part of the neurodiversity spectrum. These indications have sparked interest from Universeum to investigate if Mathrix can be a complementary learning environment for students for whom the classroom environment is less productive for their learning.

1.2 Purpose and aims

The purpose of this study is to examine if and how the mathematical exhibition Mathrix can function as a complementary learning environment to the traditional classroom environment. A learning environment refers to the physical, social, and pedagogical context in which learning occurs and includes everything that can affect the learners to engage, interact with peers and develop their abilities. The purpose in this study is in particular for students that currently not flourish in the classroom due to neurodiversity or other reasons. This study will be a pilot study to explore this topic.

1.3 Research questions

In what ways can the learning environment Mathrix be a complement to the (traditional) classroom environment (in mathematics)?

1.4 Delimitations

This study focuses on examining students and their teachers while exploring the mathematical exhibition Mathrix in Universeum, Gothenburg. The study only includes invited and selected participants and does not investigate other visitors in the exhibition. The observers' data production are only the notes taken during the observation sessions, together with the teachers' statements in the interviews. No audio or video recording were made, and interviews were conducted only with the teachers, not with the students, in order to preserve the integrity of the participating students.

Other delimitations are the geographical scope which is restricted to Gothenburg and all participating students enrolling a Swedish compulsory school located within this the area.

The study focuses only on neurodiversity in mathematics education. Other subjects in school are also important in the topic of neurodiversity, they are however not included in this study.

2 Theoretical framework

This chapter presents the learning theories that underpin the results and the analysis of the study. The selected learning theories are grounded in cognitivism, focusing on how information is processed in the brain and how behaviour changes as a result of the information acquired (15). The purpose of this study is to investigate in what way the learning environment in the mathematics exhibition Mathrix can be a complement to the learning environment in the classroom. The learning environment in Mathrix can be described as a learning environment with learning exhibits that encourage the visitor to experiment by their own and in collaboration with others to experience and learn mathematics. The idea of experimental learning to create new knowledge and to do this in collaboration with others is fundamental parts of the constructivist and social constructivist theories and hence they form the theoretical basis of this work.

By adopting an inductive research approach for this work, which will be further described in chapter 4, the specific learning theories within social constructivist paradigm that were used for analysis, were decided as a result of the processing of the produced data in this work. This aligned with the inductive approach and created conditions for a more open-minded initial relation to the data. One part of the data production of this work was focused on observations of small student groups with their teachers performing planned activities in Mathrix. When processing the data from these observations together with data from a series of interviews with each teacher the data indicated that the small student/teacher groups in Mathrix could provide favourable situations for scaffolding which is associated with Lev Vygotsky's theory of Zone of Proximal Development (ZPD). To investigate this further, ZPD was chosen as one of the constructivist theories to use in the analysis of this work. Another theory within the constructivist field that was considered to be interesting for the analysis of this work was Albert Banduras theory of self-efficacy, as there were several students in the study that was described as having low self-efficacy in mathematics in the classroom environment.

In the following section the constructivist and social constructivist theories will be described briefly and an overview of the theories associated with Vygotsky´s ZPD and Banduras self-efficacy will be presented in order to form the foundation of the analysis of this work.

2.1 Constructivism and social constructivism

The constructivist theory is based on the notion that learning is a result of mental construction and it “takes place when new information is built into or added onto an individual´s current structure of knowledge, understanding and skills” (16, p.19). Learning “involves the active creation of mental structures” (17, p.24) and is not just information that is passed over by others and passively internalised by the individual. Constructivism argues that the best way to learn is when the individual actively constructs its own understanding. Knowledge and skills are acquired and refined in the interaction of persons and situations and “learning is situated in contexts” (17, p.315). The social constructivist theory, which originates from constructivism, highlights the interaction between the learner and others, and means that dialogue is the way to share and develop ideas. The dialogue is based on the individuals prior and current knowledge and with this as a reference “new ideas and understanding can be constructed in the course of the dialogue” (16, p.27). Often a more knowledgeable other is the counterpart in the dialogue, but the dialogue can also be with peers. Social interactions form the basis in social constructivism and the exchange of thoughts, knowledge and ideas between individuals can lead to greater understanding for the ones involved in the interaction.

2.1.1 Scaffolding and the zone of proximal development

Lev Vygotsky was one of the leading theorists of social constructivism and he focused on the importance of social and cultural aspects in the creation of knowledge in the learning process. One of Vygotsky´s major theoretical ideas were the Zone of Proximal Development (ZPD) that manifested the potential cognitive development of an individual. In contrast to static cognitive measurements, such as IQ-test, the ZPD measures the potential cognitive development of the individual which Vygotsky considered to be a better predictor of the individuals educative potential (18). ZPD was defined as “the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peer” (19, p.238). The step between the current level and the next level of development is described by ZPD as a step that is “attainable through the use of mediating semiotic and environmental tools and capable adult or peer facilitation” (19, p.238). Vygotsky´s focus on social and cultural aspects of learning can be seen in the idea of ZPD where the main point is collaboration and working together with more skilled individuals to be able to learn and internalise new knowledge. The proximal development in ZPD means that “the assistance provided goes just slightly beyond the learner's current competence complementing and building on their existing abilities" (19, p.239). This assistance that is connected to ZPD is often called scaffolding and is considered to be most effective when it is adapted to the learner and later withdrawn as a response to the learner's development (18). When the learner has reached a new level of development and the scaffolding is no longer needed to solve the specific problems associated with the former ZPD a new ZPD will open up, and once again scaffolding will be needed to solve the problems associated with the new ZPD. The scaffolding can affect learning and help the learner to reach new levels of knowledge by getting through the ZPD, but just as important as receiving support from others is the belief in one´s own abilities to learn a subject or a skill. This type of beliefs is associated with the term self-efficacy and will be further discussed in the next section.

2.1.2 Self-efficacy

Self-efficacy is a concept developed by Albert Bandura and it refers to the personal perception of one´s capabilities to successfully execute a task or an activity. Bandura meant that an individual's self-efficacy played a role in the choice of activities, effort and persistence (20). A low self-efficacy in the ability to solve a task might result in an avoidance of even trying, whereas a high self-efficacy could result in a higher willingness to try to solve the task. There is also a difference when it comes to encountering difficulties in task-solving, where individuals with high self-efficacy show more persistence and work harder to solve the task than individuals who have low self-efficacy. Self-efficacy is a perception and an interpretation of oneself, and it is based on information that comes both from behaviour and from environment. "Behaviour and environment provide four sources of efficacy information: mastery experience, physiological/emotive arousals, vicarious experience, and verbal persuasion" (21, p.40). Mastery experience and physiological/emotive arousals are connected to personal behaviour and vicarious experience, and verbal persuasion are related to interpretations of outcomes related to the environment. Mastery experience provides indication of capability and refers to experience of similar or same activities which can increase self-efficacy if success in performing a task is attributed to personal ability. Physiological/emotive arousals are affective or somatic reactions to performance, and for example "[s]ymptoms signalling anxiety might be interpreted to mean that one lacks skills" (20, p.4). Vicarious experiences is information given from the observation of others, similar peers, performing a task which can generate a feeling of efficacy in the personal ability to succeed in performing the same task. Finally, verbal persuasion is the information from assessments of others on the personal ability (21). Persuasive information like positive feedback can enhance self-efficacy, "but this increase will be temporary if subsequent efforts turn out poorly" (20, p.4). So, there are several factors that bring information on how an individual is performing and self-efficacy is enhanced when the individual is making progress and feel more competent according to the interpretation of this information. Typically, success in performing task raises self-efficacy and failure lowers it, "but once a strong sense of efficacy is developed a failure may not have much impact" (20, p.4).

2.2 Other learning theories

Besides the constructivist theories of Vygotsky's ZPD and Bandura´s self-efficacy the analysis of this work will also be based on Mihaly Csíkszentmihályi's Flow-theory and on John Hattie and Betty Tärning's perspective on feedback-theories. Similar to how the constructivist theories were determined from the produced data, the processing of the data gave indications that the students participating in the observations in Mathrix considered it to be both fun and enjoyable and that levels of concentration and motivation were higher than in the classroom environment. These are attributes to the conditions of flow as described by Csíkszentmihályi and therefore Flow-theory was considered to be an interesting theory for the analysis of this work. Finally, feedback in learning is a theoretical concept that was relevant for the analysis of this work. One of the reasons to this is that feedback in some extent is a part of the other learning theories chosen for the analysis of this work. The other reason is that feedback is an important tool in the learning process, and as the learning exhibits in Mathrix are mainly based on games and other interactive activities that provide instant feedback to the user, the influence of this feedback was an interesting aspect to consider in the analysis of this work.

In the following sections an overview of Mihaly Csíkszentmihályi´s Flow-theory will be presented as well as a description of different types of feedback associated with learning.

2.2.1 Flow-theory

The flow-theory was created by Mihaly Csíkszentmihályi and came from his research on what made individuals engage in intrinsically motivated activities. Csíkszentmihályi did interview studies with chess players, surgeons, rock climbers, modern dancers, and in later studies also artists, writers and inventors to name a few. The main focus of the research was to understand why these individuals were investing so much time and effort in their activities when no one was requiring them to do so and there were so many easier alternatives available (22). The assumption was that the individuals were intrinsically motivated by the activity itself and not by possible extrinsic rewards that might be generated by the activity. Csíkszentmihályi identified different elements of flow and categorised them into two types. The first is the subjective experience of flow, and the second is the conditions of flow. The subjective experience of flow is associated with "merging of action and awareness, a loss of self-consciousness, feelings of effortless control, transformations in the sense of time, and an autotelic experience" (22, p.2). In the state of flow there is a total focus on what is going on in the moment and the individual feel a connection to the activity; there is also a sense of loss of self-consciousness and of effortlessness about what is taking place in the activity. Typically, there is a feeling of distortion of time when the individual is in a state of flow and "[h]ours may go by but the time just seems to disappear" (22, p.3). Individuals who experience flow in an activity also consider the activity as interesting and enjoyable. When it comes to the condition of flow, the intrinsic motivation comes from "a balance of challenges and skills when engaged in an activity, having clear goals, and responding to immediate, unambiguous feedback" (22, p.3). Feedback plays an important role in the flow and awareness of ongoing feedback during an activity can help the individual to adjust the performance to get a better outcome. This corresponds to what is typically said about good feedback; that it should be specific and timely. To adjust the performance to a better outcome the feedback needs to clarify the difference between the actual performance and the given goal, and the timing must be right so that the feedback information can be correlated with the task (23). As indicated the feedback needs to be specific and contain information that can direct a learner towards a given learning goal. But is this always the case? Is all feedback effective in enhancing learning or are there different types of feedback that are more or less effective in supporting learning? In the next section different types of feedback will be described and how they differ in supporting learning for individuals.

