ABSTRACT

Today, with technology being an essential part of various spheres of human life, it is important to comprehensively assess the impact of technology on user experience in the field of application. Education is one of the defining areas of social development but is often criticized for outdated methods of knowledge transfer. An interdisciplinary study aimed at evaluating the impact of new augmented reality technology applications on the learning experience, combined with the popular constructivist educational approach, is a relevant issue in today's process of worldwide digitalization. An innovative research method specifically adapted from Design Thinking is used to achieve the main aim of the study - to measure the learning potential of peer learning and augmented reality immersion - in order to fully and comprehensively explore the topic. The data is also analysed by qualitative and quantitative methods. The interdisciplinary research study considered three diverse research questions, which together form a comprehensive understanding of the user experience of learning the brain structure using the 3-D model in the augmented reality application Nevrolens. The results of these research questions provided important insights into key elements of learning with this technology. The first research question reveals the user's perception of their experience of interacting with peers in a virtual environment, and provides qualitative measures of the dynamics in pre- and post-test knowledge testing. The second research question is the measurement of user perceptions of immersiveness in a study session. Since augmented reality technologies do not provide a fully immersive experience, the difference between using the app in the Hololens headset and on mobile devices is significant. The difference in perceived immersiveness during the study session is also a significant determinant for the learning process, students' interest and in AR. The final research question is the psychological factor of assessing one's own competences and how this affects learning in a new educational context. The synthesis of the above mentioned aspects of the learning experience together form an assessment of AR application and immersion technology's educational potential.

Short summary of results/findings

Based on the results of the study through various tests with key user groups, interviews with IT, neuroscience, pedagogy and industry experts, as well as qualitative and quantitative analysis of the findings, the following conclusions were obtained. Peer-learning in AR slightly enhanced the students' performance; overall, they found the experience of augmented reality collaboration while learning the 3D brain model positive and enriching. Despite the more stable functioning of the mobile version of the app, most users reported a more valuable experience in Hololens, due to a better perception of the volumetric structure of the model. This fact, as well as the user's awareness of the space and their own actions when manipulating the model, determined the positive impact of the immersive technology on the learning experience. According to pre and post-test results, the initially most confident users showed slightly higher progress in the knowledge test. The concept "if I believe I can make it, I will make it" was also confirmed by psychological educational theory, as well as noticed in the opinions of various experts throughout the study.

Keywords: Augmented Reality, Learning theories, Collaborative learning, Self-assessment, Self-learning, Immersion, Technologies in learning

ABSTRAKT

I dag, med teknologi som en viktig del av ulike områder av menneskelivet, er det nødvendig å foreta en omfattende vurdering av teknologiens innvirkning på brukeropplevelsen på anvendelsesområdet. Utdanning er et av de definerende områdene for sosial utvikling, men blir ofte kritisert for utdaterte metoder for kunnskapsoverføring. En tverrfaglig studie som tar sikte på å evaluere virkningen av nye applikasjoner for utvidet virkelighetsteknologi på læringsopplevelsen, kombinert med den populære konstruktivistiske pedagogiske tilnærmingen, er et relevant tema i dagens verdensomspennende digitaliseringsprosess. En innovativ forskningsmetode som er spesielt tilpasset fra designtenkning, brukes for å oppnå hovedmålet med studien - å måle læringspotensialet til peer learning og fordypning i utvidet virkelighet - for å utforske temaet fullt og helt. Dataene analyseres også ved hjelp av kvalitative og kvantitative metoder. Den tverrfaglige forskningsstudien vurderte tre ulike forskningsspørsmål, som til sammen danner en omfattende forståelse av brukeropplevelsen av å lære hjernestrukturen ved hjelp av 3D-modellen i den utvidede virkelighetsapplikasjonen Nevrolens. Resultatene av disse forskningsspørsmålene ga viktig innsikt i viktige elementer ved læring med denne teknologien. Det første forskningsspørsmålet avdekker brukernes oppfatning av deres opplevelse av å samhandle med jevnaldrende i et virtuelt miljø, og gir kvalitative mål på dynamikken i kunnskapstesting før og etter testen. Det andre forskningsspørsmålet er måling av brukernes oppfatning av innlevelse i en studieøkt. Siden teknologier for utvidet virkelighet ikke gir en fullstendig oppslukende opplevelse, er forskjellen mellom å bruke appen i Hololens-headsettet og på mobile enheter betydelig. Forskjellen i opplevd innlevelse under studieøkten er også en viktig faktor for læringsprosessen, studentenes interesse og for AR. Det siste forskningsspørsmålet er den psykologiske faktoren ved vurdering av egen kompetanse og hvordan dette påvirker læring i en ny utdanningskontekst. Syntesen av de ovennevnte aspektene ved læringsopplevelsen danner sammen en vurdering av AR-anvendelse og fordypningsteknologiens pedagogiske potensial.

Kort sammendrag av resultater/funn

Basert på resultatene av studien gjennom ulike tester med viktige brukergrupper, intervjuer med IT-, nevrovitenskaps-, pedagogikk- og bransjeeksperter, samt kvalitativ og kvantitativ analyse av funnene, ble følgende konklusjoner oppnådd. Peer-læring i AR forbedret studentenes prestasjoner noe; generelt opplevde de samarbeidet med utvidet virkelighet som positivt og berikende mens de lærte 3D-hjernemodellen. Til tross for den mer stabile funksjonen til mobilversjonen av appen, rapporterte de fleste brukerne om en mer verdifull opplevelse i Hololens, på grunn av en bedre oppfatning av modellens volumetriske struktur. Dette faktum, i tillegg til brukerens bevissthet om rommet og deres egne handlinger når de manipulerer modellen, bestemte den positive effekten av den oppslukende teknologien på læringsopplevelsen. Ifølge resultatene før og etter testen viste de i utgangspunktet mest selvsikre brukerne litt høyere fremgang i kunnskapstesten. Konseptet "hvis jeg tror jeg kan klare det, vil jeg klare det" ble også bekreftet av psykologisk pedagogisk teori, samt lagt merke til i uttalelsene fra ulike eksperter gjennom hele studien.

Nøkkelord: Utvidet virkelighet, Læringsteorier, Samarbeidslæring, Selvvurdering, Selvlæring, Fordypning, Teknologier i læring

ACKNOWLEDGMENT

This thesis is an interdisciplinary research project commissioned by iPeer, the European Association of Institutes for Research on the Educational Experience of Cooperative Learning in Augmented Reality Applications, and the Kavli Institute for Neuroscience. The research is based on an augmented reality application to learn the anatomy of the rat brain systems- Nevrolens - and is a summarizing study of the learning potential of collaborative anatomy learning in augmented reality. The application and research are a continuation of the other master students' work with the application in the NTNU Virtual Reality Lab IMTEL. This paper consists of 7 chapters, beginning with a relevant theoretical background, describing the methodological approach, the progress of the study, and ending with conclusions and a final evaluation.

Moreover, I would like to express my gratitude to the people with whose help and support the writing of this thesis took place. Ekaterina Prasolova-Førland for inspiration, constructive help and support. To John Krogstie for serene confidence, advice, and encouragement. Michael Fominykh for help in all aspects of writing the thesis, life wisdom and inspiration. Menno P. Witter for his interest, help with recruiting, and inspiration. Nathalie Jurisch-Yaksi for encouraging research enthusiasm and help with the evaluation sessions. Monica Divitini for invaluable practical advice and help with evaluating the app's collaborative features. Leif Martin Hokstad for an expert pedagogical perspective on the research topic. Berit Hellan and Pia Jeanette Greger-Nilsen for their optimism and support at all stages of the thesis writing. As well as all participants for their participation, feedback, and contributions to the study.

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ACRONYMS

2D - two-dimensional.

3D - three-dimensional.

AI – Artificial intelligence

AR - Augmented Reality.

CT - computer tomography.

DH – Digital humanities

HMD - head-mounted display.

IMTEL - Innovative Immersive Technologies for Learning.

IoT – Internet of things

iPEAR - inclusive peer-to-peer learning with AR tools.

MR - Mixed Reality.

MRI - magnetic resonance imaging.

NTNU - Norwegian University of Science and Technology.

VR - Virtual Reality.

WDP - Windows Device Portal.

XR - Extended Reality.

CHAPTER 1

INTRODUCTION

Today, the world is transitioning to a new era of technological development - Industry 4.0 - in an adaptive, though rather rapid manner in terms of the historical development of society. The main features of this new phase of technological evolution are ubiquitous digitalisation, automatization, acceleration and sustainability of production processes, business operation and social life in general. The main technologies of the digital era are the Internet of Things (IoT), cloud computing and analytics, Artificial Intelligence (AI) and machine learning, and virtual reality technologies. As society gradually begins to use these technologies in all areas of life, education and training are no exception. The application of revolutionary new technologies is particularly interesting, as it is education that is usually criticized for not keeping up with modern challenges and opportunities (Scott, 2015).

One of the most promising technologies in the context of Education and Training in Industry 4.0 is virtual reality technologies. These technologies are used in many educational fields from realistic virtual tours on the surface of Mars to surgical training on a realistic 3D model. Due to the increasing number of developed applications and new methodological approaches of using VR in education, the amount of research on this topic is also increasing. Nevertheless, despite the increasing number of publications, after a comprehensive review of relevant sources on the topic, it was found that the majority of publications are focused on the evaluation of technological functionality, which is the main challenge faced in application development (Radianti, 2021). However, the success and effectiveness of an application are not only measured by its feature set and operability, the application must also fulfil its direct function of teaching and transferring knowledge to users in the current methodological educational realities.

That is why the interdisciplinary research of this master's thesis aims to evaluate the learning potential of the augmented reality application in a collaborative peer to peer learning methodology and explores the psychological factor of self-evaluation in learning as well as the role of immersion in the learning experience.

This research project has one research goal and three associated research questions that are described in further detail in Section 4.1.

Research Goal: To evaluate the learning potential of peer learning and immersion in AR

The following are the research questions that the project aims to answer in order to reach the research goal.

RQ 1 How peer learning and collaboration in AR affect the studying process?

RQ 2. How the difference in AR immersion (mobile devices/Hololens) change the learning experience?

RQ 3. How self-assessment within the Peer-Learning approach in AR affect the studying outcomes?

The achievement of the research goal and the disclosure of the research questions will contribute to the theoretical basis of educational methodology and extend it with information on the application of new technologies in the context of constructivist educational theory. A practical contribution of the results of this thesis in the technological context can be considered the qualitative evaluation of the user experience, which can be further used in the development of new applications.

The research method chosen to achieve the research objectives is an adaptation of the design thinking model, strategically developed specifically for this project. More about the research method in Part 4.2 the research methods used to analyse and present the findings of the study are qualitative and quantitative data analysis, with the findings supported by relevant theory.

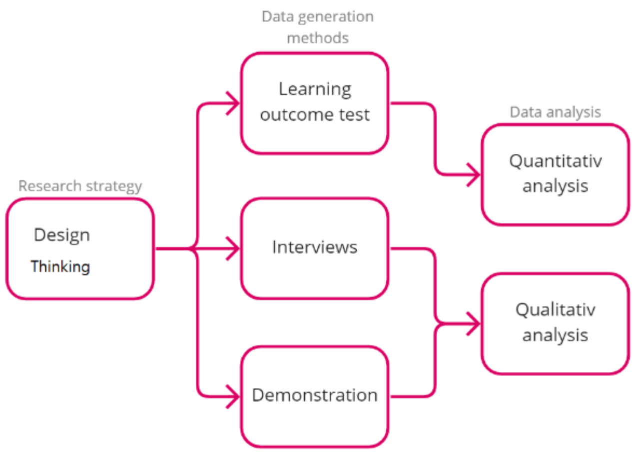


Figure 1 The research strategy, data generation methods, and data analysis used in this research.

1.1 Thesis Outline

This master's thesis consists of seven chapters. The first chapter presents the introduction to the project, the context, the research goal and research questions of the master thesis, and the research method used to answer these questions and achieve this goal. Chapter 2 describes the theory relevant to the project and the process tools used in it. Chapter 3 presents already existing relevant applications on the educational market and describes the state of the Nevrolens application and discusses the contribution of this research project. Chapter 4 describes the research goal and research questions in further detail, as well as the research method and research design. Chapter 5 reveals the stages of research and describes how the design thinking process was conducted in this project. Chapter 6 gives a summary of the evaluation of the learning potential of Nevrolens application which involves evaluating the implementation of peer-to-peer learning approach in AR, immersion and self-efficacy summary chapter then discusses the research goal and questions and presents the recommendations for future research. Lastly, the chapter discusses the limitations of the project. Chapter 7 provides the conclusion, a summary of the project contributions, and suggestions for future work.

Chapter 2 THEORY BACKGROUND

This chapter presents the necessary background material relevant to this research project. The first section is describing Extended Realty (XR) technology particularly the use of AR in education and relevant learning theory, while the second section presents the process tools that are relevant for this project.

2.1 Extended reality technologies in learning

Extended Reality (XR) is an umbrella term that refers to a group of emerging technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) that involve the use of 3D models/simulations across physical, virtual, and immersive platforms. Key features of such technologies are the connection of computer technology (such as informational and graphical overlays) to the physical world for the purposes of augmenting or extending experiences beyond the real. Considering the relevance of XR technologies for educational purposes it is worth pointing out the fact that XR encompasses a wide range of options for delivering learning experiences, from minimal technology and episodic experiences to deep immersion and persistent platforms. The definitions of different technologies vary and show the richness and not yet fully explored potential of the XR world. The key definitions of the XR technologies are:
MR - Mixed Reality - is a combination of physical and digital worlds, opening up natural and intuitive 3D interactions between humans, computers and the environment. It is a new reality built on advances in computer vision, graphic processing, display technology, input systems and cloud computing. The concept of mixed reality was introduced in 1994 in a paper by Paul Milgram and Fumio Kishino «The Taxonomy of Visual Mixed Reality Displays». The researchers viewed MR as a concept of a continuum of virtuality and a taxonomy of visual displays. At the moment, the applicability and possibilities of mixed reality have gone beyond displays and include:

- Environmental understanding: spatial mapping and anchors.
- Human understanding: body-tracking, eye-tracking, and speech input.
- Spatial sound.
- Locations and positioning in both physical and virtual spaces.
- Collaboration on 3D assets in mixed reality spaces.

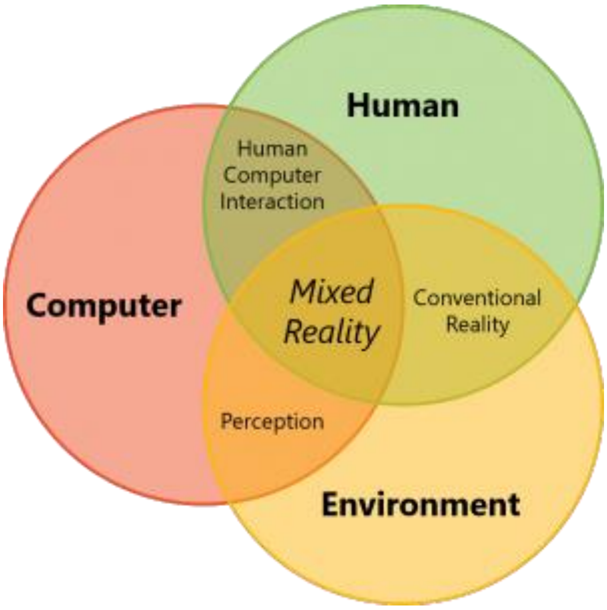


Figure 2 Mixed reality (developer.microsoft.com)

AR— Augmented reality is an enhanced, interactive version of a real-world environment achieved through digital visual elements, sounds, and other sensory stimuli via holographic technology. AR incorporates three features: a combination of digital and physical worlds, interactions made in real time, and accurate 3D identification of virtual and real objects.

Augmented reality offers a better way to design, curate, and deliver useful instructions by overlaying digital content in real-world work environments. In the educational settings, adding augmented reality to studying processes both for guided and self-learning can help enhance the better understanding and comprehension benefits for teachers and students. AR training is an educational experience presented through the software on AR devices to help students gain professional skills without leaving the classroom or during online classes. This type of training experience can be launched at any time, any place with the right software.

AR can also help guide and support educational or training processes regardless of participants' location and helps to achieve better collaboration and safer working conditions during experiments or workshops. By enhancing traditional learning methods, using the opportunity of AR technology can offer more information for better comprehension. There is some ways AR could be used in learning:

- Performance support;
- Learning and training modules
- Tools for conducting experiments in digital format
- On-demand training opportunities
- Exploration of places and objects

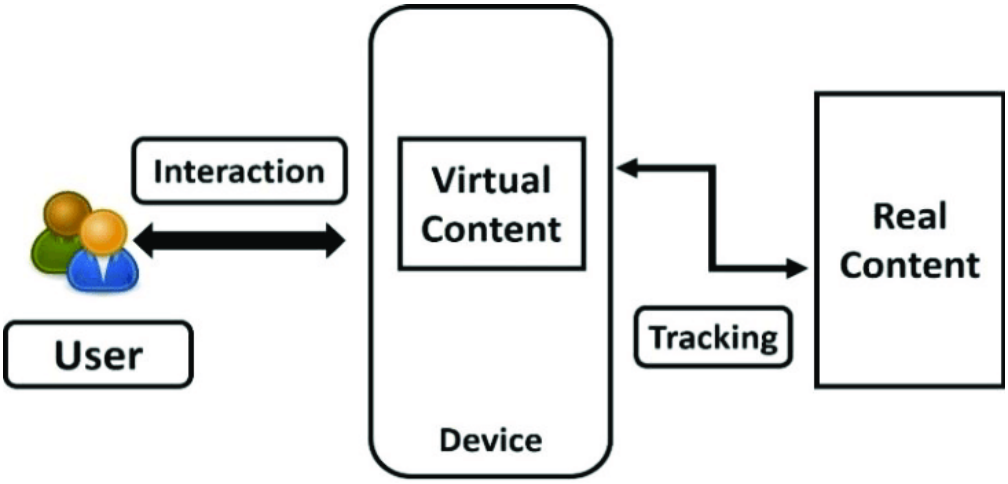


Figure 3 Augmented reality (Liang)

VR— Virtual Reality is a computer-generated environment with scenes and objects that appear to be real for human perception, creating the feeling of full immersion in the surroundings. This environment is perceived through special VR devices and headsets. VR allows us to immerse users in different environments, perform various activities and explore virtual labs or short virtual field trips.