2.2.2 Feedback in learning

Feedback is considered to be an important influence on learning and contains information from someone or something in the learning process, e.g. teacher, peer, parent, book or experience, regarding aspects of performance or understanding (24). The purpose of feedback is to highlight the gap between what is currently understood and what is supposed to be understood in the learning context, and give direction to the learner on what the next step is to come closer to that learning goal. If the feedback is given correctly and is focused on the gap between current state and desired state of performance or understanding it can enhance learning and "increase effort, motivation, or engagement to reduce this discrepancy, and/or it can increase cue searching and task processes that lead to understanding (thus reducing this discrepancy)" (24, p.102). There are several different types of feedback that can be given to a learner in a learning situation. Some have a greater effect on learning whereas others show little effect. For interactive and game-like environments there are typically simple forms of feedback that give information whether the answer or performance is correct or incorrect. This feedback is called "verification feedback" as it gives a verification if the answer is right or wrong, but do not provide the correct answer (23). Low-achieving students are less likely to find the correct answer when only given verification feedback in comparison with high-achieving students for whom the verification feedback often is sufficient to deduce the correct answer. Feedback that provides the correct answer when the learner gives the incorrect answer is called "corrective feedback". This type of feedback is more effective than verification feedback as it contains more information, in this case the correct answer, that can help the learner in the next attempt. Corrective feedback is most effective when the succeeding test is done immediately after an incorrect answer (23). Feedback that contains more meaningful information regarding the task or the problem solving is considered to support learning in a better way than just verification or corrective feedback. This feedback is referred to as "elaborative feedback" and can be seen as a scaffolding feedback, and the information can consist of comments or suggestions to help the learner to find the correct answer. It can also give information on how to improve the answers and how to "build a deeper understanding of the task at hand and the foundations upon which to structure future tasks" (23, p.257). If elaborative feedback is the most effective feedback to support learning, feedback that only gives information that target the learner as a person and only provides praise is considered to be the least effective feedback for learning. Typical feedback within this category is "encouraging feedback" and "result feedback" and the information given contains no information about the learning process, "and the effects of it are rarely converted into more engagement, commitment to the learning goals, an enhanced self-efficacy or understanding of the task". On the other hand, encouraging feedback can be useful if it is shifted towards the effort the student puts into the work instead of using praise about the student itself (23, p.259). Accordingly, feedback can influence learning but only if it contains information that helps the learner to take the next step in the learning process and getting closer to the learning goal.

3 Previous research

To understand what challenges neurodivergent students have in the traditional classroom environment, and what type of teaching and learning environments that positively influence these students in a classroom setting, a literature study was conducted. The results from the literature study will be used to discuss the findings in this work to see in what way the learning environment in Mathrix can be a complement to the classroom environment. Can Mathrix counterbalance the challenges that neurodivergent students have in the traditional classroom environment, and is Mathrix displaying the typical attributes of a positive learning environment? The analysis of the produced data in this study will be compared to what the literature study reveals about these questions which is further discussed in the conclusions of this work.

3.1 Challenges in the traditional classroom environment

Students that can be found on the neurodivergent part of the neurodiversity spectrum often have more challenges with traditional teaching as it is typically based on delivering knowledge and skills to the neurotypical part of the population. Students are often expected to sit still and listen to the teacher, which can be more challenging for neurodivergent students who in some cases need to engage in self-stimulating behaviour such as moving, pacing, or fidgeting. Traditional teaching often has a neurotypical way to interact with peers that is inappropriate for neurodivergent students (8). If the student is faced with a learning environment, similar to that of traditional teaching, that focuses on memorising and retrieving facts, solving exercises in a specified way to get the "right" result through the "right" course of action it can lead to the development of a less successful learning strategy (10). In mathematics, teaching that focuses on results rather than the process of getting to the results can typically lead to that the student avoids mathematical situations. It is also known to create anxiety related to mathematics that, if repeated, can become permanent and lead to reduction in mathematical performance. Mathematical anxiety is common among low achieving students, other typical behaviours that can be seen are memory deficiencies and difficulties to retrieve basic mathematical knowledge from the memory, inadequate strategies for solving mathematical tasks and problem with generalisation and to transfer learned knowledge to new and unknown tasks (6). Consequently, traditional teaching that focuses mainly on "the right" processes and results can be a problematic learning environment for neurodivergent students in general. Another factor that can be an obstacle regarding learning is the student's notion of mathematics and whether it is hard to learn (10). The idea that mathematics is hard to learn and not for everyone is common in society and is often amplified by people in the student's vicinity and even by teachers. Students can be strongly affected by different prejudices and perceptions about mathematics that they encounter in their everyday life and that is confirmed in the learning environment. The notion that mathematical ability is something predefined and constant can be an obstacle in mathematical learning in general. For students who due to their learning environment display low performance in mathematics risk seeing their performance as a predefined and constant state that cannot be improved.

3.2 Positive learning environments

To enhance learning and create a positive learning environment for neurodivergent students, and for neurotypical students as well, the learning environment needs to be more focused on understanding and encourage an investigative approach, reflective conversation and creative mathematical thinking (10). Mathematical knowledge is developed using abstract structures and relations that the student must discover and learn in the mathematical education and "in this process it is important that the student is allowed to encounter and move between different forms of representations" (25, p.55). By using interactive media and computer-based games, different forms of representing mathematics can be achieved. Research shows that technology that is based on creative interactive activities and visual presentations that are centred on engagement and activities of students, can enhance learning outcomes and contribute successful achievements both for students with learning disabilities and for students without (12). Augmented reality (AR) is a technology that is considered to be promising in creating learning and teaching opportunities, and when combined with assistive and instructive technology it can help students with learning disabilities to successfully learn. AR combines real and virtual objects and can be a good way to visualise abstract concepts and complex spatial relationships, and by doing that create a better understanding and learning experience. It can also enhance students' motivation and engagement, and facilitate "a positive environment in the classroom that is distinct from the traditional classroom, which was assumed to promote the positive attitude of students towards learning basic science" (12, p.566). Other studies show that interactive media can help students with dyscalculia to recognise natural numbers (1), and that computer-based play in an entertaining game-like format with proper pedagogical features and instructions, can boost mathematical learning amongst students with dyscalculia (5). The environment can also be a positive factor in learning, and learning can be more efficient if it is done in an immersive environment (26). and low achieving students that are placed in an intimate and supportive learning environment, typical for small group tutoring, can demonstrate mathematical reasoning verbally (6).

4 Methods

This chapter will introduce the methodology of this study; starting with a description of where the study was conducted, following with the data production, research approach and data analysis. An inductive research approach with a qualitative orientation was chosen for this study to facilitate the collection of non-verbal data, which is particularly useful when working with children. This method allows for a more nuanced understanding of their interactions and behaviour, especially since the activities studied are embodied action that are best explored through close observations. The study was performed as an exploratory research (27), which is research characterised by the researchers not having a clear understanding in advance of what the outcome will be. The study may aim to explore a process, a group, or a specific situation. According to the research (27), two key factors are essential for the effectiveness of such study: flexibility in data production methods and to have an open-minded approach throughout the process. For this study, the flexibility and open-mindedness will be particularly relevant in the observational part of the data production process.

4.1 Empirical setting

The study was conducted in Universeum, a science center located in Gothenburg, Sweden. The empirical work took place during the spring of 2025 and focused on the mathematical exhibition Mathrix at Universeum. Mathrix is an exhibition with the ambition to give all the visitors a different perspective and approach to mathematics (14). The study included all the interactive exhibits in Mathrix, which are divided into four different themes – “The Self”, “The Creation”, “The World”, and “The Nature”. The exhibits are primarily designed for a target group aged 13 to 18 years old, but also aim to engage families and younger children with the overall goal of creating an engaging learning experience. One of the key goals of the science center is to offer students the opportunity to approach subjects, in this case mathematics, in a more relaxed and playful manner, to challenge the common perception of the subject as difficult. The design of the exhibits encourages hands-on exploration and allows students to engage with mathematical concepts in a fun and less intimidating way, with the aim to improve their attitude towards mathematics.

Whether an exhibit was observed or not during the study depended on the teachers’ decision to engage with it, which was determined by the students’ age. The most used exhibits by the groups are listed below with a description of each exhibit.

Vågade ekvationer [*English translation:* Balancing equations]

This exhibit is a physical-digital balancing scale demonstrating the equal sign in a practical manner. The exhibit represent variables as physical pieces that are unknown, and the aim is to explore how equations work and to gain a clearer understanding of the equal sign. (see figure 4.2).

Skala [*English translation:* Scale]

An exhibit that introduces scale in a practical way to explore how to measure scale using famous landmarks of Gothenburg. The exhibit uses a spotlight to create shadows on the wall of the famous landmarks of Gothenburg. The height of the landmarks can be calculated using the shadows and the marked lines on the wall and table. The scale of each landmark is given on the figure. (see figure 4.1).

Mastermind

Like the board game but in human size. One player guesses the four-coloured code that the opponent made up. (see figure 4.1).

Nördlig [*English translation:* Nerdle]

A game where the player/s guesses a generated mathematical calculation. A mathematical alternative of the word-game wordle, where the point is to guess the correct word. (see figure 4.1).

Sifferjakten [*English translation*: Chasing Numbers]

Sifferjakten is a wall with buttons numbered 1-199, where the players can practice mathematical sequences such as prime numbers, binary numbers or all the multiplication tables from 1 to 9, by selecting the proper numbers in the sequences. (see figure 4.1).

Voronoi

A collaborative and educational game illustrating the formation of Voronoi patterns, which is a visual pattern that appear naturally in the world, for example the Voronoi pattern occurs in the giraffes´ fur. Voronoi is a simple but powerful mathematical model. (see figure 4.2).

Pusselbordet [*English translation*: Puzzle corner]

In the puzzle corner the visitors can try to solve and complete puzzles as “Tower of Hanoi”, the geometrical evidence of Pythagoras theorem and dissection puzzles “Tangram”. (see figure 4.2).

Figure 4.1: *A collage of a selection of the exhibits. Top left image: Sifferjakten. Lower image: Mastermind and Nördlig. Right image: Skala.*

Figure 4.2: *A collage of a selection of the exhibits. Left image: Pusselbordet. Top right image: Voronoi. Lower right image: (from the right to the left) Vågade ekvationer, Derivata, Hands-on.*

4.2 Research approach

For this study an inductive research approach was applied. The aim for this approach is to allow the research findings to emerge from the data produced rather than testing theories as in a deductive research approach (28). To analyse the qualitative data production an inductive coding (28) was conducted. A study (28) describes the analysing process as "Inductive coding begins with close readings of text and consideration of the multiple meanings that are inherent in the text. The evaluator [researchers] then identifies text segments that contain meaningful units and creates a label for a new category to which the text segment is assigned. Additional text segments are added to the categories to which they are relevant." (28, p. 241). The data analysis is presented and further described in chapter 4.4 *Data analysis.*

In the research the participating teachers have a major role. The teachers' experiences and knowledge of their students were crucial to this study. The professional competence and the understanding of the students provided the necessary foundation for interpreting the behaviours in the new environment compared to the typical behaviours in the classroom. Furthermore, the approach of the recruitment is presented in chapter 4.3.4 *Recruitment of participants.*

The sequence of the study outlined below:

- Pre-interview with the participating teachers
- The 1st observation of teacher/student groups in Mathrix
- Mid-interview with the participating teachers
- The 2nd observation of teacher/student groups in Mathrix
- Post-interview with the participating teachers

The steps above are explained more detailed further in this chapter.

4.3 Data production

The study is based on two primary methods of data production – observations and interviews. First, a description of how the participants were recruited is given and then the two methods of data production are described theoretically to provide a foundation for the set-up of data production methods that has been chosen in this work. The methods will then be described as they were used in this study.

For the observations the decision was to conduct early observations to capture as many phenomena and situations as possible without any major distinctions. The idea was to not focus on specific and predefined phenomena and situations to be able to be more open-minded to what was happening during the observations. In relation to this the plan was also to conduct qualitative observations and to focus on the description of the actual phenomena or situations that would occur during the observations. Additionally, there were no plans to change or manipulate the environment or the actual situations for the observations, and according to the research plan all participants should be informed of the purpose of the study.

The plan for the interviews was to conduct a series of semi-structured interviews with the teachers that were a combination of informant and respondent character, where the initial interview would have more focus on getting specific facts about the students and their situation in the classroom environment, whereas the interviews during and after the observations would have a higher degree of respondent character to capture the teachers perceptions and notions about the students and their interactions with the Mathrix environment.