VR technology opens a whole new experience of learning and knowledge acquisition. Early data of research is pointing to the fact that the brain believes that XR activities happen in the physical world and that's why the internal biochemical changes of learning are the same as the real experience (Bailenson, 2018).

Examples of using VR in learning:

- Immersive workshops and safe field trips
- The opportunity to use expensive and rare equipment in a safe, controlled environment.
- Embodiment enhance the experience and perception of learning;
- Collaborative and guided work or opportunity to work individually.

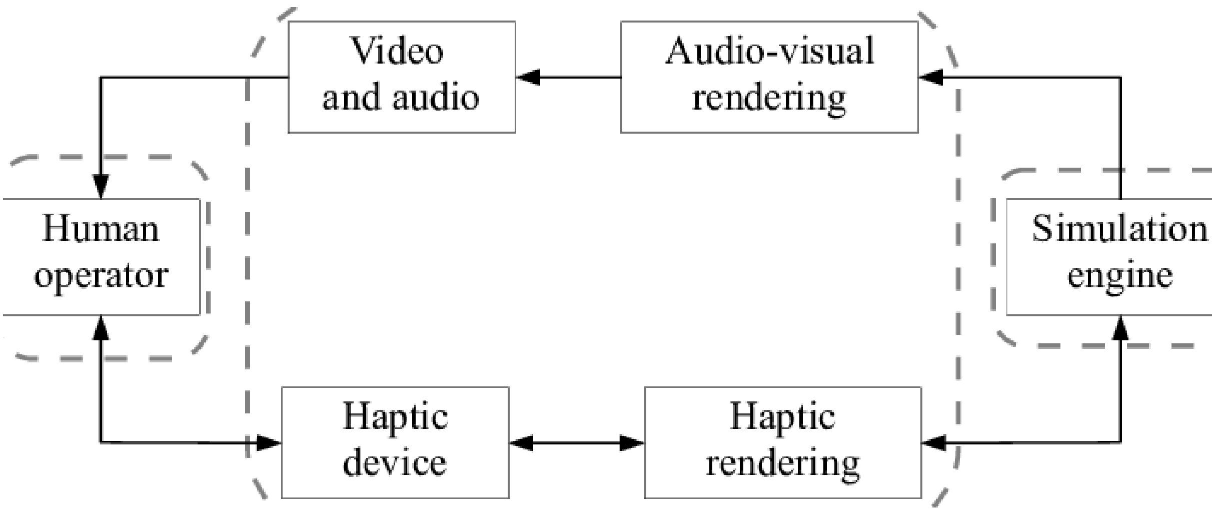


Figure 4 VR architecture (D'Andrea)

2.2 The immersiveness of virtual environments

Visualisation of information is a powerful tool for the transmission of vast amounts of data addressed to a particular user, a unique assistant in the perception and analysis of all kinds of information. The role of visualization increases particularly in the process of continuous improvement and wide dissemination of information technology (Avramenko, 2019). Through visualization tools perception, comprehension and understanding of information is facilitated, as well as its sustainable assimilation, which is the most important educational challenge.

An increasing number of educational institutions in the world are using immersive technologies. Immersiveness is usually interpreted as a coherent combination of human sensations present in an artificially created three-dimensional world in which all kinds of manipulations can be performed: changing the viewpoint, bringing objects closer and further away, reducing and increasing their size, rotating them in space, etc. The immersive approach involves the immersion of the learner in a virtual environment in order to gain substantive, social and communicative knowledge (Azevich, 2019). Immersive learning technologies are a set of software and hardware tools that promote the immersion of a learner in an artificially created environment - virtual reality.

Immersive technologies are one of the tools for the visualization of information. The diverse experience of using visualization tools goes back hundreds of years. Examples range from the analysis of functional relationships with associated graphs and surfaces to complex interactive animations that simulate physical fields and global processes in the universe. The fields of data visualisation are diverse: geology and medicine, physics and biology, geography and chemistry, etc. The main task of visualisation is to make the invisible visible. Invisible is understood as not only the usual real objects, but also abstract objects inaccessible to human eyesight.

By analyzing the means of data visualization, they can be divided, for example, according to the geometric principle: planar and volumetric. In addition, the classification should take into account the physical representation of visualization, reflecting its static and dynamic characteristics (Aranova, 2018). For example, a diagram or chart - static forms of visualization, animation and video - dynamic. Spatial forms of visualization include 3D visualization, which is widely used in computer simulation. The need for computer modelling scenes of real and imaginary worlds occurs in many areas of human activity. Designing new products, construction, design, cinema and television, simulators for professional training, computer games are examples of areas in which modelling plays an important role.

2.3 Learning theory

Learning theory outlines how knowledge is acquired, processed and retained by students in the process of learning. Cognitive, emotional and environmental factors as well as prior experience play a role in how understanding or mindsets are acquired or changed and how knowledge and skills are retained. Learning theories are evolving with society and an improved understanding of neurological, physical and behavioural patterns of knowledge acquisition and approaches to learning. At the moment, 7 main learning theories are identified, which are divided into 31 independent approaches to learning and knowledge acquisition.

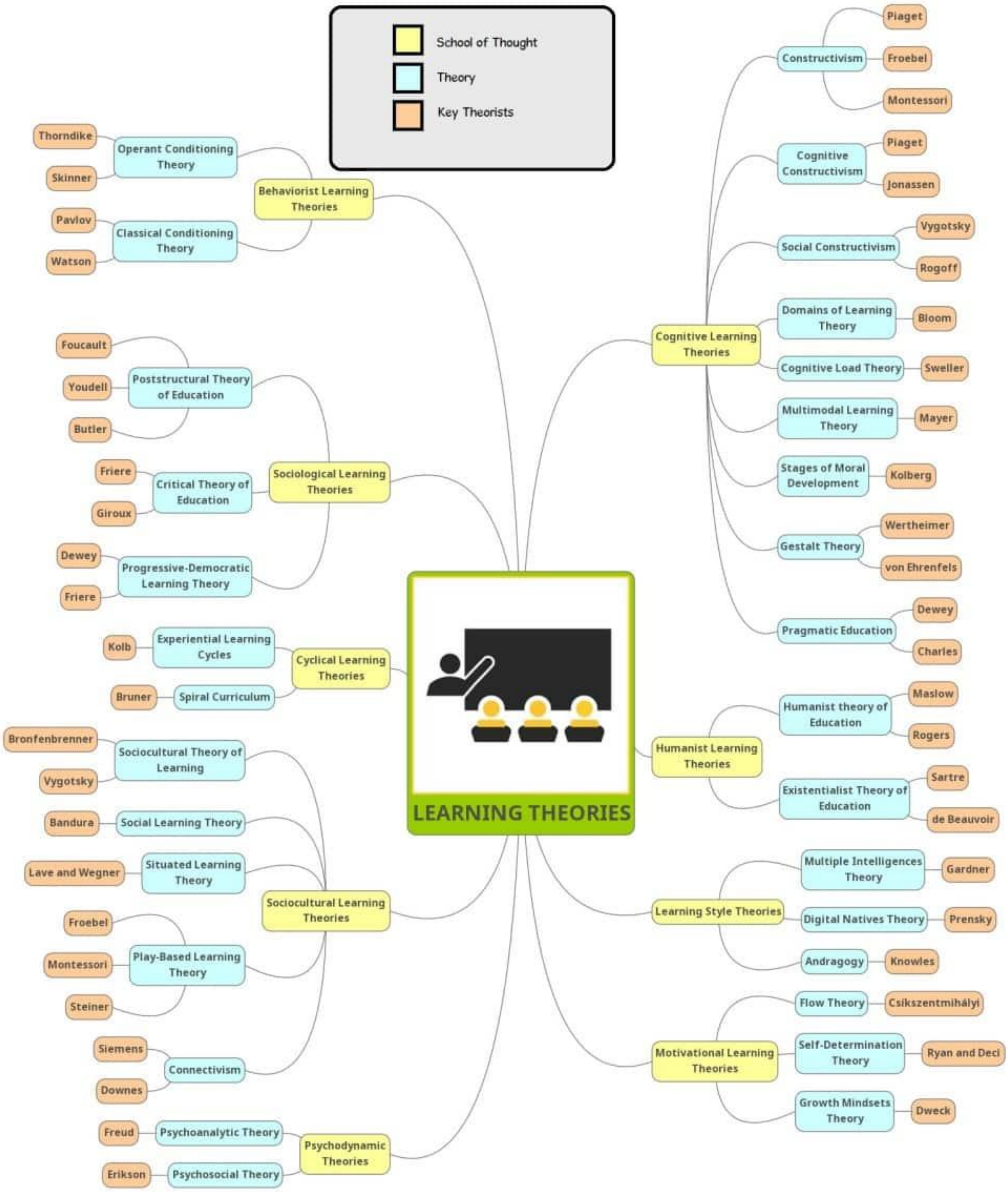


Figure 5 Learning theories (Drew)

2.3.1 Behavioural Theories

Behavioural theorists and practitioners focus on observable and measurable aspects of human behaviour. In this approach to learning, behaviourist theories highlight alterations in behaviour that occur as a result of the stimulus-response interaction associations created in the learning environment. John B. Watson (1878-1958) and B. F. Skinner (1904-1990) were the primary founders of the behaviourist learning theory. Watson suggested that human behaviour is determined by exposure to certain stimuli, which cause certain stimulus-related reactions.

Watson's basic scientific theory is based on the claim that conclusions about human learning must be grounded in the observation of salient behaviour rather than on assumptions about subconscious motivations or hidden cognitive processes (Shaffer, 2000). Watson's view of behavioural learning theory was based on the research of Ivan Pavlov (1849-1936). Pavlov is well known for his pioneering research into the learning process called classical conditioning. Classical conditioning refers to learning that occurs when a neutral stimulus becomes a specific association that leads to a particular behaviour. Behaviourist theory does not explain abnormal behaviour through studies of cognitive brain functioning or subconscious processes (Parkay, 2000).

In education, advocates of behaviourism effectively apply this system of rewards and punishments in the classroom, encouraging desirable behaviours and punishing inadequate ones. The rewards may be different, but they must be important to the student in a particular way (Shaffer, 2000). In this case, successful learning depends on the stimulus and reactions of each learner, as well as the associations that emerge individually and almost beyond the control.

The use of behavioural theory in the classroom can be useful for both pupils and teachers. Behavioural changes occur as pupils work for what brings them positive emotions and for approval from people who are important to them. Learners adapt their behaviour to suit the goals, the value of which is developed in the process.

The theoretically supported scientific basis for this behaviour modification is that most behavioural patterns are learned. If a behaviour can be learned, it can also be unlearned or re-learned. Behaviour that is not rewarded will fade away. The proponents of this learning theory believe that habits acquired through learning will not only help to achieve an increase in the quality of skills and knowledge acquired, but also help in the holistic development of the individual.

2.3.2 Social and Cultural Theories

The socio-cultural theory of learning and teaching is widely recognised in the field of educational psychology and learning methods. The main element of this theory is the study of the central role of social interaction and culture in the development of thinking and learning skills. Lev Vygotsky (1978), a Soviet psychologist, scientist, researcher of various social phenomena and founder of the socio-cultural theory, believed that human development and learning occur and are determined by socio-cultural interaction. Therefore, the ways in which people interact with others, the patterns of social behaviour and the culture in which people exist, shape their mental abilities.

There are three fundamental concepts that define socio-cultural theory: (1) social interaction plays an important role in learning, (2) language is an important tool in the learning process, and (3) learning takes place in the zone of optimal development.

Social interaction plays an important role in learning. Vygotsky believed that thinking has a social origin and that an individual's cognitive development cannot be understood without taking into account the social context in which it is embedded. He suggested that social interaction determines the main directions and features of cognitive development, especially in the development of higher-order thinking skills (Driscoll, 2011). The teacher and main founder of knowledge is society and communication, not only with an authoritative source of knowledge, but also with peers and other cultural agents, in an environment where knowledge and worldviews are formed.

The second revolutionary discovery about human cognitive and learning abilities made by Vygotsky is related to the role of language in the learning process. Vygotsky believed that social constructs determine how people learn and interact in society, which in turn shapes their cognition, beliefs, mental attitudes and perceptions of reality (Miller, 2011). Vygotsky strengthened his view by presenting human actions on both social and individual levels as determined by contingent tools and signs, or semiotics, such as language, counting systems, works of art, behavioural patterns and so on. Vygotsky suggested that through the use of such socio-cultural tools, the co-construction of knowledge occurs natively and social and individual functioning comes naturally. Such semiotic tools are an important element in the development and learning through appropriation - the process of an individual's adoption or individual adaptation of socially available psychological tools with which independent problem-solving is possible in the future (John-Steiner, 1996).

Vygotsky considered language as a semiotic synthesis of symbols and signs emerging in culture. It is potentially the greatest tool at our disposal, a form of symbolic mediation that plays two crucial roles in development: communicating with others and constructing meaning (McLeod, 2016).

The next significant step in scientist's understanding of cognitive ability is the understanding that learning takes place in the zone of proximal development. Probably the most widely accepted concept associated with socio-cultural theory is that of the zone of proximal development ('ZPD'). It is "the distance between the actual level of development determined by independent problem solving and the level of potential development determined by guided by adults or cooperation with more capable peers problem-solving" (Vygotsky, 1978) p. 86). Thus, this zone is the immediate environment in which learning takes place. Vygotsky strongly believed that learning should correspond to the level of a brain's development and suggested that in order to understand the relationship between development and learning it was necessary to distinguish between actual and potential levels of development. He suggested that the ZPD was a better and more dynamic measure of cognitive development than simply measuring what pupils could achieve on their own (Scott S. &., 2017).

Attentive teaching and guidance in the context of ZPD allow the learner to develop skills and adapt strategies that they will later apply independently in similar tasks, which is characteristic of higher cognitive skill development (Vygotsky, 1978). The role of the student's social partner is also very important because the type of social interaction and the tools and skills they use determine the outcome of collaborative activities, which can lead to both normal and accelerated development, as well as developmental delays and abnormal development (Kozulin, 1990). Thus, the ideal partner, whether adult or peer, must be advanced enough in knowledge or skills to facilitate learning, and at the same time be able to interact in an area that is not too far beyond the reach of the learner's abilities. Moreover, partners in a successful cooperative activity share a certain degree of common understanding of the task, a shared goal and responsibility for the result, which is described as intersubjectivity. It is not enough for partners to work together, they have to co-construct a solution to a problem with a coordinated effort, which implies a sharing of power and authority over the process (Driscoll, 2011).

In the 1970s Bruner, Wood and Ross added the concept of scaffolding to socio-cultural theory (Puntambekar, 2018). Scaffolding is a support mechanism that helps the learner to successfully complete a task within the ZPD and is a practical tool for implementing actions. Scaffolding describes the ongoing support provided to the learner by a more experienced partner in the process of learning and sharing the task. This process involves a reciprocal and dynamic interaction where both the learner and the assessor influence each other and adjust their behaviour in the collaborative process (Miller, 2011). Just as physical scaffolding provides regulated and temporary support for buildings under construction, scaffolding in a sociocultural learning context means that a more experienced participant provides the necessary support to the learner as they develop their skills. This support depends on the needs of the learner and is gradually phased out as the learner acquires skills, facilitating a move towards autonomy (Miller, 2011). Also, this type of support assumes that the assessor, who is knowledgeable in both content and pedagogy, can adapt the task to the learner's abilities. The assessor motivates and guides the learner by providing sufficient assistance, modelling and highlighting critical features of the task, and continually assessing and adjusting support as needed. In addition, the assessor facilitates reflection through suggestions and questions, which contributes to a more complex, meaningful and sustained learning experience (Puntambekar, 2018).

Hence, the socio-cultural theory suggests a different dynamic in the relationship between student and teacher than the more familiar and established one in school and university environments. The learner assumes more responsibility, such as defining his or her own learning goals, becoming a source of knowledge for peers and collaborating with them in the learning process. The teacher is seen as a steward, facilitator, and guider of learning, rather than a transmitter of knowledge or enforcer of rules (Grabinger, 2017). This change in roles promotes individualised, differentiated and learner-centred types of learning, which, combined with effective pedagogical practices, represents a powerful alternative for reforming existing educational systems and creating an environment that can 'enable most people to develop a deep understanding of important subjects' (Watson, 2018).

2.3.3 Peer learning

Peer education refers to learning experiences in which peers work together and support each other in the learning process. There are various forms of peer education, such as peer support groups, peer supplemental instruction, peer tutoring, peer teaching, and peer learning. Peer learning emphasizes the experience and participation of all active students. Peer support is the acquisition of knowledge and skills through active help and support among peers who are equal in proficiency to the learning task or comparable in level to their peers. Peer learning takes place among peers from similar social groups who are not professional teachers, who help each other learn, and who also learn on their own (Topping, 1998)

An additional factor in peer learning is peer evaluation. This process is carried out by students to assess each other's work on relevant tasks in a peer group. Students participate in learning and assessment by grading individual group members. Peer assessment refers to situations where peers are comprehensively and qualitatively evaluating the projects created or the learning outcomes of other team or group members. Peer learning and assessment are linked to pedagogical approaches that promote group learning and opportunities for reflective assessment, cooperative learning, collaborative learning, active learning, constructivist learning, reflective learning, and experiential learning.