4.3.1 Recruitment of participants

The participating teachers were recruited through purposive sampling. Specifically, we contacted teachers who were part of a mathematics network and had the role of mathematics developer and were already working with the science center Universeum. All teachers are interested and engaged in mathematics development and had the time to participate in the study, due to their allocated math development mission. The teachers were contacted directly via email and informed about the purpose and aim for the study. The teachers who agreed to participate were asked to select students whom, based on their professional judgement, would benefit from the environment. All participants, both teachers, students and their guardian/s were provided with a written consent form to complete (see **appendix A**).

The participation was voluntary, and all participants were informed that they could withdraw from the study without explanation.

4.3.2 Observation studies

Observation is a research method where the researcher is observing a situation with their own eyes. The main focus is on non-verbal data, i.e. what people do. This is a good method when "you want to study processes or structures that are hard to describe in words for the parties involved" (29, p.315). Observations are a common research method in educational research and are often used when research is focused on children or other individuals that have difficulties to express themself verbally. It is also common to have observations in combination with interviews given what a person says they do, and what they actually do, not always coincide.

Studies based on observations can vary in different aspects, like for instance if the observations are conducted for a shorter period of time or over many years, if the situation is manipulated or not, if the environment in which the observations are made is natural or artificial, or if the intention of the study is known to everyone involved or not. If the research project wants to generate new theory or let new perspectives emerge within a research field the observations should have a low degree of structure (29).

When the observations are started, the initial observations can be described as trawling, meaning that most of the phenomena and situations that are observed are registered without any major distinction. These observations are called "early observations" (29). As the study progresses the observations are getting more focused on phenomena and situations from the early observations that the researchers find interesting, and these observations are called "focused observations" (29).

The observation study can also be divided into quantitative or qualitative observations, or a combination of the two, depending on what type of data the research study wants to collect. Quantitative observations focus on phenomena and situations that can be registered in frequency, and qualitative observations focus on the existence and description of the actual phenomenon or situation. However, some aspects of a phenomenon or situation can be difficult to capture through observations, e.g. individuals intentions and interpretations of the phenomena or situation. These types of data can be collected by other data collecting methods like interviews, and interviews with participants in the observation can also give an idea of how their own interpretation relates to the interpretations of the other individuals involved. By not only using the subjective interpretation of the observer but also data from other sources the so-called validity problem can be handled (29).

4.3.2.1 The observations in Mathrix

The observations were conducted during two sessions with one week apart in the Mathrix exhibition at Universeum. Prior to the observations a questionnaire of the lesson plan (**Appendix C**) was filled in by each teacher, for us observers to review before the visit. During the observation sessions the teachers conducted planned lessons-like activities with the help of the different learning exhibits in Mathrix. The teachers decided both what type of learning exhibits to use in Mathrix and the layout of the activity. In that way each teacher could adapt the activities to their students in a way that they thought were appropriate. Three of the four teacher/student groups had a session time before the opening hours of Universeum on both occasions, which meant that there were no other visitors in Mathrix during the observations. All three groups were at Mathrix at the same time, but the teachers had agreed among themselves in what order they would conduct their activities to avoid ending up at the same exhibit at the same time. The fact that all three groups where there at the same time did not affect the performance of the planned activities in any significant way. The fourth group had their session time during opening hours of Universeum and there were other visitors in Mathrix during the observations. However, this did not disturb the planned activities for the fourth group in any significant way.

During the observation sessions, the situations, phenomena, and verbal expressions that occurred during the different activities were noted on paper by the observers. No audio or video recordings were done due to the integrity reasons and to keep the students anonymous. The sessions with the three teacher/student groups were observed by four observers: the two authors and the supervisor of this master thesis, and a pedagogue employed at Universeum. One of the teacher/student groups consisted of six students and were divided into two groups and therefore there were a total of four groups to observe, hence the observers observing one group each. The other sessions with only one teacher/student group were observed by three observers, the two authors and the supervisor of this master thesis. After every observation sessions each observer reviewed their observation notes and did a digital summary of the notes, whit the aim to identify interesting phenomena and expressions during the activities. The aim was not to compare between the groups, therefore different observers and no observation protocol was rather a strength than a weakness.

4.3.3 Interview studies

Interviews can be used for different purposes, e.g. when a research project is investigating an unexplored field, or to get an idea of how individuals perceive their world, that is "the meaning that individuals give to various phenomena" (29, p.261). Interviews can provide opportunities for unexpected answers, and "one of the main points is also the possibility of follow-up questions" (29, p.260). Depending on what type of information the interview study is looking for, the interview can either be an informant interview or a respondent interview. When the aim is to find specific facts about some phenomenon or situation the informant interview is used and the interviewee is usually a centrally located source with good knowledge in the specific field. In other cases, the main interest of the interview study is to find out more about the individuals perceptions and notions about different phenomena and then the respondent interview is used. The interview study can also use a combination of the informant and respondent interviews, but often there is a "purpose where either the informant or the respondent character is most prominent" (29, p.261).

4.3.3.1 The interviews in this study

The main empirical source for the data production was the interviews with the participating teachers. Each teacher participated in three interviews; an initial pre-interview, a mid-interview following the first visit in Mathrix, and a post-interview conducted after the second visit.

The pre-, and post-interview were conducted either remotely on teams or zoom, or in person, depending on what was most convenient for the participating teacher. The mid-interviews were held remotely due to their short duration and the limited time between the two observations.

An interview guide was created in advance to the pre-, and post-interview and can be seen in **Appendices B and D**.

Pre-interview

The initial interview with the teachers aimed to understand the situation in the classroom for each participating student– their behaviour, their strength and challenges in mathematics, and the teachers' perspective on how Mathrix might benefit the student. Another aspect of the pre-interview is for the teachers to get the opportunity to explore the exhibit themselves, to get inspiration for the lesson they later would carry out during the observation sessions. The plan for the two lessons were then requested for us to review prior to the observation.

Mid-interview

The interview between the two sessions in Mathrix aimed to gain insight into the reflections the teachers had made from the first session and an opportunity to discuss any questions about the exhibit or the students. It also aimed to clarify any uncertainties that may have arisen during the first observation.

Post-interview

The post-interview aimed to capture the teachers' perception and reflection on how their student engaged with the exhibition. In addition, the interview was also for the teacher to share each students behaviour in Mathrix in comparison to their behaviour in the classroom setting. The questions asked were also aimed to find out if the teachers had seen any progression. All the questions served an important role to expand the descriptions of the students, and for us to further move on in the study. The interview also served as a discussion, allowing the observers to share thoughts and interpretations of the students' behaviour.

4.4 Data analysis

The data production of this work consisting of three interviews with each teacher and observations during two sessions with the teacher/student groups in Mathrix. The data analysis consisting of three different parts. The first part was the analysis of the pre-interviews with the aim to produce an understanding of the strengths and challenges in learning in the classroom environment of the student group as a whole. In this analysis the data from the pre-interviews was categorised into different categories related to strengths and challenges to find the characteristics of the group. The second step was to conduct a categorisation of the data from the observations and the mid-, and post-interviews to find factors that in different ways affected learning among the students, and generated learning opportunities that could enhance their learning. The third step was to categorise the situations, phenomena, and verbal expressions from the observations and mid- and post-interviews into categories that are interesting to the purpose and research question of this thesis. The findings will then be interpreted through the lens of the theoretical framework of this study and will later form a basis of the analysis of this work.

4.4.1 Transcription and AI

The pre-, mid- and post-interviews were all audio-recorded and afterwards transcribed using Microsoft 365 Word. All the transcriptions were carefully reviewed and edited manually.

AI has only been used as an assistance for synonyms in processing this thesis, references to AI are therefore not necessary since text generation has not been used.

4.4.2 Categorisation

The categorisation of the data is fundamental to be able to structure and interpret all information given from the interviews and the observations. The method used is called thematic analysis and is a method where categories emerge from the produced data. The categorisations were done in three parts: categorisation by strengths and challenges, categorisation by theme and categorisation by learning theory.

Categorisation by students' strengths and challenges

The data from the pre-interviews were categorised to find typical strengths and challenges that were characteristic for the student group. This was done by reviewing the teachers answers from the pre-interviews and summarising the strengths and challenges for each student. The summarised strengths and challenges for all the students were then compiled and reviewed to find similarities between the students. Strengths and challenges that were considered to be the same type were clustered into different groups that were labelled with an appropriate category name. These categories could then be used to portrait the characteristic strengths and challenges of the student group.

Categorisation by learning situation theme

The categorisation by learning situation theme is based on both the observations and the mid- and post interviews which constitutes the main part of the produced data in this work. This categorisation was done to find what type of aspects that could affect learning among the students, and generate learning opportunities that could enhance the students learning in Mathrix. The first step in this process was to get to know the data by reading all transcriptions and notes from the observation sessions. When the data had been reviewed, another session of reading was done where interesting descriptions and utterances were marked out in the text. In the next step the marked data was discussed regarding in what way it could be connected to the students learning and learning opportunities in Mathrix. In this process the data was clustered into main categories that represented a general description of the clustered data. The data in the main categories was reviewed once again to cluster the data into subcategories under each major category. With the data divided into main- and subcategories the analysis of the data could be done.

Categorisation by learning theory

The analysis of the data was done to connect identified learning phenomena with learning theories that could constitute the theoretical framework of this study. In this process the data in each main and subcategory once again was reviewed and discussed to categorise the data into new categories associated to concepts emerging from the data, related to different learning theories. In the process of the categorisation, the concepts of the learning theories that emerged were reviewed to get a better understanding of the different aspects that could be connected to the data produced in this work. The categorisation by learning theory constitutes the foundation of the analysis of this work.

5 Results

The result of the study is presented in this chapter. Firstly, the participating teachers and students are introduced followed by typical strength and challenges within the group of students. Due to a small number of participating students with varying strength, challenges and neurodivergent diagnosis, the presentation will be at group level only. The strengths and challenges are summarised and presented to give the characteristics of the student group.

Then the characteristics of the two sessions in Mathrix is presented including a summary of the teachers' lesson plan and the session outcome overall. Lastly, a presentation of the categorisation is made of the findings followed by the results and findings from the sessions and the interviews with the teachers.

5.1 Participants

This chapter will introduce the teachers and the students that participated in the study, followed by the students strength and challenges described by the teachers in the pre-interview. In total 19 participants: 5 teachers and 14 students were recruited from four different Swedish compulsory schools in the Gothenburg region.

The students are between 8 to 15 years old, and the group included two students in 2nd grade, six students in 4th grade, two students in 7th grade and four students in 8th grade. The description of the participating students' strengths and challenges will be at group level to ensure anonymity.

Each participating teacher has been assigned an anonymous code that only reveals which grade they teach at the time. For example, "T_2" means a teacher who teach 2nd graders, and "T_4a" implies a teacher who teaches 4th graders. As there may be more than one teacher in a grade, a letter is assigned to distinguish same-grade teachers.

5.1.1 Teachers

T_2 is qualified to teach grades F-3 in primary school, as well as school-age educare and preschool. For 10 years they[1] have worked primarily as a classroom teacher for grades 1-3, and since 2021 they have held a role as a mathematics developer within the municipal education department.

[1] "They" is used as a gender-neutral pronoun throughout the thesis.

T_4a has been a qualified primary school teacher for grades F-6 for 16 years. They have mainly worked in lower primary school, but a year back they teach in upper primary school. For the last 6 years they have had a role as a mathematics developer in the municipality education administration.

T_4b has been a teaching assistant for 6 years in upper primary school.

T_7 has been a qualified teacher for 34 years in lower and upper secondary school, and for 20 years qualified in mathematics in lower secondary school.

T_8 is a qualified subject teacher in lower and upper secondary school, with teaching qualifications in science, technology, and mathematics. They have worked as a teacher for 39 years.

Note that the teachers represent different number of students, which could mean that some teachers represent more findings than others and this will be reflected in the results.