"Peer-assisted learning is an educational practice in which students interact with other students to achieve educational goals" (O'Donnell, 2000). Constructivist approaches to learning emphasize the importance of scientific discoveries in social learning theory and view knowledge acquisition as a social activity, so peer-to-peer learning has become an important means of implementing constructivist educational approaches as well as a means to enhance teaching and learning processes (e.g., (O'Donnell, 2000)

Piaget's theory of cognitive development describes that cognitive abilities in individuals develop according to the ability and refinement to construct internal schemas for comprehending the world (Thurston, 2017). According to cognitive constructivist theory, individuals create their own worldviews through their own mental models to give meaning and emotional colors to their experiences. However, an individual's picture of the world is formed inseparably from the society in which the individual lives. Thus, Vygotsky's social constructivist theory emphasizes the importance of social context in cognitive development. Hence, Vygotsky's theory and Piaget's theory require peer interaction and emphasize the important role of peer learning in cognitive development (Thurston, 2017). Interaction in Vygotsky's peer learning contexts is collaborative with shared questions and ideas among peers who work together to achieve shared understanding and better outcomes (Thurston, 2017). In cognitive constructivist theory, peer-assisted learning and peer mentoring techniques promote adaptive cognitive patterns that are more easily created between peers than between student and teacher (Thurston, 2017). Peer learning is a collaborative application of constructivist and sociocultural learning theory, which emphasize that learning is a social process during which students share, compare, and restate ideas to create new understandings and individual solutions to the task at hand. Because peer-assisted learning allows students to share their personal perspectives as well as compare and evaluate them to the views of others, students can form their own understanding through peer interaction and observation (Thurston, 2017). Collaborative learning is a valuable educational activity because peer education contributes to the core mission of educational institutions to prepare students for life in the workplace (O'Donnell, 2000). Peer education is considered to be a way to improve learning outcomes and to provide the formative experiences necessary to transition to a fulfilling life in today's increasingly technological and interdisciplinary work community.

Multiple studies of peer learning in relation to academic achievement confirm the significant positive effects achieved through a variety of peer education techniques, including cooperative learning, collaborative learning, and peer mentoring. Although these different methods show benefits in academic achievement, the mechanisms by which these practices achieve high learning outcomes are different. (Topping, 1998)

One of the peer education methods most often cited in the literature is peer-to-peer learning (peer tutoring). Peer-to-peer tutoring is one method of collaborative learning that involves evaluating the level of peer involvement in a formalized learning process, to increase students' sense of responsibility, control and collaboration with peers, and to improve academic performance. Peer-to-peer learning often refers to groups of students of the same age with comparable skills and abilities, and challenges them to learn together, with the primary goal of engaging all members of the learning group in constructive academic activities (Topping, 1998). An important element of successful learning is instruction on how to study course content, perform practice tests, assess each other's work, and give feedback as students progress on course assignments. Peer-to-peer learning is designed to activate the most effective learning strategies based on prior research on peer learning in the required domain, peer assessment, academic achievement motivation, and group reward strategies in the learning environment (Topping, 1998).

Currently, there are various commonly used methods of peer education, and the following are the most frequently used:

- Peer tutoring is characterized by a specific distribution of roles: in group work there is a dynamic division of responsibilities: any participant can take the role of a tutor at any time, while another (or others) acts as the learner(s).
- Peer modelling is the presentation of an appropriate example of desirable learning behaviour by a group member with the intention that other group participants will follow it.
- peer assistance learning can be described as providing peers with valid and reliable information about important life questions and the opportunity to discuss them informally in a peer group setting.

Peer counselling occurs when people from comparable groups, who are not professional teachers or qualified professionals, help to clarify common issues and find solutions by listening, reflecting, summarizing, and being positive and supportive.

- Peer supervision is the process of peer observation of whether their partners are going through appropriate and effective learning activities and procedures.
- Peer assessment is a comprehensive and qualitative peer evaluation of the results or learning outcomes of other group members.

Several studies (e.g., (Cassidy, 2016); (Parr, 2020); (Walker, 2020) suggest that Peer Learning emphasizes the value of peer collaboration as a tool for developing competence and lifelong learning skills. In addition, as collaborative and cooperative learning activities, peer-assisted learning leads to (a) stronger team spirit and more supportive relationships; (b) better psychological well-being, social competence, communicative skills, and self-esteem; as well as (c) higher academic achievement and greater productivity in terms of improved learning outcomes (Topping, 1998), (Walker, 2020). Also, various research shows that peer group collaborative activities in learning environments affect academic achievement, affective development, and social outcomes, but there is less certainty about how the dynamics and processes associated with these are related to learning (Parr, 2020).

Researchers have emphasized the benefits of active peer interaction in learning, in which knowledge is socially constructed by peers, as opposed to learning that traditionally occurs in a social context. Parr and Townsend (Parr, 2020) argue that peer learning assumes high levels of reciprocity, attention to partners, and mutual responsibility as peers interact in search of new, shared understanding. scholars maintain that the reasons for peer learning effectiveness are varied and can be found in several academic fields. For example, socio-cognitive theory holds that cognitive conflict leads to cognitive remodelling; on the other hand, the sociocultural approach argues that peer feedback and observational learning lead to the acquisition of positive attitudes toward the subject matter and knowledge construction (Parr, 2020). Moreover, numerous researchers have concluded that certain peer learning outcomes affect achievement directly, while others are more likely to have indirect effects on cognition and skill acquisition through immediate performance.

Peer assessment is the next important element of peer education and refers to the creation of opinions about peer performance to encourage responsibility and achievement in learning. Peer evaluation is distinguished from peer supervision in focusing on learning outcomes or educational results rather than exploring peer learning experiences and procedures (Topping, 1998).

As a result of reviewing numerous studies on peer assessment, (Walker, 2020) suggests that this assessment procedure may have the following benefits:

1) Peer assessment is an alternative method of evaluating group work because students are often more aware of the contributions made by their teammates;
2) Peer-assisted evaluation enhances student responsibility and independence while developing personal and social skills;
3) prior knowledge of the estimation procedure can lead to more accurate and higher quality work due to specific examples of the evaluated one;
4) Often the knowledge that a student will be evaluated by peers will encourage them to work more diligently;
5) Peer assessment can be used as a mean of minimizing the time teachers spend on grading and can provide feedback in greater quantity and more effective ways.

In addition, numerous studies (Cassidy, 2016), (Driscoll, 2011) assert that peer assessment is one example of an educational practice that can positively contribute to individual skills necessary for future employment of social communication skills, adaptability and self-learning strategies, problem solving, decision making, affective skills, interpersonal skills (collaboration, teamwork), self-discipline, self-management and the ability to work independently.

Research on educational constructivist practices also emphasizes the important role of feedback in learning, which is essential for the development and implementation of self-regulation skills and the ability to reflect. Feedback through collaborative work and peer assessment engages students in a cognitively challenging task that requires an understanding of the objectives of the assignment, criteria for success, and the ability to make judgments about the final outcome (Topping, 1998). Although peer feedback may be of poorer quality than the one provided by the teacher, the effectiveness of the feedback depends on both the giver and the receiver, and peer feedback can be effective in improving future performance (Topping, 1998). Topping and Ehly (Topping, 1998) suggest that peer assessment design should encompass goals, standards, group composition and selection, instructions, learning activities, monitoring, moderation, following up actions and evaluation.

Through peer-assisted learning and assessment, students play an active role in the processes of studying and evaluating, rather than remaining passive and uninvolved in the content of the courses. According to the social constructivist approach, people create meaning through interaction with one another, and shared understanding between people is socially constructed through communication, interaction, and negotiation between team members. In this way, collaborative learning and assessment allow students to be fully engaged in a diverse, active, social, and reflective learning process.

2.3.3.1 Important research and open-ended questions of peer learning

The concept of peer learning is important for five reasons: academic, economic, political, social, and affective (Topping, 1998). The importance of peer learning is summarized here as follows:

Peer learning raises standards in literacy, accuracy, and professionally relevant transferable skills. In addition, considering the benefits of peer education in an information technology environment, peers support each other in transferring IT skills, tailoring knowledge to individual experiences, and fostering cognitive skills, attitudes, and self-awareness.

Peer learning is important because it is both academically effective and economically beneficial, as confirmed by reviews of studies and meta-analyses of evaluation research.

Looking at the social benefits, peer learning is a measure of reducing social isolation by overcoming barriers of separation by age, gender, ethnic background, and socioeconomic reasons. From a political perspective, peer education delegates and allocates the responsibility for learning to students in a democratic way. Considering affective benefits, peer-to-peer learning helps to increase motivation and confidence. Peer learning also helps develop a sense of honor and accountability among peers.

Studies (e.g., (Cassidy, 2016); (Topping, 1998), (Walker, 2020) highlight the benefits of peer evaluation, which include

(1) sustained peer-to-peer interaction for productive work, quality feedback based on extensive work observations;

(2) Acquisition of independent learning skills, critical thinking skills, and communication skills;

(3) improvement of metacognitive skills;

(4) improvement of subject understanding and more comprehensive learning;

(5) increasing the responsibility and self-sufficiency of students;

(6) An understanding of rating procedures and the requirements of high-quality work.

Although there is considerable support in the literature from educational theorists and practitioners for peer assessment techniques, difficulties and limitations have repeatedly been reported, including (1) inadequate and unfair grading; (2) bias in peer assessment due to interpersonal relationships between students; (3) feelings of discomfort and lack of expertise to make judgments; (4) the task is too difficult and time-consuming; and (5) peer grading based on hostility (Cassidy, 2016), (Walker, 2020). Overall, further research and improvement in practices for peer assessment of student learning are needed to reinforce understanding of the accuracy of peer assessment (Topping, 1998).

In Cassidy's (Cassidy, 2016) study of the perception of undergraduate students toward peer assessment, students expressed positive attitudes toward peer assessment, but had concerns about their ability to assess peers and the responsibility associated with grading. In addition, the researcher points out that the introduction and successful implementation of peer assessment practices in higher education is known to be challenging, especially with regard to the reliability and relevance of assessments, potential bias, and resistance on the part of students. Topping and Ehly (Topping, 1998) argue that professional teachers should be well aware that conducting peer assessment requires careful planning and careful guidance because the purpose of peer assessment and its criteria are key elements in determining its validity and trustworthiness and because when students find themselves in a peer assessment role, social processes can affect the credibility and reliability of assessments.

Respectively, peer learning and assessment are attracting increasing attention in both higher education institutions and schools. Peer learning and assessment are seen as tools for "learning to know," which demands a fundamental transformation in students' assumptions, attitudes, and practices, as students become active participants in the learning process, trying on different roles in the process and adaptively acquiring knowledge. Experiencing peer learning and assessment helps students become aware of how they learn best and how to make the learning process as effective as possible. Peer learning and assessment develop students' metacognitive skills, including reflection and a deep, diverse understanding of course content, allowing students to share their understanding of what "knowledge" means in their discipline and what "learning" implies. The objectives of designing and developing peer learning and assessment activities in a learning environment are to help students develop a feeling of ownership of their learning and develop their confidence, to encourage students to reflect on their educational experiences, to improve their learning and performance, and to allow students to develop an understanding of the process of studying and acquiring skills and collaborative learning partnerships. Therefore, peer learning and assessment are considered to promote the development of lifelong learning skills.

2.3.4 Self-assessment and academic performance

Self-evaluation is interpreted as a personal formation, which directly participates in the regulation of human behaviour and operations, as an autonomous characteristic of a person, its central component, which is formed with the active participation of the person himself and reflects the peculiarity of personal inner world (Andrade H., 2019). The criteria of learning success are academic (learning) achievement, reflecting the level of academic achievements, as well as interest, motivation, quality and methods of brain work. Due to individual psychological differences in the structure of learning and cognitive activity, some students achieve high results in learning rather quickly and easily, others - relatively slow, and some cannot approach them at all. In this case, reference is made to properties of a person's mental development such as learning ability or educability, which refers to the internal availability acquired under the influence of education, training and guidance to various psychological restructuring and transformations in accordance with new programmes of further training and education.

According to existing classifications, self-efficacy can be correct (adequate) when a person's opinion of him- or herself coincides with what he or she really is. A person properly matches his or her capabilities and skills, takes a sufficiently critical view of him or herself, strives to be realistic and take a realistic view of her or his tends to look at his or her failures and successes, and tries to set himself or herself achievable goals that can be realised in practice (Brew, 2013). In cases where self-image contrasts sharply with a neutral self-assessment, self-esteem is most often wrong (inadequate) and may be either inflated or underestimated.
The main functions of self-assessment in the learning process include:

- statements are based on self-monitoring (what do I know well and what do I know insufficiently about the material I have learned?)
- motivational assessment (I have managed to do a lot in my work, but I haven't got it all figured out);
- projective (in order not to have difficulties in further work, I have to repeat it) (Drew).

Consequently, the main role of self-assessment in the learning process is students' self-monitoring and self-regulation. Students are not only expected to see their strengths and weaknesses but also to reflect on their own learning results and to be able to plan their own learning activities (Coopersmith, 1967).

The role of self-assessment is also high in the formation of motivation learning. By motivating students to assess their own strengths and level of knowledge, it helps them to understand their own needs and learning goals (Race, 2021). The level of students' motivation is increased, as they become participants in determining the criteria of their own knowledge. Assessment skills develop in self-evaluation.

2.4 Thesis writing process tools and research method

Writing a Master's thesis is a continuous and versatile process where a variety of digital tools are essential for a full-fledged, comprehensive study. However, the tools of the process are not only the instruments used, but also the actions and activities are undertaken to explore the research questions and achieve the research objectives. This section of the paper reveals the main tools used in research preparation and thesis writing, for a better understanding of the research process as well as a possible inspiration for future researchers.

Miro

As a tool for remote teamwork, communication, brainstorming and task sharing, Miro is a convenient application. The ease and intuitiveness of use and the ability to integrate materials with common virtual working tools such as Google Drive, Slack, Asana, Trello, make Miro an attractive solution for brainstorming and working on research tasks, identifying problems and possible solutions. Some examples of using Miro during the research:

- Creating a list of ideas/topics to focus on different stages of the project;
- Developing a user story or scenarios journey map/ideas;
- Wireframing a new concept or idea;
- Laying out a roadmap or strategy for a new chapter and connections between.

Adobe premier

Conducting a meaningful study is impossible without empirical data. In addition to having an attractive app, a laboratory with the necessary virtual reality equipment, people whose experience with the app will provide the necessary data and important feedback for evaluating the learning potential of the app are important. To create an attractive and interesting invitation to an experimental session, it was necessary for me to create a promotional video for the test sessions and the Nevrolens application. This is where the Adobe Premier video editor was very useful. Using this tool, I was able to create a short, engaging video for the participants of the experiments.

Functions used:

- Creating videos in different formats and selecting the quality
- export stock footage and images
- ability to add text and original audio tracks
- video scaling and adjustment
- export to YouTube

Tableau

After obtaining the important data from experiments, it is necessary to properly present and visualize it for further correct analysis and final outputs. There are now a wide variety of tools for visualizing data and structuring information in a practical way. One of the modern tools for the analysis and visualisation of the process is Tableau. Use Tableau is easy, and the functionality of the application varies from mathematical analysis to complex visualization tools.

Tableau functions used when working on a thesis:

- Data Blending
- Real time analysis
- Collaboration of data
- Connectivity with different database
- Live connection and extract connection

Docear

Alongside brainstorming, developing a strategy and a plan for the paper itself, it is also important to organise the list of sources and literature used for the research. In full scientific research, backing up practical findings with theory is necessary to formulate the right conclusions, as well as to ensure the relevance of the research. In addition to the sources recommended during the study process and the search for relevant papers on Google scholar and university digital libraries, it is important to organise and link the sources used in a logical way. The Docear tool can be helpful in this, which allows to organize literature, focusing on used annotations instead of documents, as well as good tool of research paper recommender systems that recommends papers that are entirely free, instantly to download, and tailored to the needed information.

Nettskjema

For gathering information from participants, the web solution Nettskjema is used. Nettskjema is a data collection tool used for research and claims to be the safest and most used solution in Norway [80]. It is also the solution that is required by NTNU for data collection in research projects [81]. Nettskjema is used to collect data from the user-involved activities, like the user survey and tests and the demonstration with personnel from the Kavli Institute. It is also used to hold the pre- and post-tests in connection to the learning outcome test and recruiting and inviting people to the different activities performed in this research project.

Devices

During the writing of the thesis, the following equipment was mainly used:

HoloLens 2

The HoloLens 2 is the second generation of the MR headsets developed by Microsoft in 2019. Compared to the first generation it provides a more immersive and comfortable experience and more options for collaborating in MR (Cooley, 2023). The headsets run on the Windows Holographic OS which is a custom holographic version of Windows 10 that provides users with a secure, robust, and performant platform. The headset offers tracking of the head, eyes, and hands (Cooley, 2023). It also has built-in speakers and a microphone that can be used to execute voice commands to control the device. An important feature of the headset is the ability to display the study session on the screen, via connection to a PC, which was very useful during the experiments, as it gave the opportunity to observe the participants' actions through “their own eyes”. The IMTEL laboratory has two HoloLens 2 headsets that were used during this research project.

Android

Android is a mobile operating system developed by Google that can be run on several different devices, including smartphones. Android has a large share of the mobile OS market, so an application developed for Android devices can reach many mobile users. During the research all work and experiments were conducted on the several Samsung Galaxy S8+ as well as Samsung Tab A.

IOS

IOS is a mobile operating system for a variety of devices. It is also a widely used OS and has its own platforms for creating and experiencing augmented reality. Publishing apps on the Apple Play is a long and complicated procedure, which is why Nevrolens was only adapted for iOS in autumn 2022. At the time of the study, users were downloading and using the app on their iOS devices.

2.5 Design thinking

Scientific research is primarily a creative process that requires an original and innovative solution, which at the same time meets methodological and research formats. Design thinking is the process of understanding the purpose of the research, the user needs in the project, identifying the main problems and finding the creative, most appropriate solution and conclusion for the scientific community and the target audience (Auernhammer, 2021). Research work in the field of evaluating the user experience (UX) of the existing application within the framework of certain scientific questions is a creative and multifaceted process for which it is important to consider the following components of the research design:

- Research Ideas: the correct definition of goals, objectives and research questions determine the basic direction and additional components of the research;
- User-Centred Design: in order to achieve the goals of the study, it is important to formulate and create a strategy for working to extract important data from interaction with users.

- Ambiguity and vague ideas are an essential part of the study, as there are initially too many different directions that need to be filtered out to select a particular course of enquiry;

- Tests. For research where understanding people's interactions with the technology and their feedback is important, several tests need to be conducted with different user groups and with different relevant data for a complete study. Most of the time and effort is spent on preparing for these tests and generating requests for relevant information.

2.5.1 Double Diamond

During the development of the research strategy for this study, the popular UX research design model Double Diamond was selected and redesigned. The Design Council introduced the Double Diamond model in 2004. It presents a framework that allows users to apply design characteristics to find creative solutions and innovative ideas. The model consists of four steps: Discover, Define, Develop and Deliver. Many companies adopted the Double Diamond design process, such as Apple, Microsoft, Starbucks and others (Elamany, 2021). For the purpose of this research the Double Diamond was specifically adopted and concrete steps and decisions within design framework are described in this chapter.

The double diamond is based on the frame innovation approach coined by Kees Dorst, Professor of Design Innovation at the University of Technology. In his approach, the design process can be divided into problem space and solution space. The problem space is when researchers explore the problem, including its complex nature and end with a clear definition of the problem (Dorst, 2020). It is where the majority of the unique design or research characteristics and value lay, including creativity and uncertainty. The second stage is the solution space, where ideas are generated, visualised, and tested some solutions. At the end of this stage, the final product is created and delivered to the end user.

Whereas the double diamond model is mainly used for team collaboration, in the process of this research the design has been successfully adapted to the single study process and research objectives. In the further description and elaboration of the design model at each step, the respective tools that are used, discussed earlier in this part, are pointed out.

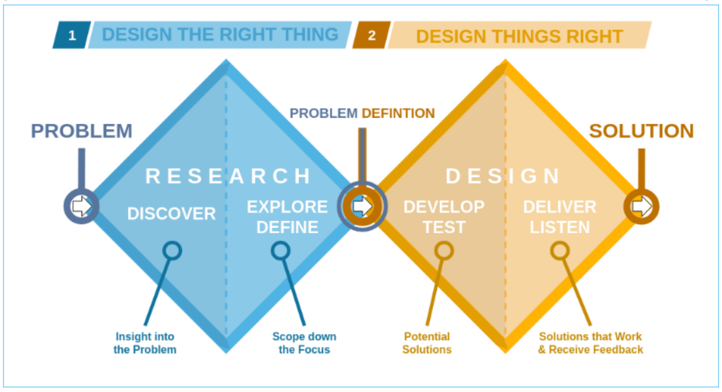


Figure 6 Double diamond design model (Elamany, 2021)

Step 1: Discover

The first stage is the exploration phase where the researcher explores possible research questions or objectives of the project, such as finding the root cause of the problem and applying field research to understand the target challenge. The main goal of this step is to examine and collect information about the research challenge. The Discover step is divergent, which means that all ideas and information are considered and included. This step appreciates uncertainty as the researcher initially explores the problem, similar to the agile and lean processes. The support of creativity is applied based on the tools used to conduct this step. Examples of these tools are below: Mind maps, Brainstorming and Reversed Brainstorming, Desk research and field research.

Step 2: Define

The Define step is the convergent part of the research process as it allows ideas to be narrowed into a clear definition of the research questions and goals. This definition will lead the whole research in the particular direction in order to achieve the goals. The defining stage involves analysing evidence and filtering ideas to reach an understanding of the desired outcome and define future workflow. The tools below are examples of tools that were used in this step: Interviews, Focus groups, Observation, User story.

Step 3: Develop

Develop is the first step in the finding solution phase. During this stage, the researcher works with the obtained data and enhance the research approach in order to get more precise and relevant results from the empirical and desk research. As well as to get the understanding of the research project target groups. It can be easily done by creating a persona for each target user. Persona is a virtual character representing the user and helps the researcher to consider the user's characteristics during the exploration and evaluation phases of the development process. Several tools were used in this process: Storytelling, User journey mapping, Observations, Interviews.

Step 4: Solution

Final stage of the research process brings the answers to research questions and covers intended objectives of the study. The relation between the researcher and study outcomes doesn't end here. Once the research paper is delivered, the feedback from the scientific community as well as users and experts' evaluation will be used as recommendations to improve the future research. The Deliver is a conversion step where ideas and outcomes of the research experiments are narrowed to the final evaluation. Examples of the tools that are used in this step include: Surveys, Discussions, Shadowing.

Therefore, in developing this research project, the double diamond concept was successfully adapted to the objectives and aims of the interdisciplinary study, enriching and adding creative elements to the process, which had a positive impact on the results and the progress of the research.

2.4 AR applications and Hololens in the learning anatomy context

Nowadays, augmented reality technologies are widely used in various fields of human activity and education is no exception to the rules. AR applications transform the learning process into an engaging immersive experience and allow not only to interact with the objects being studied, but also to activate the visual memory, needed to remember information in many academic areas. The popularity and adaptability of this educational experience are due to the ease and convenience of use, for most educational applications only a smartphone or tablet with a downloaded app is needed for individual or collaborative work. AR applications are available in different educational fields and are used at all levels from elementary school to research institutes.

A particular focus of educational AR applications is in the domains of medical and anatomical studies. This chapter describes existing AR applications that focus on the study of neuroscience and anatomy as also offering collaborative and individual learning modes. The aim of reviewing the existing applications is to provide a comprehensive and comparative look at the implementation of immersive learning experiences with a focus on considering collaborative AR experiences in the field of anatomy through examples of independent and diverse applications. The section 6 also provides information on evaluating and comparing the key features of the featured applications with the main object of the study, the Nevrolens application. This type of research and comparative analysis is needed to comprehensively address the key features of augmented reality applications that enhance the learning experience and encourage interaction with peers in the context of anatomy learning.

CHAPTER 3 RESEARCH WITHIN THE EDUCATIONAL AR APPLICATIONS

This chapter describes some of the related work that has been previously executed within the area of developing educational AR applications for learning anatomy. The aim of presenting this works is to put this research project into the context of the existing research to determine how the project can contribute to this study area. Section 3.1 presents the related work that has been performed by other researches to develop and evaluate related AR applications, while Section 3.2 describes the current Nevrolens application. The final section contains a discussion regarding the contribution of this research project.

3.1 Related works

HoloAnatomy

HoloAnatomy is an educational AR anatomy app that has been created in a cooperation between Case Western Reserve University, Cleveland Clinic and Microsoft (C. W. R., 2023) The app is available on Hololens 1 and 2 devices, and offers remote collaborative use features.

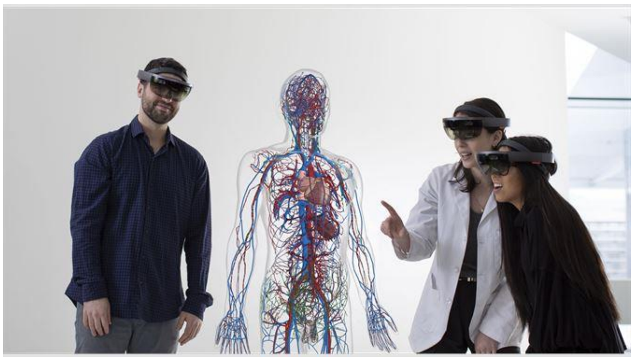


Figure 7 Holoantomy application (C. W. R., 2023)

The application provides students and teachers with the following features for an immersive human anatomy learning experience:

- Examination of human organs and the study of body structure from different perspectives and the ability of locating objects of study in a convenient location in working environment.
- Animations of human organ functioning, such as the workings of the heart or the neural connections in the brain
- Ability to read about the organs in remarks and examine different body systems together or separately, e.g., neurological, skeletal or muscular system.

In addition, the course instructor can use the HoloAnatomy Designer Tool to create 3D slideshows that can be broadcasted on students' HoloLens headsets to give assignments or explanations of the studied topic.

The HoloAnatomy app offers connection to collaborative sessions with up to 98 participants simultaneously (C. W. R., 2023). Interactivity in the app is realised by the ability to switch between different systems, organs or parts of the human body.

The application has been the subject of various studies. For instance, in a research project by Stojanovska et al. (Stojanovska, 2020) examined the applicability of AR in the study of anatomy using the example of HoloAnatomy. In order to achieve representative results of the study, medical student volunteers were divided into two groups with the same task in different settings. The first group of students were using the HoloAnatomy app to perform cadaver dissection, while the other group was directly instructed about the process in a live laboratory setting (Stojanovska, 2020).

After the experiment period, the students were asked to take practical examinations. The result of the exam showed that there was no significant statistical difference between the grades of the two groups, even though less time was required to teach anatomy using the HoloAnatomy app. This study shows that an educational AR application can be used to accelerate the process of learning anatomy outside of a practical laboratory environment (Stojanovska, 2020).

The cooperative and remote interaction features, as well as the results of such experiences on anatomy learning, are illustrated in a study by Wish-Baratz et al (Wish-Baratz, 2020). This study was conducted during the COVID-19 pandemic and distance learning using augmented reality technology was also a part of the study. In this research, collaborative learning was conducted remotely by distributing HoloLens headsets with the HoloAnatomy app to first-year medical students. The HMDs that were provided were accessed via a Wi-Fi connection where the instructor was able to share course content with the students. The students using the devices could observe the identical AR content of the lectures and the Zoom conference application was used to enable remote communication (Wish-Baratz, 2020).

According to the results of this research project, in which more than half of the students involved stated that they prefer distance learning to classroom sessions (Wish-Baratz, 2020). Many students also noted that they see the advantages of distance learning compared to full-time classes, as there is an opportunity to study in their free time. Some disadvantages, according to the students, were the difficulty of asking questions and interacting with the teacher or other students, as well as technical problems during the use of the application or the device (Wish-Baratz, 2020).

HoloBrain

HoloBrain is an AR application for studying brain anatomy, which has been developed jointly by the University of British Columbia and the Microsoft Garage Internship program. This application creates three-dimensional volumetric models of the brain from magnetic resonance imaging (MRI) for a variety of visualizations of the human brain (HIVE, 2023). The visualizations are performed as representations of three-dimensional brain structures based on corresponding two-dimensional MRI scans. The application is available on Hololens 1 and 2.

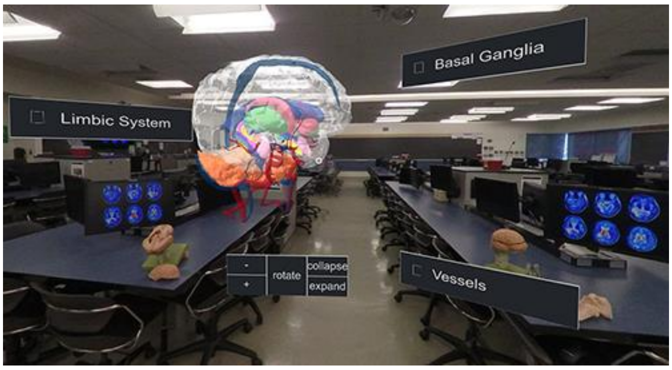


Figure 8 HoloBrain application (HIVE, 2023)

An important discovery in terms of accurate and detailed anatomical visualization of neural systems in the HoloBrain application is the use of artificial intelligence and machine learning to computerize the process of creating brain structures based on MRI scans (HIVE, 2023).

The main features of the HoloBrain application are:

- The ability to view three-dimensional brain structures from different angles;
- The ability to switch between different structures in the augmented reality model of the brain and MRI scans, as well as the option to familiarise yourself with the names of different brain parts and structures.

Collaborative learning is implemented through the ability to connect to a single session from different Hololens devices, where students can study the same three-dimensional brain structures simultaneously. Co-learning is only possible in a single learning space, without the possibility of remote access to the session.

During the COVID-19 pandemic, the HoloBrain app introduced a tool to record and broadcast the lesson, where the teacher could record the lecture material with an explanation on a visual brain model, and students could view the lessons on their mobile devices (HIVE, 2023). However, these lessons were not interactive, as students could only view the recording and did not interact with the 3D structures and each other during the session. This introduction was useful for teachers and the explanation of learning material in a remote learning environment, but did not support peer learning opportunities.

Complete Anatomy

Complete Anatomy combines elements of an anatomical 3D atlas with the ability to study and create 3D structures of human body systems, quizzes to test knowledge, dissection options, tutorial videos and information with the ability to add custom annotations. The application has been developed by 3D4Medical and is available on different digital platforms: PCs, tablets and mobile devices (3D4Medical., 2023).

Figure 9 Collaborative use of Complete Anatomy application In AR mode (3D4Medical., 2023)

The AR part of the application is limited and includes the following functions: viewing 3D models from different angles, resizing the model, highlighting individual parts with an accessible description, viewing animations such as a beating heart, and the ability to study the internal structure of organs and structures (3D4Medical., 2023). Collaborative work with the AR functions of the application is possible when session participants are in the same room.

Complete Anatomy was a part of a study conducted by Havens et al. (Havens, 2020) which investigated the impact of an anatomy app on improving the laboratory learning process of cadaver dissection.

The study compared the features that can be found in the two applications Complete Anatomy and Human Anatomy Atlas in augmented reality and non ar modes. The researchers state that the interaction with models and the ability to manipulate human body parts are useful for learning anatomy, especially the ability to move around in space during learning, as well as selecting a particular body part and looking at the internal structures of organs (Havens, 2020).

Despite the possibilities presented in the application for learning the neural system, the research considers the schematic positioning of the main structures of the system to be insufficient without precise location and detailed description (Havens, 2020). Complete Anatomy can be used for collaborative learning with peers, however, due to the limited range of features available in AR mode, this study can be considered irrelevant to the research question.

VesARlius

Research into the impact of peer learning in the field of anatomy and medicine is attracting many researchers. In 2020, for instance, the research project of Bork developed an AR app for Hololens VesARlius with a focus on collaborative learning (Bork, 2020).

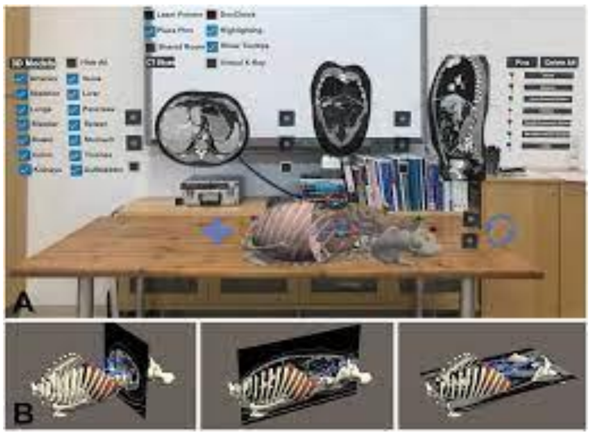


Figure 10 VesARlius application

The main functions of the app are:

- Viewing a 3D anatomical model from different angles and at different structural layers of the human body,
- Viewing computed tomography (CT) images over or inside the 3D model and the ability to select and highlight the same structure in the 3D model and in the CT scan image.
- The ability to place pointers on different parts of the model to display names, each part has its own unique colour matching the names.
- The accuracy and details of 3D models are based on re-creation of CT images, which ensures a one-to-one correspondence between the models and the images (Bork, 2020).

Since the application was originally developed to explore the features of collaborative learning, many functionalities support the effectiveness of learning interactions. Users are able to create new and connect to existing collaborative learning sessions, learners can position 3D models in an environment, the position of the models is not fixed and is individual for all participants, which is convenient when used in the same space. Moving and other manipulation of the model is also available, as well as selection of structures to be displayed in the 3D model or in the CT image, and a laser pointer helps learners understand the learning direction of other users. Joint sessions are limited to a single learning space, as there is no possibility for distance learning.

In a research project aimed at studying the effectiveness of collaborative learning using the case of the VesARlius application, medical students were divided into two groups. The first group used headsets and studied the body structure from CT scans and 3D models in AR, while the second group used textbooks and physical 3D models. At the end of the experiment, all participants completed an anatomy test, which included a pre- and post-study session test. The result showed that students using VesARlius had slightly higher knowledge scores than those studying with physical models and textbooks (Bork, 2020). In the interviews, the students stated that collaborative learning in AR, helps to understand 3D anatomy faster and supports engagement and interaction during learning.

HuMar

Another case of researchers' interest in evaluating the effects of learning anatomy in AR is the HuMar application. This Android mobile app was developed in 2015 by Shiratuddin to study the skeletal system of the human body. (Shiratuddin, 2015)

Using the mobile device camera in the app, 3D objects can be displayed and overlaid in space and the resulting AR experience can be displayed on screen. Visual models of the bone system have been generated based on photographs of the bones during 3D modelling (Shiratuddin, 2015).

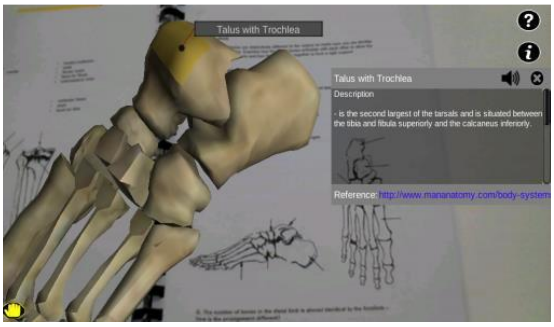


Figure 11 HuMar app screenshot (Shiratuddin, 2015)

Features offered by the app include:

- The ability to view 3D objects from different angles,
- The ability to move, scale or rotate the 3D object, as well as displaying a medical dictionary for additional information about the displayed bone.

The main purpose and advantage of the HuMar application is the ability to work on the study of skeletal systems without access to the laboratory, anytime and anywhere (Shiratuddin, 2015).

The HuMar app was also the subject of a study of learning efficacy. In a research project, a group of medical students performed a knowledge test before and after an experimental study session, where one group of students was using a physical model of the human skeleton and the other group was using the HuMar app.

The test results showed that the group that used the HuMar app significantly improved their knowledge test results compared to the other group (Shiratuddin, 2015). The researchers state that this result proves the effectiveness of the mobile AR app in improving student performance to a higher degree than traditional approaches to learning anatomy. The conducted study did not test students' collaborative work.

3.2 The Nevrolens Application. Development process and current state

The Nevrolens app is being developed by IMTEL as part of the Nevrolens project in collaboration with the Kavli Institute for Systems Neuroscience of NTNU.

Nevrolens is an application, developed by researchers from the IMTEL VR laboratory of NTNU in collaboration with the Kavli Institute for Systems Neuroscience of NTNU. Work on the app began in 2020 and the first version was done by Ravna (Ravna, 2021) under the guidance of a neuroscience expert. The app was originally developed on Android and Hololens 2 and was gradually improved with new features. Nevrolens was published in the Apple Store and Google Play during the fall of 2022. Further development and feature updates to the app are still underway.

The work on the application started at the unique time. The Covid-19 pandemic forever changed the approach to learning around the world, access to classrooms, laboratories, and collaborative learning in a shared space became impossible, due to the spread of the dangerous virus. Taking this world change into account, the development of the Nevrolens app was focused on a mobile version that is accessible to learners and teachers from their personal devices in a remote collaborative learning environment, as well as for individual studying sessions. The app was originally developed for Android and then adapted for iOS.