5.1.2 Students

The participating students consist of 14 individuals: 5 girls and 9 boys. All students enrolled a Swedish compulsory school located in Gothenburg, and the group included two students in 2nd grade, six students in 4th grade, two students in 7th grade and four students in 8th grade. Within the group there is one student diagnosed with ADD, one with ADHD and two students that are diagnosed with language disorder. Remaining students have no formal diagnosis and have been selected based on the teacher's professional judgement and experience from the classroom setting, as they believe the learning environment would benefit them.

5.1.3 Typical strengths and challenges of the student group

In the pre-interviews the teachers describe strengths and challenges each student has in the classroom environment. Due to the small number of students participating with varying challenges and neurodivergent diagnosis, the analysis of the participants will be at group level only. Typical strengths and challenges of the whole group are summarised, and a selection of quotes from the teacher's description of the students are presented to give the characteristics of the student group. A more comprehensive list of descriptive quotes is available in **appendix E**.

Strengths

The strengths of the students that are described by the teachers in the pre-interviews displayed three characteristics that can be seen in several students: *the desire to learn*, *being ambitious and putting effort into the schoolwork,* and *other strengths.*

Strength	*Number of students*
Desire to learn	*5 students*
Being ambitious and putting effort into the schoolwork.	*7 students*
Other strengths	*10 students*

***Table 5.1**: An overview of the number of students included in each category of strengths.*

The first one, *desire to learn*, the teachers associate with five of the students in the student group. The other category described, *being ambitious and putting effort into the schoolwork*, is associated with seven out of fourteen students in the group. The two characteristics are for some of the students described in relation with each other like "they are ambitious and want to learn" (T_4a) and "really wants to learn and have a great fighting spirit" (T_4a).

The third category, *other strengths,* the teachers describe two of the students as being good at working with practical materials in mathematics. One of the students is described as having good mathematical thinking but needs to describe it verbally, and another student has a high capacity in mathematics according to the teacher but needs individual help to overcome insecurity. Mental calculation is another strength described by the teachers and it is described for two of the students in the student group. Being social, communicative, a good listener and a good friend is also described as a strength by the teachers and in different ways associated with four of the students.

Challenges

The typical challenges that are described by the teachers in the pre-interviews can be categorised into six different categories including *Concentration, carrying out and perform math, self-efficacy in math, verbal instruction, communicating math,* and *numerosity and problem-solving.*

Challenges	*Number of students*
Concentration	*6 students*
Carrying out and perform math	*5 students*
Self-efficacy in math	*4 students*
Verbal instruction	*5 students*
Communicating math	*6 students*
Numerosity and problem-solving	*6 students*

Table 5.2*: An overview of the number of students identified in each category of challenges.*

The first one, *concentration*, is related to the ability to preserve and keep focus. As an example, one of the teachers describe a student as having "challenges keeping focus, easily distracted" (T_8).

The second one, *carrying out and perform math,* is associated with getting started and getting things done in individual work. Typical descriptions from the teachers are "to get started with individual work takes time" (T_8) and "needs an adult to help to get through and finish tasks" (T_4a).

S*elf-efficacy in math,* is about trusting their own ability to learn mathematics. One example of a teacher description is "unsecure, even when they know" (T_2).

Verbal instruction is about understanding and being able to assimilate information. The teachers' descriptions from the pre-interview include difficulties in assimilate information and knowledge in full class and follow the lectures.

Communicating math, the difficulty with expressing and communicating their knowledge in different ways. The descriptions that emerged in this difficulty was the challenge in expressing verbally and using pen and paper to show their knowledge.

Lastly, *numerosity and problem-solving*. The teachers describe one of the students as having "challenges with multi-step exercises and tackling the abstract" (T_4a), and another student is described as having "challenges with perceptions of numbers and positioning systems" (T_4a).

5.2 Session characteristics

Prior to the observation in the mathematical exhibition Mathrix, the teachers were given information and descriptions of the mathematical purpose of each exhibit. They had full autonomy in designing the lessons, allowing them to create activities that they think will support their students learning experiences in the best way.

All teachers except one provided a lesson plan before the initial visit. The lesson plan included which exhibits they intended to complete during their visits. The most common exhibits that appeared in their lesson plan was “Vågade Ekvationer” and “Mastermind”. Many of the students had never been to Universeum before and therefore half of the teachers included free or supervised exploration in the learning environment in Mathrix.

There were different strategies adopted by the teachers. The strategies ranged from a more relaxed approach to a very structured lesson. The teachers with a more flexible plan based their first visit on the basis of how the students reacted in the learning environment in Mathrix and followed by a more structured lesson the second visit. It resulted in a feeling that the group wandered more through the exhibition and missed the chances to engage deeply with the learning potential of each exhibit.

The teacher who had the most structured visit spent the entire lesson at one exhibit and they had prepared a number of exercises. The students in their group were familiar with Mathrix and have been there multiple times during school hours.

5.3 Categorisation of the results

The results and findings of the study were categorised into three overarching main categories: *Teaching organisation, Teaching-learning activity* and *Impact and impressions.* These categories also roughly reflect the chronological progression of the visits and can be understood as representing the phases before, during, and after the visits.

The first main category that was identified in the analysis was *Teaching organisation* which included three different subcategories – *group size, group composition* and *structure*. This main category aims to highlight the observers, and the teachers' thoughts about the benefit or disadvantage of the visits in addition to the exhibition.

The second main category that was identified was *Teaching-learning activity* with subcategories including *engagement*, *interaction and dialogue, persistence and duration, embodied mathematical practice* and *courage and confidence*. The aim for this category was to identify the benefits or disadvantages of the exhibition as a learning environment itself.

Lastly, the third main category identified was *Impact and impressions* including subcategories: *Confidence and self-esteem, benefits of practical materials, group composition* and *observation*. The statements and the utterances for this category is what the teachers pointed out has been different in the classroom, for the students, after the visits.

Following tables present the categories and a description of each subcategory.

Teaching organisation

Subcategory	*Description*
Group size	*Statements and observations regarding the ability to customise the group size.*
Group composition	*Statements and observations regarding the ability to customise the group in general.*
Structure	*Statements and observations regarding the importance of structuring the visits and the lessons for these students.*

Table 5.3: *Description of each subcategory associated with the main category "Teaching organisation".*

Teaching-learning activity

Subcategory	*Description*
Engagement	*Statements and observations related to the student's level of enthusiasm, curiosity, motivation, and active involvement in the exhibits.*
Interaction and dialogue (mathematical talk)	*Statements and observations including interactions between students, insights, and statements of facts from the teachers.*
Persistence and duration	*Statements and observations related to the student's level of focus in Mathrix.*
Embodied mathematical practice	*Statements and observations to the role and impact of practical learning methods.*
Courage and confidence	*Students demonstrating courage and confidence in Mathrix as well as willingness to try.*

Table 5.4: *Description of each subcategory associated with the main category "Teaching-learning activity".*

Impact and impression

Subcategory	*Description*
Confidence and self-esteem	*Statements from the teachers of students change in confidence in the classroom after the visits.*
Benefits of practical materials	*A teacher describing a modification in content of lessons made in the classroom after the visits.*
Group composition and observation	*Teacher describing a difference made regarding group composition and the importance of observing their students*

Table 5.5: *Description of each subcategory associated with the main category "Impact and impressions".*

The following chapter presents the main categories with their corresponding subcategories and to demonstrate the results in each subcategory it will follow with several examples and quotes from the teachers.

5.4 Results from the sessions and the interviews

In this chapter the results from the observations during the visits are presented together with the results from the mid- and post-interview. The interviews constituted our main source of data in this study. The observations gave some additional data but gave first and foremost a better understanding of the students and the teachers descriptions of them in the interviews. The results are categorised as described in the previous chapter *5.3 Categorisation of the results.* For a more comprehensive list of examples and quotes, see **appendix F**.

5.4.1 Teaching organisation

The results related to the main category *teaching organisation* including data production from the observations by the observers, and statements from the interviews. The data is related to the size of the group, the composition of the group and the importance of structure of the lesson in the learning environment in Mathrix.

Example from the data

Group size

All five teachers see the benefits in having small groups and that it matters in this kind of learning environment. The teachers agree that the embodied mathematical practice should not be just a game, which they think it would be if they were not able to supervise. The feeling of being enough is always something a teacher struggles with in general; they want to be sufficient in the classroom and with small groups in Mathrix they managed that.

Group Composition

T_4a noticed that one of their students made the other student more active and engaged in the learning environment in Mathrix compared to the classroom. They also observed that a student had shown the courage to talk with peers they would not normally interact with in the classroom.

“Huge difference in participation and social interaction with peers, as the friend they rely on the most was not there” – T_4a.

A collaboration that had never occurred in the classroom emerged in the learning environment in Mathrix, which pleasantly surprised T_7.

T_2 claims that the composition allowed a beneficial interaction between the students.

Structure

T_4b believe that Mathrix can be a good complement for the students but believe that involving a teacher is necessary to explain the exhibits and for the students to fully understand.

One student had difficulties remaining focused at one exhibit and complete it, as they preferred to move on and follow their interests and desires, according to the observer notes and confirmed by T_4a.

According to T_7 the student need structure in order to keep their concentration. In Mathrix they managed to stay focused, and everything functioned better than in the classroom.

One of T_2's students appeared less engaged during one exhibit, as they already knew what to do, and did not find it as stimulating.

5.4.2 Teaching-learning activity

The results related to the main category *Teaching-learning activity* including data production from the observations by the observers, and statements from the interviews concerning engagement, interaction and dialogue, persistence and duration, embodied mathematical practice as well as courage and confidence.

Engagement

Two of the teachers, T_4a and T_4b, describes one or more of their students as showing greater enthusiasm and curiosity in the learning environment in Mathrix compared to how they usually behave in the classroom.

T_2, T_4a, T_4b and T_8 all stated an experience of stronger engagement and higher motivation in the learning environment in MathrixT_4a mentioned that one of their students said that "Math is fun here".

"I think it is important to meet children in their own world, and if you can draw them in, I believe they will learn much more quickly!" - T_4b

For T_4a, one student appeared clearly more active in general in the learning environment in Mathrix, and another student was more socially active in Mathrix compared to the classroom.

According to T_7, one student experienced Mathrix as more enjoyable and joyful, as they tend to put a lot of pressure on themselves in the regular classroom setting.

Interaction and Dialogue (Mathematical talk)

For T_8, the learning environment in Mathrix encouraged dialogue rather than traditional questioning, hearings or one-way communication. They emphasised that "in order to learn, we have to interact with each other" noting that the prevailing classroom environment often limits such interactions due to the idea that a good environment is a quiet one.

T_7 noted that one of their students managed to put what they did into words in another way compared to what they do in the classroom. The student who typically does not engage in mathematical dialogue, found it easier in Mathrix, to share the process and explain to a peer what they had done, where the pace is slower and more relaxed.

Persistence and duration

Notes from observation of T_4a and their students: The student showed a strong willingness to learn, stayed engaged with the exhibits and actively exploring, testing, and working through the tasks.

T_7 also stated that one of their students showed greater endurance in Mathrix compared to the regular classroom setting. According to the teacher, in the classroom they miss one third of the time [due to not being able to stay focused and concentrate on the teaching-learning activity in the classroom].

For T_2, two of their students normally give up and start to do something else in the classroom; in Mathrix both stayed motivated to continued until the last minute.

Embodied mathematical practice

What proved more effective for all students was the opportunity to engage in hands-on activities in Mathrix, which suited their beforehand known practical learning style, according to T_4a. One student showed the ability to present their results physically, without the need for verbal explanation, one student demonstrated greater engagement when given the opportunity to learn through trial and error, and one is a "highly practical learner".

A student was given the opportunity to explore their learning in a harmless way, and allowing countless repetition until understanding was achieved. T_8 thinks that the possibility given in Mathrix, for simple, risk-free repetition was highly beneficial.