Hololens 2 provides an immersive experience of using and manipulating the model with physical gestures. Initially, it was planned that students would connect to the study session from their mobile devices and the teacher would demonstrate the learning material on Hololens. They can cooperate in a shared virtual learning space, working with the 3D model. This scenario is dictated by the high price of the Hololens device, as this HMD is aimed at companies rather than individual users. The main features and important features for learning in augmented reality Hololens 2 are described in the chapter, here it worth mentioning the possibility of streaming to the screen the process of working with the 3D model in the HMD, which also facilitates and improves the learning process in AR.

The app is being developed by researchers and students of NTNU and at the moment the app is a finished educational product, the research of the effectiveness and supplementation of the functionality of which is still in process.

3.2 Nevrolens features and design

On the start screen of the Nevrolens app, the user can launch an individual study session, create or connect to a collaborative one or watch a tutorial video on how to use the app. When selecting one of the menu sections, additional possible options will appear that form the manual menu. On Hololens 2 devices, which have been the focus of development, the menu appears when the hand is raised, in the direction of the user's gaze. On mobile devices, the menu is in a fixed position.

The design and functionality of the Nevrolens application can be divided into five main groupings, namely the hand menu, the brain system, the information board, the collaboration aspect, and the administrative features. These main groupings are discussed in this section.

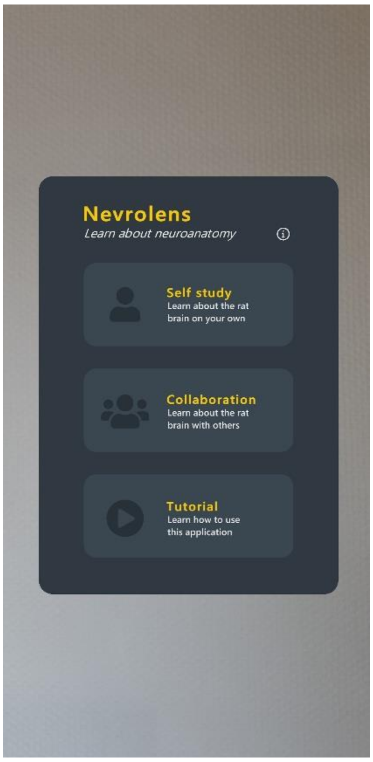


Figure 12 Main menu Nevrolens app

The Brain System

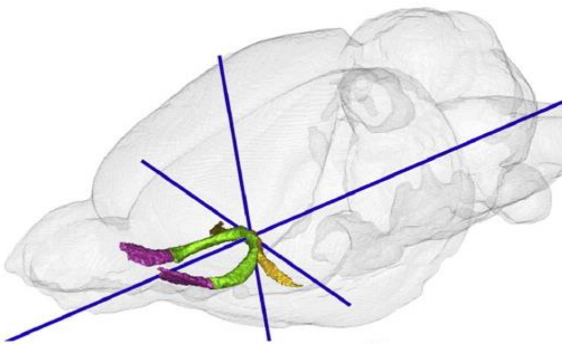


Figure 13 The Waxholm Space (Papp, 2014)

The main app element is a high-resolution 3D model of a rat brain defined as The Waxholm Space Atlas of the Sprague Dawley Rat Brain (Ravna, 2021). The researchers from the University of Oslo and NTNU manually constructed an accurately structured, three-dimensional model of the rat's brain while developing this brain model. When the model was transferred to the augmented reality (AR) application Nevrolens based geometric measurements on the volumetric brain model were used in the rendering process.

The Waxholm Space (WHS) is a vector division of the brain structure, defined as the most accurate and standard division of rat brain space. (Papp, 2014). This division is used as a coordinate system for the most logical interconnection of anatomical atlases. The International Centre for Neuroinformatics Facilitation (INCF) developed this model originally for the mouse brain and it was subsequently implemented in the rat brain. (Hawrylycz, 2011).

The 3D model, implemented in the app, has an accompanying color-coding scheme which is used in the application to color the model. The features that are possible to make within the brain system are the adjust, brain parts, reconstructing, nameplates, cluster, and dissect features. These features are discussed in the following paragraphs.

The Adjust Feature

The adjust feature allows the user to move, scale, and rotate the brain model, and, when it is active, a rectangular prism is shown around the model. The user can move the model by grabbing the surface of this rectangular prism or scale and rotate it by using the cubes and spheres shown on the rectangular prism, respectively. The adjust feature is active when starting the learning session and can be toggled on and off by pressing the Adjust button in the hand menu.

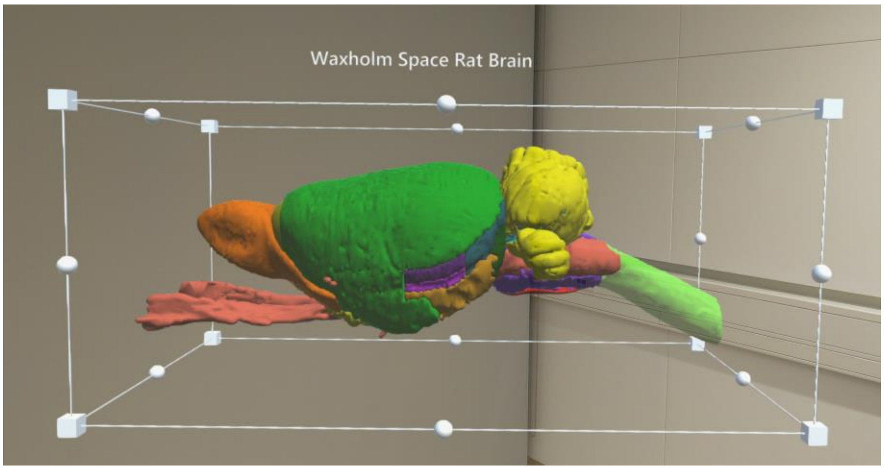
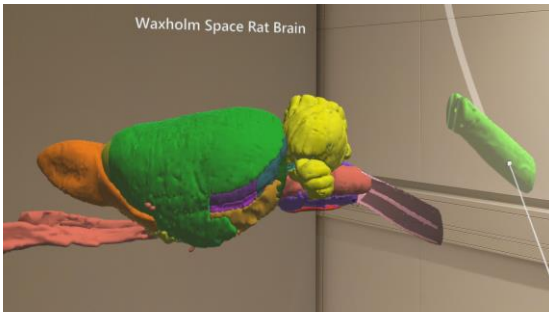


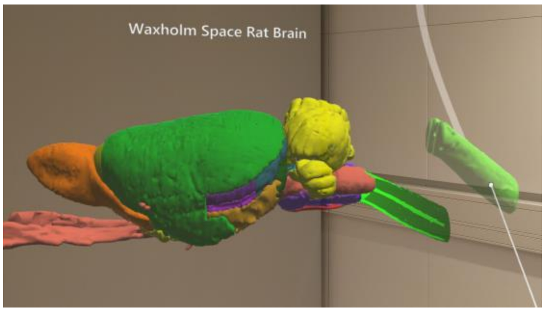
Figure 14 The brain system and the rectangular prism shown when the adjust feature is active.

The Brain Parts Moving Feature

In addition to interacting with the whole brain model, the user can interact with individual brain parts. Each part can be moved in space and rotated but not scaled individually. When a brain part is grabbed, an outline of that part is shown at its original position in the brain, as shown in Figure 3.10. This visual cue makes it easier to see where the part belongs in the brain and thus move it back to its original position.

In addition to the brain part outline, the Nevrolens application provides three other functionalities that make it easier for the user to reconstruct the brain. Firstly, the application can "snap" a brain part back to its original place. To use this snapping functionality, a user must grab a brain part and move it close enough to its original position so that the outline of the brain part changes color from red to green, as shown in Figure 3.10. When the user then releases the brain part, it is snapped back in place. Secondly, the application provides a clean-up function that can be used to move all brain parts back to their original positions. This function can be induced by pressing the Clean-up button in the hand menu. Lastly, a user can revert the state of the whole application to its starting point by pressing the Reset button in the hand menu.





(a) When red, the brain part will not snap in place on release (b) When green, the brain part will snap in place on release.

Figure 15 An example of the outline that is shown in the original position of a grabbed brain.

Nameplates

The Nevrolens application shows the name of a brain part when the user points at it, as shown in Figure 3.11. This functionality can be turned on and off by toggling the Name Plates button in the hand menu.

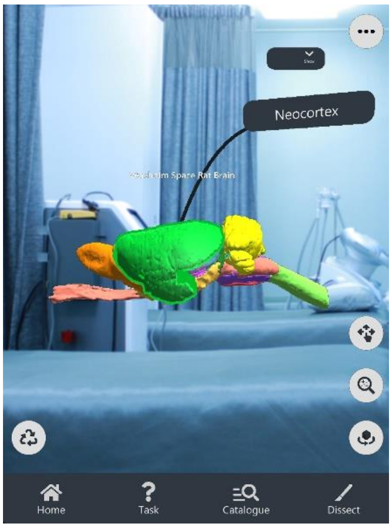
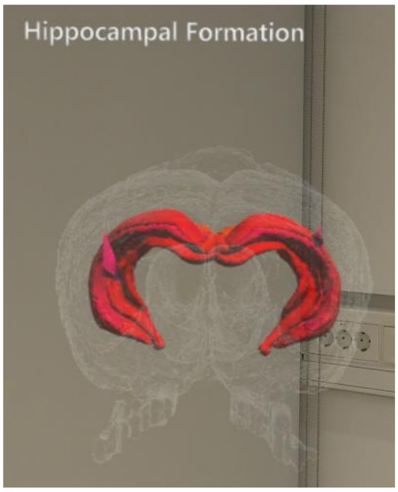


Figure 16 Name of the brain part appears when user is pointing to it.

The Cluster Feature

The cluster feature provides the ability to go through different groupings of brain parts, which are called "clusters" in the application. In total, four clusters are available in the application and Figure 3.12 shows one of them. To access the cluster feature, the user must toggle the Cluster button in the hand menu which causes the first cluster to be presented. Additionally, the hand menu is updated to show three extra buttons, as depicted in Figure 3.8b. These buttons present the ability to toggle the visibility of the brain outline, go through the different clusters, and change between the two color-coding schemes for the brain parts shown in Figure 3.12.



(a) Cluster color-coding scheme based on the HSV color model. (b) Cluster color-coding scheme based on the color-coding scheme of the Waxholm Space model of the rat brain..

Figure 17 The Hippocampal Formation cluster and its two-color options.

The Dissect Feature

The dissect feature lets the users explore different cross-sections and inner structure of the brain. The axes can be pre-defined: horizontal and vertical or customed by user.

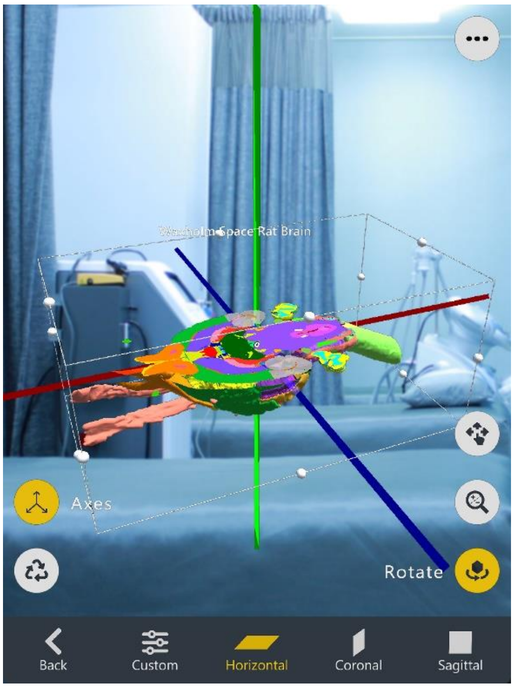


Figure 18 Model dissection

The Information Board

The information board is a special tool that shows an informative blackboard. The content of the information board mainly consists of a title and informational text beneath but can also include pictures. This content changes depending on inputs from the user. When starting the application, the information board displays a description of the Waxholm Space Atlas of the Sprague Dawley Rat Brain as shown on the Figure 13. This description is the only one among the informational texts added to the application that includes a picture. When the user selects a brain part, the board shows information about it. If information about a brain part is not available, a selection of the 'Lorem ipsum' placeholder text will be shown instead. The Nevrolens application consists of 10 brain parts that have description in the application, and 19 that show the 'Lorem ipsum' placeholder text instead.

Figure 19 Nameplate of the chosen brain part

Collaboration

The Nevrolens application has a cooperative work feature where users can create their own AR collaborative learning environment or join already existing session. A room can include up to 10 participants, and certain functionalities in a room are synchronized. These functionalities include the toggling of certain buttons, movement of brain parts, the placement of the cross-section of the dissection cut, and the viewed clusters.

When the user is in a room they can see where other participants are pointing or grabbing a brain part by looking for a sphere similar to the one marked by the red square in Figure 3.15. Furthermore, all of the participants have an avatar similar to the one marked by the blue square in Figure 3.15. These avatars are distributed around in the game view, and their position, rotation and angle indicate where the participants view the shared game objects from. The avatars are the only indication of how many participants there are in a collaborative session and who those participants are. The synchronization of the above functionalities, including the use of avatars and pointers, does not always work as intended. Ravna (Ravna, 2021) suggests that future work should be performed to fix the synchronization, add a voice chat to enable remote communication and enhance learning experience.

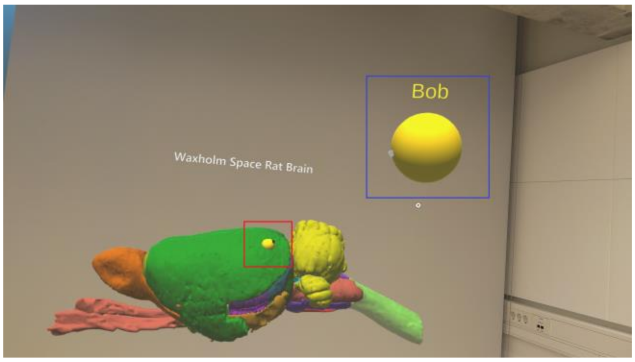


Figure 20 The avatar of a participant and the sphere indicating where the participant is pointing.

Learning objectives of the app

The neuroscience focuses on the structural organisation of the nervous system. Mostly students learn neuroscience from anatomical atlases and graphic materials and also practice on physical samples in the laboratory using animal cadavers, which is resource-intensive, unavailable at any time and is also considered as a controversial ethical issue. During the definition of the research objective and the main goal of app development, consultation with experts as well as a consideration of relevant literature sources showed the limited amount of educational and practical tools, available for studying rat brain anatomy. Especially the study (Ravna, 2021) emphasized the complete lack of available and convenient ways for learners to practice the dissection and examine internal structures of the rat brain beyond the laboratories of research centres or institutes.

Immersive learning experience is one of the key relevant features of AR, so an increasing number of applications for learning and professional training in different educational domains using AR technology are emerging in research projects and in practical use. Therefore, many educational institutions are using available applications to replace laboratory and practical work with immersive experiences for student work in augmented reality on HMD or mobile devices, reducing the necessity of training on expensive and not always available equipment.

Given these learning requirements of neuroscience learning particularities, the Nevrolens app presents an immersive, interactive experience with a 3D model of rat brain in augmented reality. The available functions of the app help students to explore the brain structure on the device at any time and in any learning manner, preferred by the student. Various studies (Haugum, 2022) emphasise that the learning process is individual for each student. The main relevant educational theories have been discussed in chapter 2. The developers of Nevrolens were inspired by socio-constructivist theory, where communication with peers in the process plays a major role in the successful learning process. This is why the educational method of peer-learning fits perfectly into the concept of a collaborative session in Nevrolens, where learners can work together on a model, take it apart, explore its internal structure with dissection feature and test their knowledge in quizzes or create their own tasks. With the remote collaborative session option, students can work together at a distance or in a common learning space on different devices, either under the guidance of a teacher or on their own. In addition to collaborative work, students can study brain structure, practice dissection or test their knowledge on their own.

Thus, the main educational goal of the Nevrolens app is to provide accessible, interactive and practical neuroscience studying material to enhance learning, experience practical preparation for real dissection, and present opportunities for collaborative, remote learning.

3.3 Contribution to the project

Due to the increasing requirements of educational programmes, the amount of content that medical students have to master is increasing, which stimulates the need for alternative approaches to learning, such as educational AR applications. In addition to the development and spread of AR applications for learning anatomy, these kinds of research projects need to be evaluated not only for technical functionality and effectiveness, but also for user experience and evaluation of the educational impact of the applications.

The learning is an individual and at the same time a social process, for most students the greatest progress in knowledge acquisition occurs when working together with peers. therefore this research project aims to investigate how collaborative augmented reality study sessions affect the learning experience of students, and how immersion contributes to the learning of neuroanatomy in an educational AR app. The type of neuroanatomy knowledge acquisition that can be supported by such an app includes learning the names and functionality of different parts of the brain, the relative location and size of brain parts, how these parts look in 3D, and different cross-sections of the brain and its parts.

Therefore, this research project aims to summarise the findings to assess the learning potential of AR applications for collaborative peer learning with a focus on the role of immersive augmented reality environments in learning anatomy. Furthermore, to provide recommendations for features that can improve the collaborative, peer-learning approach to learning anatomy in educational AR applications. By summarising these recommendations, this project can contribute knowledge that can be used to create different types of educational AR applications around anatomy in the future. This knowledge can also contribute to the creation of new learning scenarios that will improve the user's educational experience as well as be more adaptable to the different needs of learners.

3.4 Comparative analysis with other apps

Table presents a summary of the features that are offered in the existing Nevrolens application and similar applications developed within the anatomy studying domain. The aim of observing and comparing the existing applications is to gain understanding of valuable features that apps provide to the customers as well as get the inspiration for the functions that learners can and prefer to use while studying the anatomy in AR. HoloAnatomi and HoloBrain apps are only available on Hololens devices, which makes them less accessible to a wide range of users, due to the limited distribution of HMDs and the high price of the device. Almost all apps are available on android devices, due to the popularity of the operating system and the easier process of developing and publishing an app for Android devices. Nevrolens is available on Hololens, Android and iOS, which allows a wide range of users to be reached.