Courage and Confidence

One student of T_4a had the courage to say what they thought and believed [about their inner thoughts and what they do] in Mathrix, which they never do in the classroom setting, where they easily can sit an entire lesson without doing anything and not asking for help.

"You can see that in a suitable environment, you can do things in a completely different way, and in a suitable environment they can also establish and obtain a different kind of understanding" - T_4b.

T_8 stated that one of their students had more explicit thoughts in Mathrix. "The classroom setting with all 30 students does not benefit them and they have difficulty in absorbing a lesson without their own review afterwards. They are nervous about being questioned and do not want to speak in class. That barrier makes Mathrix a more accepting environment without doubt." - T_8.

T_7 is convinced that one of their students feel less pressure in Mathrix compared to what they do in the classroom setting.

5.4.3 Impact and impressions

The results related to the main category *Impact and impressions* are including data production from the post-interview concerning confidence and self-esteem, benefits of practical materials and group composition and observation. The statements refer to the differences observed by the teachers in the classroom after the visits.

Confidence and self-esteem

"They talked without interruption after the visit, never heard so many words come out their mouth before" [about a student with language disorder] - T_4a.

One of T_2:s students explained a task to a peer in the classroom, which they never done before. The teacher was surprised. The student noticeably improved their confidence and did not give up as easily as before the visits in Mathrix.

Benefits of practical materials

All five teachers stated the benefits in practical materials and want to be able to do more practical activities in the classroom setting.

“Visiting Universeum is time well spent, as my students achieves recollections into the classroom” - T_8

Group composition and Observation

“In Mathrix, a significantly different approach can be made, and you can analyse your students in another way that the classroom environment does not allow” - T_8

T_7 is considering their students to cooperate more in the classroom as realising them working together went unexpectedly well in Mathrix.

6 Analysis

The categorisations made and presented in chapter 5 are in this chapter analysed both in themselves as a category, and through the lens of the theoretical frameworks of social constructivism and other learning theories outlined in chapter 2. The aim is to interpret the statements and observations and to deepen the understanding for our research question of how and if the learning environment in Mathrix can be a complement to the classroom environment in mathematics. The analysis is divided into the categories as mentioned in chapter 5: *Teaching organisation, teaching-learning environment* and *impact and impressions*, and as mentioned, roughly reflect the chronological progression of the visits, and presents the phases before, during and after the visits.

6.1 Teaching organisation

The main category "*teaching organisation*" contains descriptions related to the teacher's organisation of the sessions in Mathrix, as described in chapter 5. For this theme the subcategories that occurred from the data collection were *group size, group composition* and *structure,* regarding all statements and observations as described in **table 5.3**.

6.1.1 Group size

When it comes to learning opportunities the size of the student group can have a major impact whether learning is effective or not. The teachers were united that a small group of students are convenient for such learning in the exhibition. Regarding a question asked in the interview concerning if they could see their students mathematical thinking in Mathrix, T_7 replied that they could, but thought it was related to the advantage of having few students to observe. The teachers also stated that the composition of the group influenced whether learning took place. A variety of reactions emerged from the teachers concerning their composition such as T_2 who said that the composition of their group culminated in "beneficial interaction" and for T_4a their students demonstrated a "willingness to help each other and cooperate", all in comparison to how they typically behave in the classroom environment.

These examples above can all be seen through the lens of *ZPD* and *scaffolding*. The scaffolding can manifest in three different ways – from the teacher, from the peer, and from the exhibit. This is related to the description of ZPD as "attainable through the use of mediating semiotic and environmental tools and capable adult or peer facilitation". As further described in chapter 2, *the zone of proximal development* is a space where you want your learners to be in to maximise the opportunities to learn. Small groups enhance the possibility for the teacher to scaffold at an appropriate level and by being both physically and cognitively closer to your students, it is easier for the teacher to identify their ZPD and tailor the support. For a supportive learning environment, maintaining a great relationship between student and teacher is key, and with the teacher's identification of the students needs, it makes it easier to build trust and maintain that relationship.

6.1.2 Group composition

Another aspect that occurred in these two subcategories are students that demonstrate a greater courage and a huge difference in social interactions with other peers. For one student of T_4a the group composition was surprising for the teacher, and the increased courage happened despite being totally out of their comfort zone. The teacher added that they also think that the environment is a contributing cause of that courage. Two other students would not even dare to make a guess in the classroom, but in Mathrix they did. This can be seen as an improvement and an increase in the self-efficacy due to the verbal persuasion. As described in chapter 2, the verbal persuasion is related to interpretations of outcomes related to the environment. Verbal persuasion can affect self-efficacy by giving information on one´s own ability to perform or solve a task. This efficacy information can come from assessments or feedback and is therefore also connected to ZPD. That is, given appropriate help, one will be found in the zone of proximal development, whether the scaffolding is received from a teacher, peer or the environment. And if they succeed in this, it is possible that the self-efficacy will increase.

6.1.3 The structure

For the third subcategory, *Structure,* that emerged from the produced data T_7 stated that one of their students "needs structure in order to stay focused and keep their concentration" and T_4b mentioned that they believe Mathrix can be a good complement for the students but that involving a teacher is necessary. The statement above from T_4b along with the expressed self-awareness about their preparation as not being optimal and further mentioning that without appropriate support from a teacher the exhibits will not be fully utilised, is more or less what Vygotsky meant that scaffolding was all about. T_7 mentions that one of their students needs guidance and a more guided approach both in general and in Mathrix, and from a "scaffolding point of view" it applies to every learner, that with the appropriate help at the appropriate level and by the right people, one can achieve more than they would do alone.

Further, in the same category several teachers mentioned in various ways that their students have difficulty in remaining focused. T_2 describes that one of their students was dedicated to everything during the first session in Mathrix but during the second session they showed that "now I know this, can we continue". T_2 thinks that the patience dropped during the second session. These descriptions can be related to how the experience of flow manifests when performing an activity. Individuals that experience a state of flow when performing an activity will consider the activity as interesting and enjoyable, which of course is something desirable when it comes to learning. T_4a gives an example of when the flow is directed towards another learning exhibit during the sessions in Mathrix. T_4a describes that one of their students sometimes had difficulties staying at the learning exhibit that the teacher wanted the students to complete, "they wanted to do other learning exhibits that they thought looked more fun and that they thought they knew how to do". These descriptions from T_2 and T_4a are related to how the state of flow disappears or is directed towards something else in the learning environment in Mathrix. The examples indicates that it is important to adapt the organisation of the learning activities in a learning environment like Mathrix so that the students find it interesting and motivating in order to find a state of flow that can contribute to the learning. According to Csíkszentmihályi learning is perceived when the student finds the task both meaningful and challenging. If the environment or the teachers do not sustain student's interest or focus, the quality of learning is probably more likely to decrease, as the attention is somewhere else.

The outcome of these statements and observations concerning in this analysis is the insight and realisation in the importance of adapting a structure and a suitable group size and composition to maximise the learning opportunities for the students.

6.2 Teaching-learning activity

The main category "*teaching-learning activity"* contains descriptions related to the exhibition as a learning environment in itself, as described in chapter 5. For this theme the subcategories were *engagement*, *interaction and dialogue*, *persistence and duration*, *embodied mathematical practice* and *courage and confidence*, see **table 5.4**.

6.2.1 Engagement, persistence and duration

Engagement can positively influence learning as it makes the learner more interested and motivated to perform a learning activity. T_2 says that one of the students was overall displaying much more engagement in Mathrix than in the classroom environment. The same student is described by the teacher as having difficulty maintaining concentration and for the students to be concentrated requires a high level of interest and engagement, which the teacher considered to be the case in Mathrix. Another description related to engagement is taken from T_4a who describes one of their students when in Mathrix compared to the classroom as follows: “motivation and engagement is like day and night compared to the classroom environment”. Both descriptions are examples of increased engagement during the sessions in Mathrix which can positively affect learning, and can both be seen in terms of flow theory. These and similar expressions of engagement that emerge in the empirical data are all related to the subjective experiences of flow, and more precisely one of the related elements describes as “an autotelic experience”. This type of experience is associated with intrinsical motivation, curiosity, fascination, and engagement. There are also descriptions under the subcategory *persistence and duration* that can be related to flow theory and aspects of an autotelic experience. T_7 describes one of the students as having better persistence in Mathrix. T_7 says “they didn´t get tired and didn´t want to leave”, T_7 continues “for a short while they lost concentration during the three hours in Mathrix, in the classroom they miss one third of the time [due to not being able to concentrate on the teaching-learning activity in the classroom]”. T_2 also describes that one of their students had an increased engagement in Mathrix compared to the classroom environment, as they usually give up and get irritated and leave to do something completely different from what they are supposed to do in the classroom. T_2 continues; “but in Mathrix they were engaged the whole time”. The increase in engagement, persistence, and duration in Mathrix in relation to the classroom, as described above, can have a positive impact on the learning process as it contributes to a feeling of flow in the learning activity, which makes it feel more interesting and enjoyable for the students.

6.2.2 Courage and confidence

The subcategory *courage and confidence* can also generate positive effects on the learning process as it can make students dare to try out thoughts and ideas, and to participate more actively in the learning process. These types of effects can be related to Bandura’s theory of self-efficacy. According to Bandura an individual's self-efficacy is determined by information from either the environment or the behaviour, see chapter 2. One of the environmental aspects of efficacy information is the vicarious experience that can increase self-efficacy in the individual by observation of others, similar peers, performing a task which can give a feeling of personal ability to succeed in performing the same task. T_8 highlights the possibility for the students to observe each other in other ways in Mathrix compared to the classroom environment. T_8 describes the positive characteristic of the learning environment in Mathrix as follows; “the learning environment offers more opportunities for observation, which benefits the student who has low confidence in their ability, compared to the classroom where you can only possibly see the notes of the classmate next to you". The possibility to observe other students as described by T_8 can contribute to a vicarious experience that can increase the student's self-efficacy and have a positive influence on the learning process. Efficacy information from behaviour, on the other hand, can come from physiological/emotive arousals, which is associated with affective and somatic reactions to performance. Feelings of pressure and anxiety in relation to performance can decrease self-efficacy and lower the willingness to engage in learning activities. T_7 describes that they think that one of the students who they feel have a lot of pressure from the home environment to succeed in school did not feel this pressure to succeed in Mathrix. It resulted in the student expressing their mathematical thinking verbally to a greater extent in contrast to the situation in the classroom where they generally only want to do exercises without talking or discussing it. Another description that can be related to how physiological/emotive arousals affect self-efficacy is the statement from T_4a regarding one of their students. T_4a says that "usually they are quiet and let others do the talking, but during the visit in Mathrix, they made their voice heard which is a bit unusual". These two examples show that the learning environment in Mathrix can positively affect the students to demonstrate more courage and confidence in expressing their thoughts and ideas, and to be more involved in the learning process. Another positive impact is when the student has the courage to expresses their ideas and mathematical thinking. The teacher can then more easily understand why the student is solving a certain problem in a certain way and give adequate feedback to enhance the learning.

6.2.3 Embodied mathematical practice

The learning environment in Mathrix is based on active learning where the visitor, or the student in this case, are supposed to experience mathematics by physically interacting with the learning exhibits. The subcategory *embodied mathematical practice* contains descriptions and statements from the teacher on the importance of practical learning methods and how it can help students who are more confident in expressing themselves through practical material rather than with pen and paper. T_4a describes one of their students in relation to embodied mathematical practice as performing better in the learning environment in Mathrix where they could work with their hands and says that "they are more of a practical person". T_4a describes another student in a similar way pointing to the fact that the key factor for the successful sessions in Mathrix was that they could work "hands on" in the learning exhibits. These descriptions are categorised under the self-efficacy theory and can be related to the efficacy information an individual gets from mastery experience, meaning that self-efficacy is increased if the individual can relate to success in similar or the same activity. In this case the students can relate to their ability to work with their hands and with practical material and get an increase in self-efficacy in the learning environment in Mathrix as it contains practical learning exhibits which require hands on interaction. The increase in self-efficacy can be positive for the learning process as it contributes to the students feeling more confident engaging with the exhibits and testing and trying things out.