During the AR apps observation, it was also noted that some applications facilitate collaborative learning. These applications include the existing Nevrolens application, HoloAnatomy, HoloBrain, Complete Anatomy, and VesARlius. The HoloBrain application also offered recording and broadcasting of lessons to facilitate remote learning, but the students could only view the lessons and not interact with the 3D models themselves. Among these applications, the existing Nevrolens application and HoloAnatomy seem to be the only ones that can be used for remote collaboration where students can interact with the AR environment. However, these two applications do not have any features for remote communication making it difficult for students to communicate with each other or their teacher (Wish-Baratz, 2020). In addition, among the applications that support collaborative learning, there seem to be a limited set of features that can be used to facilitate different approaches to learning in collaborative sessions. Table 1 summarizes the findings.

Application	Devices	Collaboration	Main features
Nevrolens	HoloLens, Mobile devices	In-person, Remote without communication	View 3D model from multiple angles, adjust model, select and move structures, read name labels, read descriptive texts, custom dissect, view clusters. Quiz features, collaborative session up to 10 participants
HoloAnatomy	HoloLens	In-person, Remote without communication	View 3D model from multiple angles, watch animations, read name tags, change between different models, use Designer Tool. Collaborative sessions up to 90 participants
HoloBrain	HoloLens	In-person, Remote without communication	View 3D model from multiple angles, change between structures and MRI scans, point at structures to reveal name
Complete Anatomy	HoloLens, Mobile devices	In-person	View 3D model from multiple angles, adjust model, point at structures to reveal name, read textual description, watch animations, view predetermined separations of structures
VesARius	HoloLens	In-person	View 3D model from multiple angles, view associated CT images,

			select and highlight structures, place pins on structures to reveal name, use laser pointer to reveal gaze direction
HuMar	Android devices	Not available	View 3D model from multiple angles, adjust model, read descriptive texts, follow link for more information

Table 1 An overview of the features that are offered by the existing Nevrolens application and other anatomy studying apps.

CHAPTER 4 RESEARCH QUESTIONS AND METHODS

The first section of this chapter describes the research goal and its accompanying research questions and why they were chosen. The second section describes the chosen research method used to define and achieve the research goal, as well as define and answer the chosen research questions. The third section describes the research design.

4.1 Research questions and study objective

Today, digital technologies are used in almost all areas of life, accelerating, automating and enhancing the user experience. Consequently, there is a need for systematic and comprehensive research into the effects of these technologies on the domain of use. Educational applications are usually studied and evaluated in terms of application design, functionality and usability, but research rarely focuses on measuring the learning effect of the application, its compatibility with educational methodologies and theories and also the qualitative evaluation of the application itself as a learning tool (Logeswaran, 2021).

This study is based on the augmented reality application Nevrolens, which allows users to gain knowledge about the brain's neuronal structure by working with a 3-D model (Ravna, 2021). In addition to presenting visual and contextual information while working with the model, the application allows users to use a collaborative mode for cooperative learning and synchronous interaction with the educational material. This study focuses on considering this feature from the perspective of constructivist educational theory, focusing on peer-learning methodology, and examining the differences in user experience of immersion effectiveness depending on the technology used. Based on the above, the research objective is formed.

Research goal: To evaluate the learning potential of peer learning and immersion in AR.

The relevance of this topic is driven by the increasing interest in the use of technology in an educational context and the reinforcement of application effects with appropriate educational methodologies and evaluations of the user experience of technology-based learning. The educational peer-learning method is a popular development of constructivist educational theory, with proven effectiveness, however the use of this method in a collaborative virtual learning environment has not been investigated. Also, an important topic is to study the specificity of XR technology of immersion in a virtual environment and how the difference of this effect affects the learning experience. In order to fully reveal the main purpose of the study, the following research questions were formulated:

RQ 1 How peer learning and collaboration in AR affect the studying process?

The constructivist social learning theory, originally developed by the Soviet scholar Lev Vygotsky, is a popular and effective learning methodology widely used around the world. Chapter No. explored learning theories, especially emphasizing the constructivist theory's focus on the social factor of learning, as the learning and development of the individual are possible in the community and invariably imprint upon the learning experience (Vygotsky, 1978). From social theory, a new methodological approach to learning evolved, peer-learning, which is considered a very effective method of collaborative learning, where the role of the teacher is taken over by the students in turn (Tullis, 2020).

This approach is especially relevant today with the development of technologies and their extension to different areas of human life, the availability of various educational applications, the autonomy and convenience of which allows learning outside the study room with a teacher.

The research topic of measuring the educational effect of the collaborative educational methodology peer-learning in augmented reality is the main research focus of the i-pear project. The project is focusing on the creation of innovative open-source educational resources for academics that support and integrate collaborative learning approaches in different academic fields using AR technology. the main idea of the project is to expand the pedagogical practice and support collaborative, inclusive learning that meets current scientific requirements and student preferences. (eucen, 2023). While working on this study as part of the evaluation of the augmented reality application Nevrolens, developed by the IMTEL team, contributes to the research base of the project, contributing to the cohesion of the scientific community, sharing research experiences and expanding the knowledge horizons.

RQ 2. How the difference in AR immersion (mobile devices/Hololens) change the learning experience?

Addressing the next important element of the study of the learning potential of AR applications and the role of immersive technology in the learning process, it is worth noting that this side of the study is a case study of the user experience and the role of technology in human life. This element is an inseparable part of the academic focus of Digital Humanities, which explores the application of technology for the benefit and development of society, to the service of technologies to humans and sustainable devices and the sustainable use of technology (Arnold, 2023). The use of augmented reality technology on mobile devices and HMDs is not fully immersive and only adds AR objects to the user's reality as perceived through the device's screen or through augmented reality glasses. However, the difference between using the app and the technology on Hololens 2 and mobile devices is a completely different experience of the learning session (Marques, 2022). The difference in user experience and learning potential of using augmented reality on two different devices is the focus of the second research question. The findings of this research question may in the future help developers and educational institutions to decide on the development base for a learning application.

RQ 3. How self-assessment within the Peer-Learning approach in AR affect the studying outcomes?

The main motivation for developing the third research question at the intersection of learning theory and psychology is the researcher's personal interest in the phenomenon of "I can because I believe I can". In addition to the beautiful phrase, there is a scientifically proven fact behind this statement that the learner's self-confidence influences their success in academic studies and performance in examinations. (Kang Y-N, 2019) In this study, it was particularly insightful and important to look at learners' assessment of their experience when working with traditional neuroscience teaching methods: textbooks and atlases and working with the 3D model in augmented reality. In addition to insights into the data on the self-efficacy assessment phenomenon itself, this topic brings to the fore the discourse of comparing the effectiveness of traditional teaching methods with the use of new technologies in the assessment and understanding of the learners themselves. Although, the limitation of the study to a single scientific field, the technology and the very limited data obtained cannot guarantee a complete answer to this phenomenon and the researcher emphasises the importance of research in other fields, nevertheless the findings can be useful for similar research in further research domains.

4.2 Research methods

The research method used in preparing this project is described in part ! of the chapter! This is a specially tailored for the project design thinking model of the Double Diamond. This section details the actions taken in each of the research phases and links them to the model.

In the first stage of Discover, there was conducted a study and consideration of the research topic, the following actions were taken:

- Acquaintance with the Nevrolens application as well as with the requirements and the requests of the future study;
- Preliminary data collection - expert interviews;
- Qualitative research - literature reviews related to the research topic and consideration of relevant scientific findings;
- Brainstorming.

The next research stage - define- was the step of narrowing down potential research requests and developing a detailed strategic work plan.

- Defining the research objectives and research needs;
- Creating a research plan;
- Preparation of materials and tools for answering the formulated research questions;
- User mapping.

In the Develop phase, the most active research stage, the focus was on creating of an appropriate and specifically tailored context and the preparation of tools for a successful study.

- Recruiting different user groups;
- Interviews with experts ;
- Consultation with industry representatives, interested in the research project;
- Data collection;
- - Clarification of research questions.

The final step in this project Solution aims to evaluate the findings and draw conclusions that uncover the research results.

- Data analysis
- Summary of research limitations
- Summary of the research findings
- Formulation of recommendations for future research

It is important to emphasise that at each stage of the study, the findings were evaluated using both qualitative and quantitative methods (Mackenzie, 2006). At each stage, a qualitative literature survey was conducted to ensure the relevance and consistency of the research with current knowledge on the topic. Each data collection met the requirements of the quantitative data collection method and the data obtained was analyzed according to the qualitative research method. By using these three different methods for generating data, finding and evaluating the outcomes this research project achieves method triangulation which makes it possible to look at the chosen area of interest in different ways (Oates, 2016). Additionally, by using more than one research method it allows the data found from one method to be compared with the data found from another method. In this master thesis, the results of the interviews, learning outcome test, and demonstration can be compared to increase can be analysed, for an independent review of the findings and an unbiased approach to the conclusions in order to demonstrate that the results are not tied to the chosen research method, which can nevertheless be considered as a limitation of the study. (Oates, 2016).

4.3 Research design and strategy

The development of a research study is a multifaceted and structured process to discover the aims and answers to the research questions. The description of the research method in the section 2 provides the main solutions and chosen methods for the design of this research project. The main stages of the solution design and the steps of creating the thesis will be disclosed below. Also provided here are descriptions and examples of the main ways to collect research-relevant data: examples of pre- and post-test questionnaires, anatomy knowledge, user experience of immersion in an AR learning session, measurement of self-efficacy and learning preferences as well as interview questions from education experts, neuroscience professors, IT experts in collaborative learning applications, and industry representatives interested in the findings of this research.

To achieve the research goal and answer the research questions, this project employs the design and creation strategy based on the adopted Double Diamond design model, as mentioned in chapter 3. This strategy is performed to A comprehensive and creative approach to exploring the educational effects of neuroscience in Peer-Learning collaboration as well as the role of an immersion into augmented reality environment within a learning session.

The design thinking process is an iterative and user-centred process that can be used to create an understanding of the needs of the users and identify solutions for meeting these needs. The research method of design thinking is also successfully suited for interdisciplinary research that covers multifaceted and methodological topics from different scientific fields. By applying and adapting design thinking techniques, the research can harmoniously integrate the diverse demands of the various scientific fields, as it is done in this thesis, which answers methodological questions of an educational dimension, gives an assessment of user experience in augmented reality app, as well describes the psychological factor of self-efficacy assessment.

For this project, the design thinking process consists of four research phases. These phases, together with the main goals and performed activities, are shown in Figure 21, which is the remade for this thesis Double diamond design model. As seen in the figure, phase 1 has three aims. The first aim was to gather data about students studying neuroanatomy. This was done by conducting a user survey and a workshop with users that are studying neuroanatomy on different educational levels. The second aim was to start the literature review that is continued throughout the project. Within the first research phase the review was focused on the literature sources about use of AR in education, learning theories and analysis of learning potential evaluation. The third aim was to gain insight into the perspective of a professor. This aim was accomplished by conducting two expert interviews with a professor of neuroscience. The first interview was conducted early in the process to obtain an initial understanding of the research area as viewed by the professor, and the second interview was hold at a later time to get their thoughts on the proposed requirements for the research.

The main objectives of the second phase of the research include the formulation of research objectives and research questions, the development of strategies and enquiries to the conclusions of the research topic. During this research phase, questionnaires, user and expert tests were developed, Bachelors in Neuroscience were recruited and a series of experiments were conducted in the laboratory with the involvement of a neuroscience professor. The collected information was systematised and analysed according to the objectives and research needs. The theoretical basis of the project was also further expanded.

The third research phase was the most expansive and demanding. The main tasks of this step were to actualise and revise the research questions, to theoretically justify the results of the empirical experiments and to slightly change the research strategy. The focus at this stage was on the experiences of users not directly related to neuroscience, but curious about the use of technology and learning neuroanatomy. This shift from the neuroscience community extends the research to the experiences of pedagogy and IT specialists. To achieve these new aims, a series of experiments were conducted with masters and bachelors in IT and pedagogy, as well as application demonstrations and interviews with experts on virtual reality performance, especially on the use of AR in education. The findings from the experiments also contributed to broadening the theoretical base.

In the final phase of the evaluation and conclusions on the research topic, the main aim was to finalise the data analysis, summarise and develop conclusions of the research. For successful finalization, this phase included new tests with Masters in Neuroscience, interviews with neuroscientists, specialists and developers of collaborative IT applications and industry representatives. All data obtained were analysed and the final evaluation and results of the study were supported by suitable theoretical material.

For the sake of visibility and to briefly summarise the research design process, the main objectives and activities undertaken for each stage are illustrated in Figure 1, which represents an adapted model of the Double Diamant.

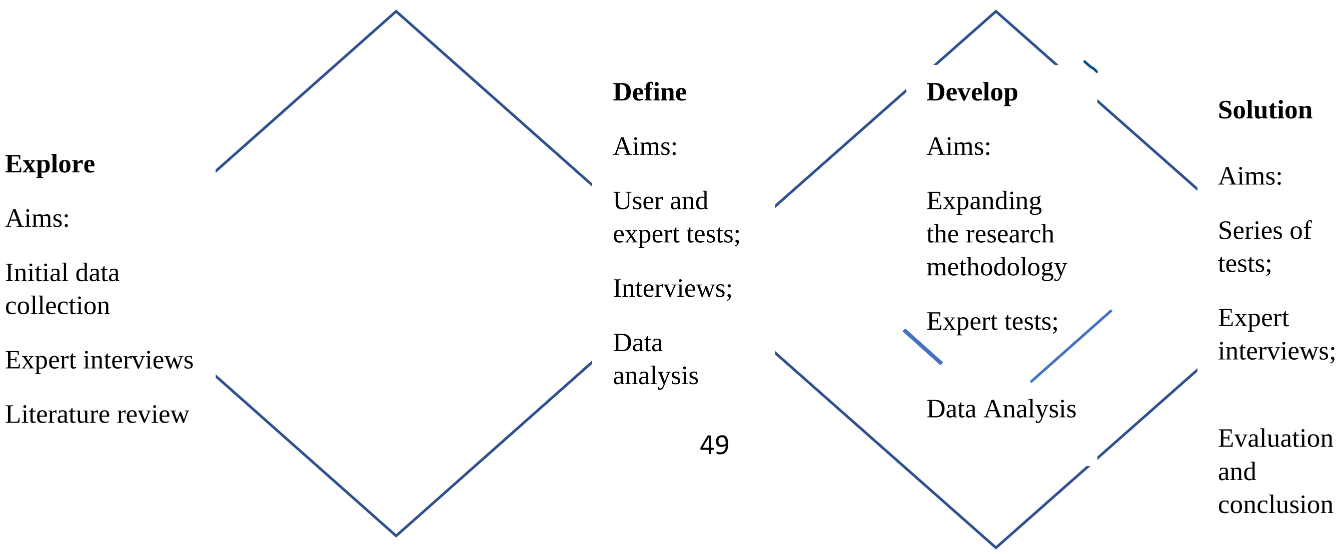


Figure 21 Double diamond model

4.3.1 Data Analysis

During the research process, all collected data and information were carefully and comprehensively analysed through qualitative data analysis from questionnaires and interviews with different user groups, while quantitative data analysis was based on data from knowledge tests, pre- and post-tests and other questionnaires. A description of the research process of data analysis is given below, while the data collection materials and the description of the workshops are given in the next chapter.

Quantitative Analysis

In this research project, a quantitative analysis is conducted to measure the difference in the results of the pre- and post- knowledge tests to evaluate how the use of the Nevrolens application supports the learning of neuroanatomy, self-efficacy perception and the learning preferences. These data results can contribute to the final evaluation of the Nevrolens collaborative learning potential.

Throughout the research process, due to limited research resources and a one-person researcher, different sized groups of respondents were accessed at different stages of the process. From large groups of 17 people to small surveys with 2-4 experts. All of this certainly affects the data obtained and the analysis process, hence the final conclusions of the study. In this research project, a Q-Q plot is used to check the assumption of a normal distribution. This plot is a graphical method that can be used to investigate the normal assumption in samples of any size (Bland, 2018). If the observed data are from a normal distribution, the points on the Q-Q plot forms an approximately straight line with no pronounced curves (Bland, 2018)Due to noise and disturbances that can occur in the observed data, there is some tolerance for minor deviations from the straight line at the extremes (Miot, 2017).

Qualitative Analysis

The user surveys and interviews aim to gain insight into the perspective of students on the research topic, while the expert interview aim to gain insight into the perspective of experts from different spheres on the same subject.

Analysing the interviews and surveys, it is important to identify patterns and themes in the different interviews by conducting a thematic analysis of the transcripts. Thematic analysis is chosen for this research project because it can offer a detailed description of the data set and highlight similarities and differences across it. The thematic analysis conducted in this project is inductive, meaning that there are no predefined patterns or themes the researcher tries to fit the data into (Braun, 2016). This form of thematic analysis is data-driven, however, it is important to note that the researcher plays an active role in selecting what to report and might thus influence the results based on the views, knowledge, and goals (Braun, 2016).

Braun and Clarke (Braun, 2016) divide the execution of a thematic analysis into six phases that are part of a nonlinear process where one moves back and forth as needed. In the first phase, the goal is to familiarize oneself with the data. This is done by, among others, reading the data several times and actively reading it by for example searching for patterns and meanings. It is also advised to take notes or mark ideas for coding. In the second phase, the initial codes for the data are produced. These codes are then sorted into potential themes in the third phase which ends with a collection of candidate themes, sub-themes, and related data extracts. In phase four, these themes are reviewed and refined, and in phase five the resulting themes are further refined. During phase five, what each theme is about is identified and what aspect of the data the theme captures is determined. The final phase, phase six, involves reporting the results of the thematic analysis and discussing these in connection to the research questions. This research project follows these six phases when conducting the thematic analysis of the students and experts interviews.