6.2.4 Interaction and dialogue

The subcategory *interaction and dialogue* describe the interactions between the students in the learning environment in Mathrix. This is an important aspect of learning according to the social constructivist viewpoint, which considers the interaction and dialogue between the learner and others to be an important part of constructing new knowledge and understanding. T_8 describes the learning environment in Mathrix as an environment that invites to dialogue instead of inquiring, “the students can describe instead of just answering questions”. T_7 describes that one of their students uses ear protection and works individually in the classroom environment, but in Mathrix they collaborated well and had a good dialogue with T_7´s other student. These types of dialogues can generate an understanding of the student's actual knowledge so that the teacher can scaffold them to learn new knowledge. This type of information that can make the zone of proximal development visible is a positive property of the learning environment in Mathrix that can positively influence the learning process for the students. The interactions and dialogues are not only important for the teachers to get information about the knowledge and understanding of the students, but it can also contribute to scaffolding between the students themselves and affect learning in a positive way.

The descriptions and statements in the main category “*teaching-learning activity*” show that the learning environment in Mathrix can positively influence different aspects that are related to learning. Student *engagement*, *persistence and duration* are increased in Mathrix in comparison to the classroom environment which can be related a state of flow where the activities performed become more interesting and enjoyable. *Interaction and dialogue* between the students are more focused on describing rather than only giving answers, which can provide the teachers with more relevant information about the students' knowledge and understanding, contributing to better scaffolding. This type of dialogue where methods, strategies and solutions are discussed, is also an important source for the students own learning. There are also indications that *courage and confidence* among the students is higher in Mathrix and that self-efficacy is increased due to the possibility to observe other students performing similar tasks and that the learning environment is not associated with the same pressure as the classroom environment. Self-efficacy can also increase among students that are more confident with performing tasks with practical materials as the learning environment in Mathrix is more focused on *embodied mathematical practice* in comparison to the classroom environment where pen and paper often are the main mean of expression.

6.3 Impact and impressions

The main category "*impact and impressions*" contains descriptions from the teachers relating to their perceptions of the students after the sessions in Mathrix and how it has affected them in the classroom environment. The subcategories for this theme are *confidence and self-esteem*, *benefits of practical materials*, and *group composition and observation*. The subcategories are described in **table 5.5**.

6.3.1 Confidence and self-esteem

The subcategory *confidence and self-esteem* contains descriptions and statements from the teachers regarding the changes in the student's confidence in the classroom after the visits in Mathrix. An increase in confidence and self-esteem is a positive outcome of the visits that can contribute to a better learning situation for the students. An example of this is provided by T_2 and their description of one of their students after the two sessions and how they, in a way that T_2 never heard before, actively explain how they solve a problem, and with the purpose to solve the problem, not just to finish it and to get it done. This description can be interpreted as an effect of the sessions in Mathrix on the student's self-efficacy in a positive way, and the effect can come from successful experiences and performances in Mathrix that create a mastery experience that the student brings back to the classroom environment. T_4a also describes how their students demonstrated a boost in confidence and self-esteem when T_4a introduced the internet version of Nerdly in the classroom and the students that participated in the sessions in Mathrix could describe and show how to solve the tasks to their classmates. T_4a specifically highlights one of their students who did not like Nerdly in Mathrix but when they introduced it in the classroom found it more interesting and participated in the demonstration to their classmates. Like the previous description from T_2 this increase in self-efficacy can be related to mastery experience created by performing Nerdly in Mathrix before it was introduced in the classroom environment.

6.3.2 The benefits of practical materials

The subcategory *benefits of practical materials* are related to descriptions from the teachers on modifications in content of lessons in the classroom after the visits. T_4a says that they want to introduce more practical material in the classroom as they have recognised that many of the students tend to be more practical. T_4b gives the example that they could build equations with practical material instead of just write them on paper. This different form of representing math support students in the development of mathematical knowledge and can also help the teacher to recognise what the students understand in another way than working only with pen and paper. This information can then be used to scaffold the students in a better way to construct new knowledge and understanding. Scaffolding a student through their zone of proximal development requires that the teacher knows at what level of knowledge and understanding the student´s ZPD starts, and if the student has difficulties to show their knowledge and understanding using only pen and paper, practical material can be a way for the teacher to detect this level. This can be seen as a positive consequence of conducting learning activities in Mathrix as it can give information about the students' knowledge and understanding that is not always visible in the classroom environment. Information that the teacher can use to scaffold the students in a more effective way to enhance their learning.

6.3.3 Group composition and observation

The third subcategory is *group composition and observation* which relates to the teachers' reflection on the cooperation and interactions in the student groups and on the benefit of being able to observe their students. T_7 drew the conclusion after the sessions in Mathrix that the cooperation between their two students worked well and that they thought that they could get to work together in the classroom environment as well. As scaffolding also can come from a peer the opportunity for this kind of observations can be important for a teacher to get information regarding if a student constellation is positive for the learning process and can enhance the learning for the students. The benefit of being able to observe the students is something that T_8 also describes, and they think that the benefit of Mathrix is not only for the students but also for the teachers as they can observe their students and understand how they are thinking and their reasoning. As described above this type of information can give important insights to the teacher regarding in what way to scaffold the students to enhance their learning.

In the main category "*impact and impressions*" it is shown that teachers and students in different ways been affected by the two visits in Mathrix. For the subcategory *confidence and self-esteem,* the students show a change in their behaviour in various ways by taking socially initiatives as a result of mastery experience. The teacher has also been influenced by the visits as many of them expressed a willingness to make a change in the classroom with practical material and some of them already started to introduce new materials, due to their belief in more practical exercises and that they thought it will benefit more students in the classroom. The learning environment in Mathrix also exposed cooperation's that never occur in the classroom environment due to several reasons which amazed the teachers and affected them positively.

7 Discussion

The analysis of the data shows that the learning environment in Mathrix can have a positive influence on learning and that the learning process is affected by advantageous opportunities to scaffold, not only for the teacher but also for the students and the learning exhibits. The analysis also shows an increasing degree of self-efficacy among the students due to the possibility to work with practical materials and being able to display mathematical knowledge in a different way than in the classroom environment. There is also strong evidence in the data that the learning environment in Mathrix increase the students engagement, persistence and duration by being an interesting and enjoyable environment, which can be associated with a state of flow among the students when working with the learning exhibits.

7.1 The typical challenges of the student group

The characteristic challenges of the student group described in chapter 5 have to some extent been positively influenced in the learning environment in Mathrix. *Concentration* being a typical challenge for the students in the classroom environment, is reported to be better during the session in Mathrix which is seen in the increase of engagement, persistence and duration. This can be related to the positive effects of interactive learning and AR (12), where this type of technology enhances motivation and engagement and promote a positive attitude towards learning. The embodied mathematical practice in Mathrix and the practical material had a positive impact on the students and increased their willingness to perform the mathematics in the learning exhibits in Mathrix, which is positive in relation to the classroom environment where the typical challenge is to *carrying out and perform math.* As described in the literature (25), it is beneficial for the students development of mathematical knowledge if they are allowed to encounter and move between different forms of mathematical representations, where the learning exhibits in Mathrix represent an alternative form compared to what the students typically encounter in the classroom environment. The immersive environment in Mathrix can also contribute to the willingness to perform mathematics as this kind of learning environment can generate more efficient learning (26).

Other typical challenges of the student group are *self-efficacy in math* and *communicating math* which improved in Mathrix, and also to some extent in the classroom environment after the sessions in Mathrix. This is evident in the fact that the students dare to try out their thoughts and ideas and talk about what they are doing and describe their mathematical thinking in a way that is not seen by the teacher in the classroom environment. This could be related to the entertaining game-like format of many of the learning exhibits which is described in a study (5), and together with pedagogical features boost mathematical learning.

Another factor that could be a part of the positive effects, and is related to the typical challenge *communicating math*, is the learning environment in Mathrix itself and the composition of the student groups that could be considered to generate an intimate and supportive learning environment that according to the research (6), can help low-achieving students to demonstrate mathematical reasoning verbally. The characteristic of the student group also describes difficulties to understand and take in *verbal instructions* as one of the typical challenges. The analysis of the data shows that the students could engage in the tasks and understand the verbal instructions from the teacher in a better way in Mathrix. This could be an effect of the combination of the teachers' instructions and the practical and interactive representation of the tasks in the learning exhibits. *Numerosity and problem-solving skills* is the final typical challenge of the student group, and it was present in some way in all the learning exhibits that the students encountered in Mathrix. The teachers could in different ways see and also hear the students describing how they were thinking when solving a problem in the learning exhibit, and in some cases, they could detect the students problem-solving strategies, but it is difficult to conclude that the learning environment in Mathrix improved the students' problem-solving skills.

7.2 The typical strengths of the student group

The typical strengths of the student group described in chapter 5 may have contributed to the positive impact on the learning process seen in the analysis. The student group is described as having a desire to learn and being ambitious, and this can of course be associated with the increase in engagement, persistence and duration when the students get to work in a learning environment that they experience as both fun and interesting. The desire to learn can also entail that the students try to solve the problems in the learning environment instead of just doing them for fun, and by doing so displaying their actual level of knowledge and understanding, which can help the teacher, peers and the learning exhibits to scaffold them in a suitable way. Finally, when the students get to work with practical material in the learning environment in Mathrix the ambition and willingness to put effort into the work can generate a higher level of success in solving the problems which in turn can lead to an increase in self-efficacy in the students. This could be compared to if the students had low ambitions and no willingness to put effort into the (school) work. Accordingly, the typical strengths of the student group could have influenced the positive consequences seen during and after the sessions in Mathrix indicating that these positive effects were not only generated by the learning environment and the learning activities alone but also came from the characteristics of the student group.

7.3 Other aspects that may have affected the results

Besides the typical strengths of the student group, other aspects of the study might have affected the positive consequences of the learning activities in Mathrix. The students may have been affected by the fact that they were selected for this study and that they are doing something special that may lead to a positive impact on other students after the study. This type of feelings can of course contribute to a higher level of engagement and have the consequence that the students put more effort into the learning actives during the sessions in Mathrix than what they normally would have done. Another effect that could influence the students in the study is the effect of doing something new and different in comparison with what they do every day in the classroom. This could probably also contribute to more engagement and higher willingness to participate in the different learning activities performed in Mathrix. In relation to this "pleasure of novelty" the question is whether the student engagement and interest would have persisted if the visits had continued. Would the same effect and findings occur if the study continued over a longer time with the same teacher/student group and recurred visits?

What the teachers mention as favourable during the study are indeed key factors that influenced this study into a positive direction. To scaffold each and every student in a way that the student can be in their zone of proximal development in every lesson is hard to manage when the teacher often is alone in the classroom and responsible for about 30 students. To visit Mathrix with a small group of students and conduct learning activities in that learning environment is then of course an unusual phenomenon, both for the teacher and the student. The opportunities of creating a beneficial lesson with a positive learning outcome are therefore greater when you are responsible for only a small number of students, and this would probably also be the case in the classroom environment as well as it has, to some extent, been shown to be in the learning environment in Mathrix. However, the positive consequences of the sessions in the learning environment in Mathrix are not only due to the size or composition of the student groups, but also due to the immersive environment in Mathrix with its interactive and game-like learning exhibitions that generate motivation and engagement, and a possibility to display mathematical skills and knowledge in a different way than in the classroom environment. These properties of the learning environment in Mathrix can positively influence the learning process, especially in neurodiverse students, which has been shown in the results and analysis of this study. These properties also align with what Forsman set as indicators on a positive learning environment that can enhance learning, namely an environment that encourages an investigative approach, reflective conversation and creative mathematical thinking in order to increase the focus on understanding (10).