4.3.2 Ethics

This research project relates directly and indirectly to several groups in the scientific community, and the honesty and transparency of the research is essential for a productive and ethical scientific collaboration (Oates, 2016). The indirectly involved in the project include researchers who will be reviewing this Master's thesis or using it in future research studies. In order to provide relevant and honest information to this research community, the research project follows the intended research method, ensures the completeness and honesty of the data provided, and addresses the research questions and aims of the research. The group of people who are directly involved in the project includes participants in activities related to the planning and development of the research strategy, the collection of relevant data, the user and expert opinion on the study topic. These participants have the right not to participate in the research project, to withdraw from the project, the right to give informed consent, to anonymity and to confidentiality (Oates, 2016). In order to respect and guarantee the rights granted to the participants, the people directly involved in the project complete a consent form that informs them about their rights and what participation in the project means for them. There are four consent forms used in connection to this research project, all of them are approved by the Norwegian center for research data (‘NSD’, 2023). Three of the consent forms are connected to this research project as a part of a master’s student project at IMTEL VR lab. All the participants of the different activities presented in this thesis signed one of these forms. The fourth consent form is connected to the iPEAR project, this form was an additional form given to the participants of the learning outcome test and user interviews to enable the findings of these activities as they will be used in the iPEAR project as well.

Moreover, as the research is conducted in the context of the use of the augmented reality educational neuroscience app Nevrolens, where users use a realistic 3D model to study the structure of the rat's brain, and especially the possibility of dissection also provides an opportunity to reduce the use of animals in laboratory experiments. This has not been confirmed in the current study or in other studies related to this topic, but it is a potential ethical alternative within the discourse on the ethical use of live laboratory samples.

CHAPTER 5. EVALUATION

This chapter of the research thesis explores all the steps of the study according to the research questions and research objectives. The main activities undertaken at each step, the motivation and explanation for the choice of these activities, the progress of the study and the difficulties encountered, the relationship and logic of the research strategy, and a short conclusion on the research step and the analysis of the findings is given briefly after each stage. The research design is in line with the Double Diamond design thinking technique and therefore the research phases described are in line with this methodology and reveal its potential in interdisciplinary research. A full conclusion on the findings of the study will be given in the next chapter.

5.1 Phase 1 Explore

The first research step focuses on an initial understanding of the research topic and objectives, developing a strategy for obtaining relevant and applicable information, and mapping the research field. The theoretical part consists of a search, analysis and advanced research of literature and digital sources related to the requirements and initial objectives of the thesis to actualise the research questions and topic. As the research is not a purely theoretical review of the issue, it was important to identify users whose opinions and assessment are relevant and meet the research objectives.

The main target audience of the app and the research is students of neuroscience, anatomy and medicine. In order to conduct a meaningful study and answer the research questions, it is important to identify the users' attitudes towards the learning process, especially peer learning. It is also important to understand how self-efficacy assessment affects learning performance and how differences in technologies affect the user learning experience. Workshops and surveys were conducted for the user mapping, the procedure of which will be described further on.

In addition to student users, whose experience of using the app is the research goal, the opinions of professors and experts in neuroscience are worth paying attention to. They are the best experts to help to assess the learning potential, to help with the development of the user scenario and to explain the training methodology in a classical way. Also, the opinion of experts is important to understand the professional expectations of the learning application and how exactly the collaborative work of the students in the peer-learning methodology influences the effectiveness of the learning.

5.1.1 User survey

As mentioned earlier, a user survey was an important first step to get information about how students prefer to learn neuroanatomy and their own perception of effective learning. This survey was answered by 13 neuroscience Bachelor students. Of these students, more than 65% stated that they prefer to learn through reading the syllabus, solving problems, and participating in lectures, while more than 70% believed they learned well from watching videos, conducting experiments themselves, and interacting with physical 3D models.

In addition, more than 75% of the students believed they learn better in collaboration with other students, without much difference in the role distribution in the learning session. Almost half of the respondents mentioned that they prefer to study alone, as they can better focus on the subject and work in their own pace. Less than 45% pointed on the importance of self-efficient confidence during the studies, while almost 60% noticed no difference in their studying performance regarding their self-assessment. Four of the students mentioned educational applications they liked, and one of the reasons behind liking such an application was that it provided a 3D representation of the brain anatomy. Regarding experience with immersive technologies like AR and VR, seven of the students had some experience in general, while other 5 had small or zero experience of using these technologies in an educational setting. 62% are sure that immersion can be relevant in studying neuroanatomy, especially in preparation for the real procedure of dissection as it can give some preliminary knowledge on the inner structure, very approximate movement and space awareness during the experiment.

The content of the user survey is presented in the appendix in 1 and more detailed results are given in Section 6.

Based on the results of the survey, which focused on the primary understanding of the target audience - the object of the study - students of neuroscience, medicine and anatomy, 4 collective user images were formed. The formation of these allegorical models is part of the design of the empathy mapping method and allows for to better understand the requests, the perspective and the users themselves (Browne, 2023). Users were categorised by level of experience in neuroscience, preference for individual or collaborative learning, and level of confidence in their knowledge. The purpose of creating these personas was to improve the research audience's understanding of what strategy should be developed to meet the research objectives with the benefit for students and science. Personas are presented in the Figure 22 below.

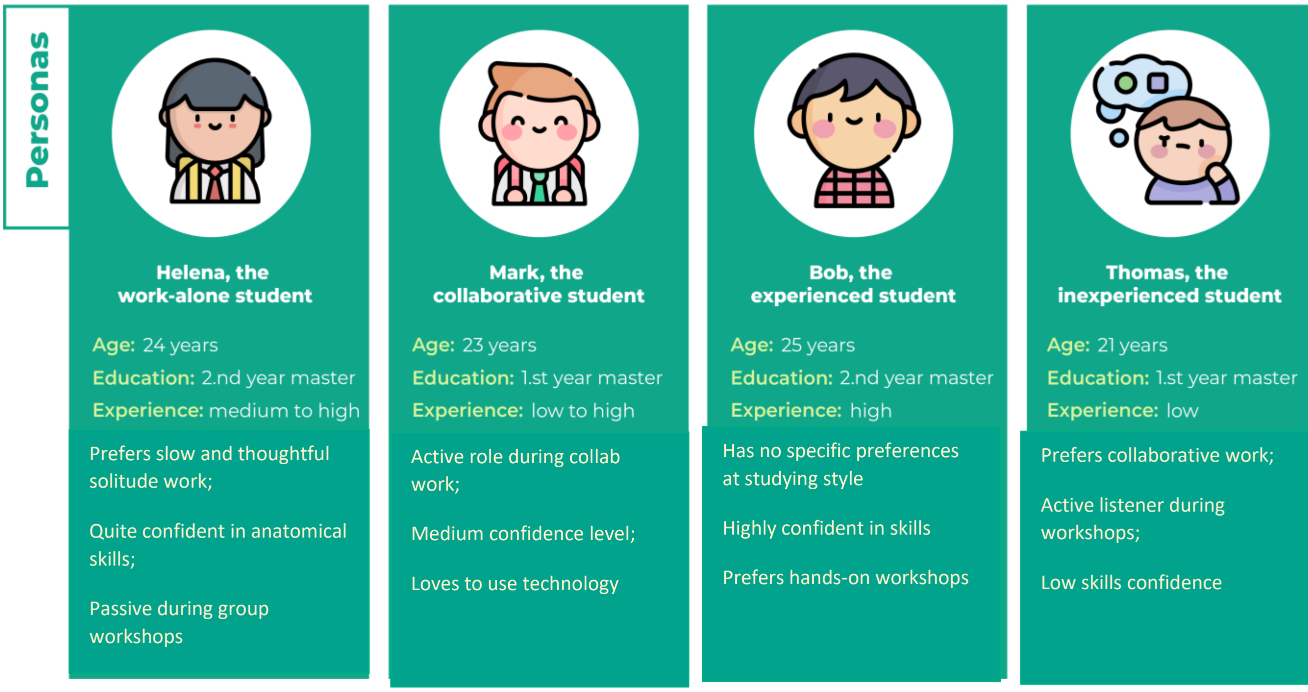


Figure 22 User mapping

5.1.2 Expert Interviews

During the first Explore step, two interviews were held with a professor and a researcher who teach within the field of neuroscience. The first interview was held at the very start of the research formulation and was an introduction to research topic, as well as acknowledgement of the current challenges within learning anatomy, preferred methodological approach to studying and the possible improvements that an AR application can provide, as perceived by a professor. In order to protect the confidentiality and anonymity of the respondents, the thesis will not include their names or any other identifying information. The interview questions are listed in section A.

Interviewees reported that neuroanatomy is mainly taught through the study of textbooks, anatomical atlases and sometimes the use of video materials. Despite the methodological quality and full relevance of the teaching materials to the curriculum, students often lack an understanding of the volumetric structure of the brain, both in terms of internal structure and external elements. Physical experimental seminars with dissection and the study of the internal structure mostly take place during the phase of the Master's programme and are time-limited and resource-consuming. Both professors enthusiastically commented that working with a 3D model in a virtual environment can be an excellent preparatory step before a laboratory study, shortening the students' adaptation time to the procedure, giving a basic understanding of the internal structure and increasing confidence. However, it is not possible to completely replace laboratory experiments with experiences in the application without compromising educational competence.

Referring to the importance of immersion, the professors came to the view that without practical experience of students using the technology, it is difficult to make assumptions, as the process and experience will be individual for each student. Kavli Institute researcher, after the first trial and demonstration of the application, added that a fully immersive experience with the

3D model could be more effective, as images of the virtual world would not overlap with reality objects, which is distracting and prevents focus on the learning process entirely.

In the teachers' experience, students generally prefer to work individually and rarely team up to study together, except for the preparation of assignments. However, during workshops, groups of students succeed much faster and better than individually working students. During collaborative work, students collectively solve problems and make decisions more quickly, and are more engaged in the process, as observed by the professor. Collaborative work sessions usually take place under the supervision of the professor, and in the process, someone in the class takes the lead in the process. Both professors emphasise the importance of the social environment in the learning process and believe that in most possible cases it is worth resorting to peer-learning methodology to improve the learning experience.

Regarding the importance of student assessment of their own performance and student confidence in their skills, neuroscience experts emphasised that more confident students tend to succeed better in tasks, are not afraid to make a mistake in order to correct it in the future, and inspire other students in the learning process. These opinions were formed on the basis of personal observations by professors and are not supported by accurate evidence.

In general, the professors spoke enthusiastically about the aims and questions of the research, emphasised the importance of the findings for the teaching community and the possibility of extending the scientific application of the results.

5.1.3 Literature review

In order to conduct a meaningful and comprehensive study, it is important to investigate the existing academic experience on the theme. In addition to improving understanding of the research area, familiarity with and review of existing sources allows insight into the relevant queries of the field, the methods that researchers apply to the research design, and important theoretical material to support the points made in the thesis. Figure No 23. shows the main keywords for which the sources were searched, filtered and examined.

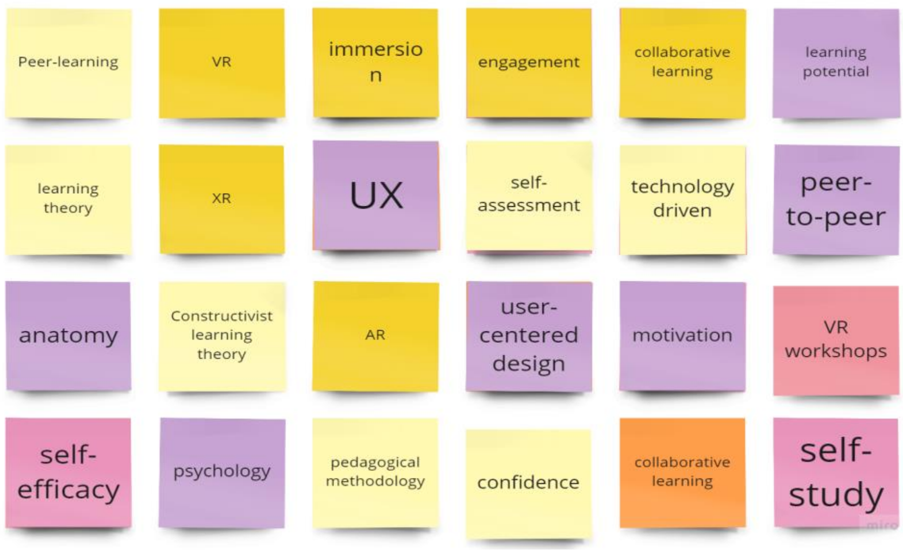


Figure 23 The overview of the used key words

5.1.4 First step summary

This section focuses on summarising the findings of the first stage Explore of the study. This summary will help in the future final evaluation of the research findings, and will also clearly reveal the progression to the next stage of the study. Table No 2. illustrates the findings of the study and divides them into data sources and research questions respectively.

Data source	Peer-learning	Immersion	Self-efficacy
Experts	Prefer collaborative learning during the study sessions	See the potential for obtaining knowledge of spatial structure	Confident students perform better
Literature sources	The importance of social interaction is emphasized in many studies	Immersion is an engaging technology, adds fun and focus	Confidence matters
Students	Various preferences on the learning method, roles and pace	Experiments are needed	Individually, the majority noticed no difference in studying performance

Table 2 – Summary of the phase 1

5.2 Phase II. Define

The first phase of the study outlined the main research topics, defined the scope and methodology of the research, and initial data on users, method and expert advice was obtained to prepare consistently and fully for the next step. After reviewing the data obtained and theoretically reinforcing the initial knowledge about the subjects and objects of the research, the importance of the empirical research became evident.

The preparation for this study included various steps: consultation with teachers and experts, finding and recruiting the target participants, preparing questionnaires, interview questions and a user scenario for the experiment, preparing the equipment and consequently the experiment itself. All of these activities are further revealed, as well as a small indicative analysis of the results is given at the end of Part 2.

5.2.1 The recruitment of participants

After identifying the relevant user group in the previous step, the researcher proceeded to find potential participants for the experiment. In order to successfully reach participants, it was important to create an attractive advertisement explaining the purpose and procedure of the experiment, as well as the potential positive learning effect of the app. A video was created using Adobe to demonstrate the features of the app and the relevance of the study. Fifteen undergraduate neuroscience students responded to the announcement and were divided into small groups for the convenience and efficiency of the ongoing experiment.

Having participants, it was important to formulate questions and create a scenario for the experiment to get the right information in an effective and inspiring way. The questionnaires were created with a synchronised adaptation of the basic principles of UX survey design, an educational and methodological approach to evaluating the academic experience combined with psychological self-assessment questions. The questionnaire is provided in the appendix.

5.2.2 Pre-test

The pre-test of the learning outcome test is included to learn more about the knowledge level of the participants before they interact with the application, The first part of the pre-test asks the participants to rate their own knowledge and skills confidence about the anatomy of the rat brain and the anatomy of the brain they are the most familiar with, in addition to asking about their experience with XR applications and learning preferences. The second part asks the participant to answer a knowledge test created by a professor in neuroscience. This test consists of 10 tasks which ask the participant to name one to seven specific parts in the brain that are marked on pictures of the rat brain or subdivisions of it. The pre-test is given in appendix.

5.2.3 User scenario

For a successful experiment in a multi-disciplinary study, it is not enough to demonstrate an application and receive feedback on the user experience. The experiment should expose the aspects and peculiarities of collaborative exploration of the virtual 3D model, encourage participants to cooperate, feel the importance of immersion in a virtual learning environment, and inspire and allow them to feel more confident in their skills and actions. In order to bring all these requirements together and to meet the 45min experiment, a specific user scenario was developed. The script was designed together with a professor of Kavli Institute and is aimed at individual and collaborative work with the application. The individual work phase is necessary as a measure of familiarisation with the app, adaptation to the device and understanding of the functionality for the participants. In the individual session phase, participants have to find the requested parts of the brain using the different functions of the app. Then, in the collaborative session phase, students had to create a collaborative study session and join in collaborative research and problem solving. In the collab session, students also had to find the parts that were originally shown in the photograph of the dissected rat brain. The next step of the collaborative task was to find and identify the parts in a designated specific region of the brain without the requested structures. And also in the user scenario, special emphasis was placed on discussing certain anatomical terms and structural features with a parallel study of the 3D model.

5.2.4 Post-test

After having used the application in the learning session and completing the experiment scenario, the participants need to fill the post-test. This test consists of four main parts. The first part asks the participant to carry out a new rating of their knowledge about the anatomy of the rat brain and how their perception of their own skills and abilities changed after conducting the experiment. It also asks them which features of the app, they found the most useful to support their learning. The second part consists of the same knowledge test the participants conducted in the pre-test. The aim of this part is to gather data that can be used to evaluate if there is an increase in the knowledge level of the participants after they have used the application in the learning session. The data analysis method used to evaluate the data gathered from the pre- and post-test is described in Section 4.3.3. The third part of the post-test asks the participants to evaluate their collaborative experience within AR, especially their interaction with each other as an essential part of the peer learning approach, how the collaboration in virtual environment with 3D model affected their learning experience. Also post-test asked about the difference of application use on different devices and how the immersion variety changed the learning experience. The full post-test is given in Appendix 5.

5.2.5 Interviews.

In addition to the information from the pre-formulated questionnaires, it was important to get live feedback from the students on their experiences in order to better understand the collected data. To achieve this goal, questions were formulated for the final discussion, where students were able to summarise the main aspects of their experience that were relevant for the study. The short interview included the following questions:

1) What did you like about today's experiment? Why?

2) In what ways was it more interesting and productive to work with the model today?

3) How did the difference in devices affect your experience with the app?

4) Did your confidence in your knowledge and skills increase after the session?

5) How do you think your self-assessment of your competence affects your learning experience?

5.2.6 Process of the experiment

As mentioned in the previous description of participant recruitment, 15 people signed up for the experiment. However, due to high study load, personal reasons, and also not fitting the dates of the experiment with the personal schedules of the participants, 10 undergraduate neuroscience students came to the experiment directly. They were divided into groups of 3-4 students respectively to ensure successful and equal participation of all students in the experiment. The experiment took place in the virtual reality laboratory of IMTEL NTNU.

Initially, students were given consent forms of participation in the experiment, which are given in the appendix. The students then completed pre-tests. In order to ensure the anonymity of students' participation, no personal information or identifying data was collected and each participant had his/her own number. After completing the tests, after a brief safety instruction and an introduction to the experiment procedure, participants proceeded to familiarise themselves with the application and to complete the scenario in KMD Hololens 2 and in the Nevrolens mobile application on the personal devices of the participants. Throughout the learning session, the researcher kept notes on the participants' performance, advised them on how to use the app, and guided them in the app. There were no problems with the mobile version of the app, apart from the technical inability of some participants to run the app on their iPhones. They were given Samsung tablets to continue the experiment, where participants had no trouble exploring the 3D model and completing tasks in the user scenario. In general, all participants encountered operational difficulties with Hololens 2, due to the complexity and sometimes slow response time of the HMD control system. These difficulties arise when first getting to know the device, as using this technology requires adaptation to the functionality and interface. Nevertheless, the researcher observed that participants using Hololens in a study session were much more engaged in the process and were more willing to explore the 3D model in augmented reality. The figure 25 shows the process of experiment.