7.4 Mathrix as a complement to the classroom

This boils down to the research question of this study: in what way can the learning environment in Mathrix be a complement to the classroom environment? What is shown in this study is that the learning environment in Mathrix can enhance various aspects of learning that can be positive for the students' learning process. The analysis of the data in this study show that the immersive environment can make mathematics more interesting and enjoyable and thus increase engagement and motivation to perform mathematics in Mathrix. There are also indications that self-efficacy is increased when performing mathematics in the more practical and "hands on" learning environment where specific procedures and the correct answers are not in focus, but rather the process of doing, investigating, and exploring mathematics. The learning environment in Mathrix also seems to be positive in enhancing self-efficacy by the beneficial possibility to observe other similar peers, perform mathematics and solve problems, and thereby contribute to a positive feeling about one´s own ability to succeed in the learning environment. The possibility to observe also contributes to the teachers understanding about the students' knowledge in mathematics in a way that can make scaffolding more effective, both in Mathrix but probably also in the classroom environment. On the other hand, as discussed above, the teaching organisation also play an important role in the positive effects and consequences on learning that emerged in this study. The size of the student groups made it possible for the teachers to observe, guide and scaffold their students in a different way compared to when teaching a full class. The size and composition of the student groups may also have contributed to an increased courage to speak and try out thoughts and ideas when performing the learning exhibits, which could be a part of the explanation to the increased self-efficacy. The discussion also points to the fact that the circumstances during this study may have affected the results of the study in a positive way. The effect of doing something special and be chosen among the other students in the class to participate in a research study, and the new environment that Mathrix constituted could all have contributed to a higher level of engagement and interest among the participating students.

7.5 Future work

Several ideas for future work have emerged during the study. First, it would be valuable to assess students' knowledge or behavior prior to, and after the visits to investigate whether any measurable learning occurred as a result of the experience in the learning environment in Mathrix. Pre- and post-assessment could offer a clearer understanding of the learning impact and outcome and can be a way to help understand whether the learning environment in Mathrix contributed to such learning.

Further, a more structured and targeted planning process could be developed in future studies to explore specific exhibits or specific pedagogical planning tools. For instance, if a particular learning goal is defined in advance, the visits can be tailored allowing for a focused analysis of how this goal is supported or challenged by the learning environment in Mathrix.

It would also be interesting to apply the same approach to a larger group or a full class setting, to challenge one of the concerns the teachers emphasised during the study. To explore how to approach the challenge of visiting Mathrix in full class and have a meaningful visit where the students gain experience and knowledge.

Lastly, the possible influencing factors mentioned at end of the previous chapter would also be interesting to investigate further, to maintain a general validity of the results.

8 Conclusion

The purpose of this study was to investigate if and how the mathematical exhibition Mathrix at Universeum in Gothenburg could constitute a learning environment that can be a complement to the classroom environment in mathematics. The research questions grew out of indications from visiting teachers who believed that Mathrix would benefit specific students who do not make themself justice in the typical classroom environment in mathematics. These indications sparked the interest at Universeum to investigate the matter further, and this master´s thesis is the first step in that research and investigating the research question: *In what way can the learning environment in Mathrix be a complement to the classroom environment?*

The study was conducted as an exploratory case field study with observations of five teacher/student groups who visited and performed learning activities in Mathrix at two occasions. Besides the observations a series of interviews were conducted with the teachers to get their view of the students before, during and after the visits in Mathrix. The data was then analysed in relation to aspects of different learning theories to see if the learning environment together with the performed learning activities in Mathrix displayed any favourable features regarding learning and promoted learning opportunities that could enhance learning among the students.

The study concludes that the learning environment in Mathrix can positively affect student engagement and interest in performing mathematics through aspects related to the state of flow as described by Csíkszentmihályi Flow theory. The practical and "hands on" learning environment in Mathrix can also make it possible for students to observe each other solving mathematical tasks which can both increase self-efficacy when watching similar peers succeed and make peer scaffolding possible. The practical materials in the learning environment in Mathrix can also increase self-efficacy in students who have challenges in demonstrating their mathematical knowledge with pen and paper. The study also concludes that the teaching organisation needs to be adapted both regarding size and composition of the student group to make it possible for the teacher to observe and scaffold all participating students. The structure of the learning activity also needs to be adapted in a way that enables the teacher to discover and understand the mathematical thinking and knowledge level of the students to be able to scaffold the students more effectively. If the learning environment in Mathrix is combined with such teaching organisation this study suggests that it can result in beneficial learning opportunities that can support the students in their mathematical learning in the classroom, thus making Mathrix a complement to the classroom environment.

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Appendices

I. Participant information sheet

Informationsformulär för deltagande elev

Studie om Mathrix som alternativ lärmiljö för matematikundervisning

Ditt barn är inbjuden till att delta i en studie på Universeum som är en del av ett examensarbete på mastersprogrammet Lärande och Ledarskap vid Chalmers tekniska högskola under handledning av professor Lena Pareto. I det här dokumentet får du som vårdnadshavare information om studien och hur den kommer att genomföras.

Deltagandet är helt frivilligt och du eller ditt barn kan även välja att när som helst ångra sig och avbryta sin medverkan.

Vad handlar studien om och varför är det viktigt?

Syftet med studien är att undersöka om lärmiljön Mathrix vid Universeum kan bidra till att förbättra lärandet av och förståelsen för matematik hos barn och ungdomar. Då en del elever har svårt att visa och utveckla sin matematikförståelse i klassrummet kommer den här studien undersöka om Mathrix kan fungera som en kompletterande lärmiljö för dessa elever. En ökad förståelse för hur olika elever lär sig matematik är en viktig del i att utveckla och förbättra matematikundervisningen i skolan och öka elevers matematikkunskaper.

Hur genomförs studien?

Studien kommer genomföras som en kombination av intervjuer med lärare och observation av läraktiviteter i Mathrix lärmiljö. Eleverna kommer utforska och arbeta i Mathrix lärmiljö tillsammans med sina lärare på Universeum under två entimmes tillfällen. Intervjuer med lärare sker före, mellan och efter dessa två tillfällen på Universeum och behandlar elevens möjligheter och utmaningar i klassrummet och lärmiljön Matrix. Observationer kommer att vara inriktade på de lärandeaktiviteter som eleverna deltar i, samt vilka reaktioner och uttryck som aktiviteterna ger upphov till.

Dataskydd och sekretess

Datainsamlingen sker genom en förintervju med lärare, följt av observationer i lärmiljön Mathrix på Universeum, och sedan avslutas med en efterintervju med läraren. Information som inkluderas är svar på frågor om ditt barns uppvisade förmågor och utmaningar i matematikundervisningen, med fokus på interaktioner och kommunikation som uppstår under observationen. Ingen ljud- eller videoinspelning kommer ske med eleverna. Ljudupptag av intervjuerna med lärare kan förekomma för att sedan transkriberas.

Elevernas identitet och personuppgifter är enbart kända av lärarna, i studien kodas eleverna med pseudonymnamn. All insamlad information behandlas konfidentiellt och hanteras i enlighet med gällande dataskyddslagstiftning, inklusive EU:s dataskyddsförordning (GDPR). Insamlade uppgifter kommer att lagras på en säker server, i lösenordskyddade filer och kommer endast att vara tillgängliga för de ansvariga på projektet. Inga enskilda deltagare kommer att kunna identifieras i datafiler, rapporter eller presentationer av resultaten. Data sparas fram till att forskningen är avslutad och raderas därefter på ett säkert sätt.

Samtycke

Jag har tagit del av informationen om studien och förstått syftet, hur datainsamlingen kommer att genomföras samt hur mitt/vårt barns information kommer att hanteras. Jag är medveten om att deltagandet är frivilligt och att jag när som helst kan avbryta deltagandet utan att ange orsak.

Jag samtycker till att mitt barn deltar i studien enligt de beskrivna villkoren.

☐ **Ja, jag samtycker till att mitt barn deltar i studien**

☐ **Nej, jag samtycker inte till att mitt barn deltar i studien**

Namn vårdnadshavare: ______________________ ______________________

Underskrifter: ______________________ ______________________

Datum: ______________________

II. Pre-observation interview - Interview guide

Frågeformulär – Förmöte inför observationsstudie på Mathrix

Lärare:
Antal elever:
Datum:

Fyll nedanstående frågor för respektive elev. Elev 1, Elev 2, osv.

Elev 1

Beskrivning av elev

Ge en kortfattad beskrivning av eleven.

Beskrivning av elevens tillvaro och utmaningar/styrkor i den klassiska klassrumsmiljön

Vilka utmaningar har eleven i klassrummet?

a) Generellt

b) Inom matematikundervisningen

c) Inom andra ämnen

Vilka styrkor har eleven i klassrummet?

a) Generellt

b) Inom matematikundervisningen

c) Inom andra ämnen

Kan du ge några exempel från klassrumsmiljön som beskriver elevens situation och tillvaro?

Möjligheter med en alternativ lärmiljö

Varför och på vilket sätt tror du att eleven kan ha nytta att jobba i Mathrix?

Elev 2

Beskrivning av elev

Ge en kortfattad beskrivning av eleven.

Beskrivning av elevens tillvaro och utmaningar/styrkor i den klassiska klassrumsmiljön

Vilka utmaningar har eleven i klassrummet?

d) Generellt

e) Inom matematikundervisningen

f) Inom andra ämnen

Vilka styrkor har eleven i klassrummet?

d) Generellt

e) Inom matematikundervisningen

f) Inom andra ämnen

Kan du ge några exempel från klassrumsmiljön som beskriver elevens situation och tillvaro?

Möjligheter med en alternativ lärmiljö

Varför och på vilket sätt tror du att eleven kan ha nytta att jobba i Mathrix?

III. Questionnarie - Lesson plan

Frågeformulär – Lektionsupplägg inför observationsstudie på Mathrix

Lärare:
Datum:

Övergripande lektionsupplägg Mathrix tillfälle 1 & 2

Vad tänker du att eleverna ska göra vid tillfälle 1?

Vad tänker du att eleverna ska göra vid tillfälle 2?

IV. Post-observation interview – Interview guide

<u>Intervjuguide – efterintervju</u>

Om eleverna sedan innan
Ta upp vad de skrivit om respektive elev, utmaningar respektive styrkor, och fråga om de vill komplettera något.

Jämföra respektive elev i klassrum vs Mathrix
Hur upplevde du att elev A/elev B reagerade på lärmiljön i Mathrix jämfört med klassrumsundervisning?

Var det något i miljön Mathrix som fungerade bättre än klassrumsmiljön för elev A/elev B? Isåfall vad? Något som fungerade sämre? Isåfall vad?

Om du skulle jämföra Mathrix mot klassrummet för elev A/elev B, uppfattade du någon skillnad vad gäller

a. Motivation och engagemang?
b. Koncentration och uthållighet?
c. Sätt att visa sin matematiska förståelse/tänkande?
d. Sätt att fungera socialt och delaktighet?

Efter besöken för eleverna
Har du märkt någon skillnad på elev A/elev B efter besöken I Mathrix?
Har elev A/elev B själva uttryckt något efter besöken i Mathrix?

Besökens påverkan på dig som lärare
Påverkade besöken din syn på hur elev A/elev B lär sig och trivs i olika miljöer?
Tar du med er något från dessa besök in i ordinarie undervisningen? Någon förändring?

Om Mathrix som lärmiljö
Vad ser du för möjligheter med en lärmiljö som Mathrix för elever med särskilda behov?

Ser du några problem eller svårigheter med att använda sig av en lärmiljö som Mathrix?

V. Descriptive quotations Challenges

Challenges	*Examples descriptive quotations*
Concentration	*"Challenges keeping focus, easily distracted".* - *T_8* *"Challenges with concentration".* - *T_2* *"Having a short concentration span".* - *T_4a*
Carrying out and perform math	*"Have challenges getting started".* - *T_4a* *"To get started with individual work takes time".* - *T_8* *"Challenges with individual work".* - *T_4a* *"Needs an adult to help to get through and finish tasks".* - *T_4a*
Self-efficacy in math	*"The trust in their own ability fluctuates".* - *(T_4a)* *"Unsecure, even when they know".* - *T_2* *"Does not trust their own ability".* - *T_4a*
Verbal instruction	*"Challenges absorbing information in full class".* - *T_4a* *"Challenges to follow lectures".*

	- *T_8*
Communicating math	*"Have challenges with everything that includes pen and paper".* - *T_4a* *"To verbally express how they are thinking".* - *T_7* *"Challenges showing their knowledge in writing".* - *T_8*
Numerosity and problem-solving	*"Challenges with multi-step exercises in several steps and tackling the abstract".* - *T_4a* *"Challenges with perceptions of numbers and positioning systems".* - *T_4a* *"Need to practice on their problem-solving skills".* - *T_2*

Table XX: *An overview of the number of students included in each category.*

VI. List of examples and quotes from the sessions and interviews (in Swedish)

A comprehensive list of extracts of examples and quotes from the mid- and post-interviews, and notes from the observation sessions. (in Swedish).

Subcategory	*Examples and quotes*
Group size	"Om man är där i helklass kan det vara svårt att räcka till som lärare och kunna vara med och visa och stötta. Så att det praktiska inte bara blir lek." - T_4a Lärare T_8 menar att det är enklare att vara få elever för att veta vad eleverna har gjort och kunna återkoppla till det. Svårare att veta vad alla har gjort om man är i Mathrix med helklass. T_7 påpekar att hen kunde se det matematiska tänkandet hos eleverna, men att det var mycket kopplat till att det endast var två elever. Hade läraren haft med sig hela klassen så hade inte varit så stor skillnad trodde hen, då hen ser svårigheter i att ha en hel klass i Mathrix och få ut någonting bra av det. T_2 ser fördelar med att vara i matrix i små grupper. Ser det lite problematiskt med att få ut max av att vara där i helklass.
Group Composition	T_4a berättar att två av hens elever stöttade varandra. Den ena eleven drog i den andra eleven, och fick igång hen lite mer än vanligt. T_4a tyckte att det var stor skillnad i Mathrix då eleven vågade prata med andra som hen vanligtvis inte pratar med. T_7 visste inte att deras samarbete skulle fungera så bra som det gjorde, då de inte sitter i klassrummet ihop annars, och är heller inte "bästa kompisar".

	T_2 gjorde en medveten ihopparning och sammansättningen gjorde att ett fördelaktigt samspel skedde mellan eleverna.
Structure	T_4a säger att en elev hade ibland svårt att stanna kvar vid den station som hen ville att de skulle genomföra. Eleven ville göra andra stationer som hen tycket såg roligare ut och som hen trodde sig veta hur man skulle göra. “Hen är luststyrd och är koncentrerad och uthållig när det är saker hen vill göra, men har lätt att tappa koncentrationen när hen upplever att hen kan eller ser något annat som är roligare.” - T_4a Läraren T_4b tror att Mathrix kan fungera bra som ett hjälpmedel och kan få dem att se grejer. Men hen tror att man behöver en pedagog som är med och förklarar vad de ser, varför de ser vad de ser och varför resultatet blir som det blir. Eleven behöver enligt T_7 ett mer uppstyrt upplägg, det hade inte gått att bara släppa hen fritt. Alla grejer funkade bättre tyckte T_7, när det var styrt. T_2 säger att ena eleven tyckte lärstationen var "inte tillräckligt spännande". Hen vill ha ett visst mått av spänning och utmaning.
Engagement	T_4a upplever att eleven är väldigt mer entusiastisk och nyfiken i Mathrix jämfört med klassrummet. Ville testa och undrade vad man gjorde på de olika stationerna osv. I klassrummet sjunker hen ihop och sitter och tittar. Har svårt att komma till skott överhuvudtaget i klassrummet om läraren inte sätter sig med hen. “Hen har mycket högre motivation och engagemang i Mathrix. Säger att matte är kul där.” - T_4a T_4a berättar att motivation och engagemang jämfört med klassrummet för

	många av eleverna var som natt och dag. Den var väldigt, väldigt mycket högre. Det som bidrog till detta var det praktiska, att få trycka och greja. "De såg ju det (Mathrix) som en lekplats och då har man ju lyckats om du får lärande att vara som är lek och tycker att det är kul" - T_4b T_8 såg att eleven tyckte det var roligare i matrix än i klassrummet. T_7 berättar att ena eleven uttryckt sig efteråt att det var väldigt roligt att vara där (Mathrix), och ville inte därifrån. “Det är ingenting hen säger på en vanlig mattelektion direkt.” Miljön ger eleven glädje, och inte så mycket press. (T_7) Hen har väldigt svårt för koncentration och att hålla uppe den, då ska ett otroligt inresse finnas, och det ska engagera, vilket T_2 tyckte var annorlunda i Matrix.
Interaction and Dialogue (Mathematical talk)	“Miljön inbjuder till dialoger istället för förhör, eleverna kan beskriva istället för att svara på en fråga.” - T_8 “För att kunna lära oss måste vi interagera med varandra och prata och då måste det få låta lite. Normen är att ett tyst klassrum är ett bra klassrum och då är det svårare att tillåta interaktion.” T_8 ser Universeum som en frihet där eleverna kan interagera med läraren och varandra. “Hen satte ord på vad hen gjorde på ett annat sätt i matrix än annars, vill annars jobba individuellt och inte prata matte (i klassrummet)” - T_7 För ena eleven berättar T_7 att det lugnare tempot i Mathrix gjorde det mer naturligt att berätta för kompisen hur hen tänkte.

Persistence and duration	T_4as ena elev visade på arbetsvilja, då hen höll kvar vid en och samma uppgift länge, kunde stå kvar och testa och jobba. I klassrummet har hen annars svårt med fokus. “Vanligtvis ger hen upp och blir irriterad, och går och gör något helt annat. Men i matrix var hen engagerad hela timmen” - T_2 Mycket bättre uthållighet i Mathrix. Höll på längre med lärstationerna. Tröttnade lite på Vågade ekvationer och Nördlig. T_7 säger ändå att det var väldigt stor skillnad i jämförelse med klassrummet. I klassrummet måste läraren fokusera mycket på att hen ska vara engagerad, då hen annars stör sina klasskompisar, men i Mathrix kunde hen hålla fokus. (T_2)
Embodied mathematical practice	"Lärandet är inte i fokus, utan det är görandet". Att kunna använda det de gjort i matrix i klassrummet sedan, som minnesbilder tror T_8 väldigt mycket på. T_4a upplever att det som fungerar bättre i Mathrix miljön var att hen kunde använda händerna. “Hen är mer av en praktiker.” Hen kunde visa sin matematiska förståelse bättre i Mathrix genom att hen kunde visa och inte behövde förklara i ord. Till exempel Skala och Tornet som hen löste väldigt snabbt. (T_4a) “Hen blev väldigt fascinerad av miljön i Mathrix och ville gå runt och titta och trycka på allt. Hen är ju en praktiker av rang. Hen gillar slöjd och teknik och den typen av lektioner i skolan. Gillar att få jobba med kroppen, och i Mathrix kunde hen visa vad hen kunde för där fick hen jobba med kroppen, till skillnad mot klassrummet där det är penna, papper och bok.” - T_4a

	T_4a upplever att det som fungerade bättre i Mathix var när hen fick jobba "hands on". Även de mer abstarkta stationerna som Nördlig försökte hen tappert med och tog för sig väldigt mycket mer. Hen fick chans att testa sina idéer på ett ofarligt sätt vilket T_8 tror var jättebra för hen. Att kunna och få upprepa saker tills hen förstod. Läraren tycker att möjligheten till att göra lätta upprepningar är bra. T_7 säger att det är konkret och visuellt i Mathrix (Vågade ekvationer), och ger eleven tydligare och ökad förståelse än att lära in metoden för att lösa ekvationen.
Courage and Confidence	"Hen vågade säga vad hen tyckte och trodde, tog mycket mer plats i matrix än i klassrummet." - T_4a "Vanligtvis är hen tyst och låter andra köra på, men under Mathrixbesöket, när hen förstod så gjorde hen sin röst hörd, vilket är lite ovanligt." - T_4a T_4a berättar att hen reagerade med entusiasm på Mathrix-miljön. Tog för sig jättemycket både när hen förstod och inte förstod och ville verkligen visa och göra, vilket aldrig syns i klassrummet. "man ser att i rätt miljö så kan man ta för sig på ett helt annat sätt, och i rätt miljö kan de också skapa och få en annan förståelse" - T_4b "Helklassituation gynnar inte hen, hen har svårt att ta till sig en genomgång i helklass, behöver en egen genomgång efteråt, nervös för att få frågor i klassrummet, vill heller inte redovisa inför klassen. Den blockeringen gör att Mathrix är en mer tillåtande miljö utan tvekan." - T_8 T_7 tror inte att hen kände lika stor press på sig, att hen behövde lyckas på lärstationerna jämfört med vad hen känner i klassrummet.

	Mer lustfyllt. Miljön generellt inbjuder till mer egna idéer och egen kreativitet.
Confidence and self-esteem	läraren introducerade webbvarianten av nördlig, där eleverna som varit med i Mathrix, fick en boost av att få förklara för sina resterande klasskompisar. (T_4a) Eleven pratade oavbrutet efter besöken. Läraren har aldrig hört hen prata så mycket någonsin. eleven har även sökt upp T_4a och ställt frågor, någonting hen inte gjort innan. Efter besöket i Matrix hade eleven sagt "jag tyckte det var jätteroligt idag". Efteråt har eleven visat på att hen kan förklara, säga hur de ska göra (vid en samarbetsuppgift), där T_2 trodde att det var bänkkompisen som skulle förklara. Aldrig hört eleven aktivt förklara på det sättet innan. även i syfte att lösa uppgiften, inte bara bli klar med uppgiften. Efteråt har hen visat på större säkerhet och bättre självförtroende. (T_2) Efteråt har eleven visat på att hen inte ger upp lika lätt och har heller inte blivit förbannad som hen tidigare annars kunde bli, utan fortsatt och kämpat. (T_2)
Benefits of practical materials	Läraren T_4a vill ha mer praktiskt material i klassrummet, då det ju visar sig att många är mer praktiskt lagda av eleverna. Vill erbjuda praktiskt material i större utsträckning. T_4b vill jobba mer med konkret material och exempelvis bygga ekvationer fysiskt istället för att skriva dem på papper. Om man jobbar kontinuerligt i denna lärmiljö tror T_4b att lärandet blir mycket bättre, att de lär sig mer och snabbare. Alla T_8s elever bekräftar att användandet av material i matematiken är viktigt. T_7 har börjat skissa på en analog variant av nördlig. Läraren vill jobba mer konkret i

	klassrummet, ha mer samtal och lösa uppgifter tillsammans. T_2 vill våga sig på ännu mer av att använda praktiskt material, olika sorters övningar, då T_2 tror att det kanske kan vara fler elever i klassen som kan blomma ut på samma sätt. T_8 tycker att besök på Universeum är bra investerad tid, då hen märkt att eleverna minns vad de gjort där.
Group composition and observation	T_8 vill observera sina elever mer. "De kanske får jobba tillsammans fler gånger" - T_7 Mycket bekräftade det T_7 anat om eleven tidigare och tycker i efterhand att det var bra att hen valde just den eleven att få delta.

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