Figure 24 The Lab experiment

In the collaborative activity with the app, the participants changed the devices used, those in individual work using HMDs switched to mobile devices and other students were able to try their hands on Hololens. Also, to test the remote collaborative function of the app, the students were located in different rooms during the session. From observations during the collaborative work, some students started to feel more confident in initiating parts search and engaging the participants in discussion. When working together, the speed of identifying brain parts increased significantly, despite the methodological complexity of the tasks. When working together, students intuitively distributed roles in the process, changing roles as they worked and as discussions progressed. Also, when students interacted with each other in a study session their engagement in the process increased significantly, with the observation that differences in enthusiasm for using the app on different devices disappeared and students were equally engaged in the process. After 45-50 minutes of the experiment, participants were invited for a final discussion, a post-test and an interview. The analysis of the data from this experiment is described below.

5.2.7 Feedback from the professor.

A neuroscience professor from Kavli joined the experiment and worked with the researcher to observe and participate in the experiment. After a brief discussion following the final experiment, according to the expert, the difference in engagement and enthusiasm of the participants using Hololens compared to the mobile device is due to the novelty of using the technology. This point of view is also confirmed in a similar study by Petersen, where in a similar experiment the involvement of participants using HMD was explained by the excitement of using the new technology (Petersen G. B., 2022). The professor also emphasised the importance and effectiveness of peer collaboration during study sessions, noting improvements in accuracy and speed of decision-making. Greater involvement in the learning process was also noted, as confirmed in a study of in which medical students working together were able to significantly improve their performance compared to the group working alone and under the supervision of a teacher (Tullis, 2020). The tacit allocation of roles in collaborative work was explained by the psychology of the participants, as in this series of experiments there were different dynamics of interaction between the participants in each group. Overall, the expert was satisfied with the experiment and the results obtained.

5.2.8 Evaluation summary of the Second phase

To summarise the second part of the research, it is worth noting that the objective of collecting relevant data during the empirical experience has been achieved. In the analysis of the findings, particular attention was paid to the data that directly forms the determinants of the current research questions. For this reason, in the following discussion of the data, the most relevant information for the study is presented and analysed by qualitative and quantitative methods, with theoretical support from the relevant literature. The figure 25 illustrates findings regarding the first research question.

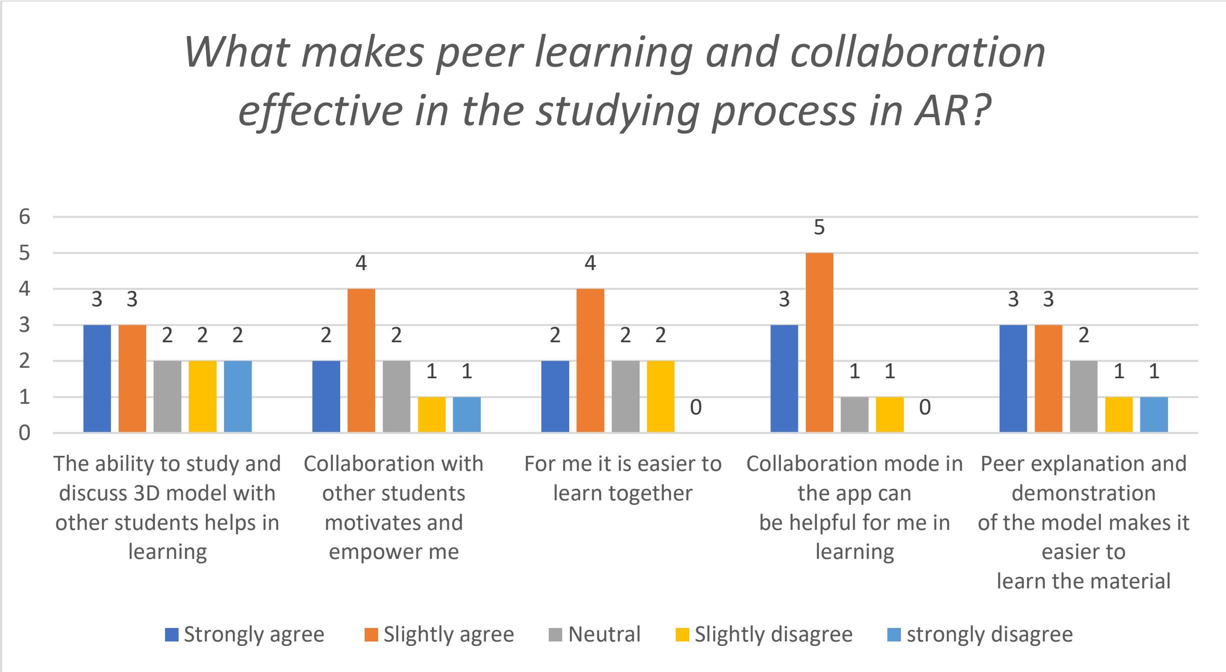


Figure 25 What makes peer learning and collaboration effective in the studying process in AR?

Considering the data obtained after the series of the first experiment, focusing on the directly important for the research question of the effectiveness of augmented reality peer learning, the first findings can be reported. According to the feedback from the students, for the majority of the participants, the collaboration with the augmented reality model improved and accelerated the learning process. This is also confirmed by the observation of the participants as it took them less time to work on the tasks for the joint session. Also, working with other students is encouraging and adds confidence to most of the users, which was also noted by the professor when observing the increased enthusiasm and engagement with the assignments. 60% of respondents said that it was easier for them to learn together with others, as demonstrating certain parts of the brain and explaining to peers helped them to learn better and more easily. 80% noted the usefulness and importance of the collaborative mode in the app for interacting with peers in study sessions.

These results will be analysed in more detail in the final summary evaluation of the app and closure of the research questions. However, at this stage of the study, it is worth noting that the results overlap with findings from other studies and confirm the importance of constructivist theory in education regardless of the study session setting (Cassidy, 2016). Details are illustrated in figure 26.

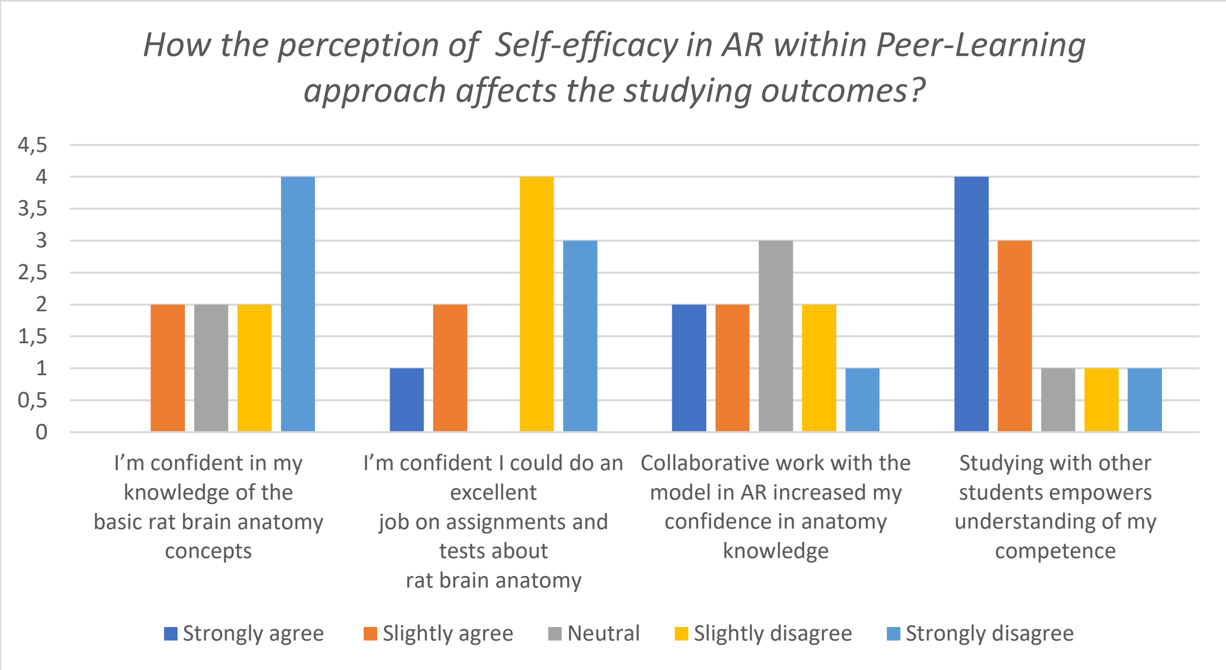


Figure 26 Self-efficacy test highlights

The data obtained after the experiment with the bachelor students shows a low level of confidence in their own anatomical knowledge, which is absolutely logical in relation to the beginning of the academic neuroscience journey. Nevertheless, after the experiment the students were able to slightly increase their self-confidence. There are several explanations for this phenomenon in educational and psychological theories of self-perception, which will be revealed in the final part of the summary of the study results. The fact that it is after working together that students feel more confident in their abilities confirms the aforementioned importance of the social side of knowledge acquisition highlighted by constructivist educational theorists. (Miller, 2011). Figure 27 points to the most relevant aspects of the immersion evaluation.

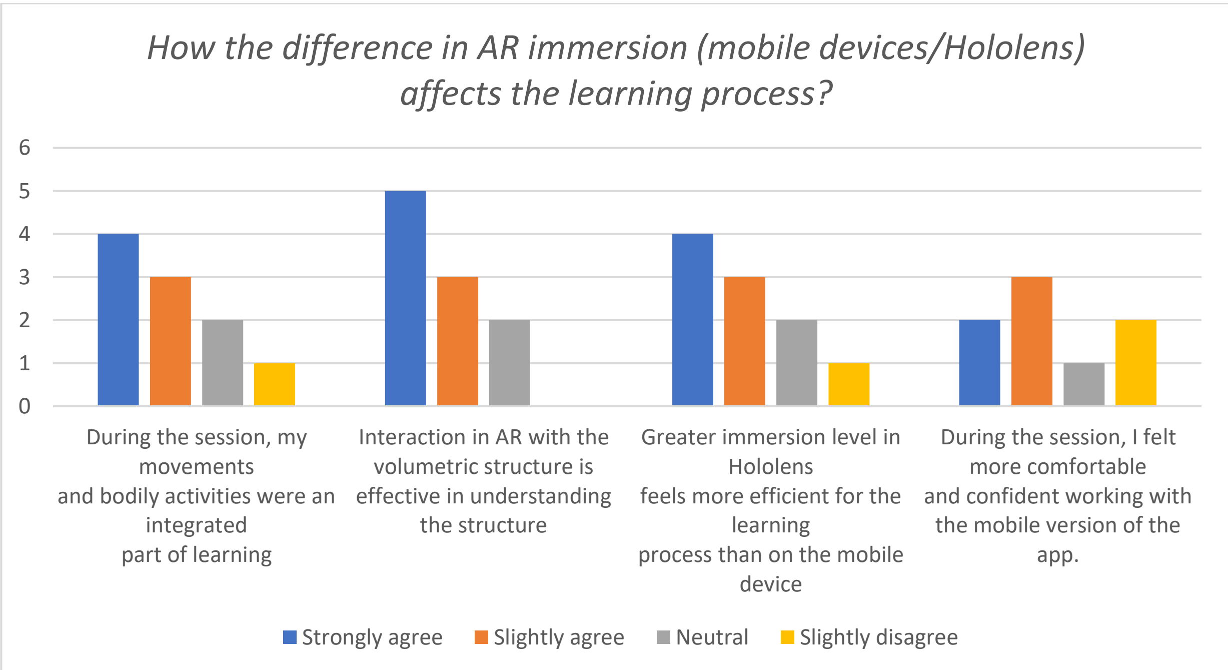


Figure 27 Immersion evaluation

Research findings on the role of immersion on the learning experience focus on the main defining features of this function. For students, the ability to interact and influence the brain model through gestures and body movements is a significant and enhancing learning experience. As well as the ability to perform various manipulations on the brain model improves the understanding of the volumetric structure of the brain, which from the very first interview with neuroscience professors was called a vulnerability of neuroanatomical learning. The new immersive, interactive experience of interacting with the model in the Hololens HMD was described by the majority of respondents as effective for learning. However, on the other hand, also half of the respondents noted the convenience and confidence of using the mobile version of the app, where the level of immersion is much lower. This twofold information is an interesting factor that is worth exploring further in future experiments or studies.

5.3 Phase III Develop

5.3.1 Expanding the study

During the third phase of research development, having obtained sufficient relevant data from empirical experience, consultation with experts, and review of corresponding literature, it was important to focus on developing and extending the study. As the study combines the application of educational theory in the design of the application, examines the user experience as well as the psychological aspects of learning, in addition to experimenting directly with the key audience of the NeuroLens application - the academic neuroscience population, it was important to conduct trials, interviews, and generally obtain expert opinions from areas directly relevant to the research objectives. In the process of revising the research questions and research strategy, it was decided to conduct experiments with Master's students from the fields of IT and pedagogy.

Evaluation and feedback from IT specialists can provide useful insights into the functionality that enhances and supports the collaborative characteristics of an application. The perspective of people working directly from the inside on creating, designing and supporting applications for collaborative work will expand the research by understanding exactly what features make collaborative work in an application engaging and inspiring. As well as how IT researchers view immersive virtual environments in terms of improving user engagement and performance.

The opinions of pedagogy experts can better reveal a methodological perspective on the app's educational effectiveness. Pedagogical students can evaluate how the features performed in the app influence the learning process from methodological and psychological aspects of learning. Also their feedback can be useful in evaluating the peer-learning approach, especially when working together in a digital environment.

In addition to planning experiments with students in two areas, interviews and demonstration applications were planned with a group of teachers working in the field of creating and using AR technologies in educational practice. The aim of these interviews was to obtain qualitative data and evaluation of the application in terms of practical application of technology in collaborative learning, as well as insights from their experiences of working with students in AR.

5.3.2 Testing with Masters in IT and pedagogy

Nine people took part in the second interdisciplinary application test. 4 Masters students from Applied Computer Science and 5 Masters students from Pedagogy. The experiment took place in the VR laboratory of IMTEL NTNU, and in preparation for the test the questionnaires of the participants were shortened and reformulated. Questions about knowledge of the rat brain were removed from the pre-test and post-test, due to the unnecessary request for confirmation of anatomical competence. The questionnaires were widened towards the respondents' competence areas, with the request for research-relevant objectives, and the updated version of the questionnaires can be found in the appendix. Before the experiment began, participants completed consent forms of participation, familiarising themselves with their rights and the academic use of the research data. During the experiment, observation notes were taken by the researcher and participants tried the app on mobile devices and Hololens individually and collaboratively remotely. The results of the surveys and interviews are shown below.

5.3.3 Testing with experts in AR learning.

During a guest visit by a delegation of virtual reality practitioners, the researcher was able to conduct a series of demonstrations and interviews. Due to the limited time of the experiment, textual questionnaires were not used and all information was obtained through verbal interviews. The group of experts were interested to try out the compatibility of the collaborative session on different Hololens platforms and mobile devices, and they shared their experiences of using virtual and augmented reality applications in training for construction workers, engineers and manufacturing workers. In total 4 experts took part in the interviews.

5.3.4 A discussion on the results of the experiments.

As a result of the experiments, data were collected on the use of the Nevrolens application by Master of Applied Informatics and Pedagogy. The main points of the findings are supported by relevant theory and summarised below.

IT experts on collaborative work in an AR application

- From the perspective of technological design, one of the mandatory features for a collaborative learning session is the possibility for the participants of a study session to interact with the educational material simultaneously. This provides an equally interactive experience, allowing joint exploration of the learning material without disrupting the process and increasing the involvement of the participants. This insight has been theoretically supported by numerous studies (for example (Ferrer-Torregrosa, 2017) where one of the determining factors in creating a successful collab app was to ensure that all students participated in a single and meaningful way in a medical procedure. The Nevrolens app allows up to 10 participants to join a collaborative session and ensures that everyone is working synchronously on the model. (Haugum, 2022)

- The next important feature of successful cooperation in an AR study session is the participants' understanding of the physical/virtual location of the other involved. As well as awareness of the participants' belonging to the actions being performed (Billinghurst, 2021). In addition to spatial awareness of the location of peers, the ability to identify actions with a specific person enhances the learning process, especially when remote voice communication is possible in the app. In the Nevrolens app, participants are displayed in augmented reality in the form of nickname spheres, and features to improve the visibility of the participant's connection to the activity will be added soon, as well as voice support for chat in a collaborative remote session.
- Moreover, IT professionals have highlighted the importance of mechanisms for engaging participants in collaborative work, such as the ability to test knowledge in tests, interactive game-based collaborative tasks, and the ability to ask each other questions and create tasks. Most of these features exist in the current version of the Nevrolens app, and the importance of game-based, competitive elements during study sessions has been confirmed by research of Garzon on the application of game theory in educational methods of using technology (Garzon, 2020).

IT experts on features that improve user confidence during a learning session in AR app

- Information accessibility and user-friendly functional design. From a user experience standpoint, the less the user suffers with mastering the app, its features and responsiveness, the more the app inspires and empowers the user. The intuitiveness and ease of access to information allows one to focus directly on learning, without wasting time and efforts on mastering technology. This monumental pillar on the importance of the app's usability and functionality is highlighted in a number of studies, where much of the feedback on the app's usefulness was based on operability and usability, which inspired and empowered users. (Milgram, 2011) The mobile version of the Nevrolens app is, according to user feedback, more intuitive and easier to use. On HMD Hololens, the users are more likely to experience difficulties in using and mastering the app.
- Support and appreciation of users' actions by the app is also mentioned by experts as an important function to increase users' confidence in their actions and consequently in the knowledge and skills gained. This corresponds to a psychological study of Emaliana where students receiving positive feedback even for minor actions were more motivated to learn and more confident in their abilities (Emaliana, 2017). In Nevrolens the user receives feedback during a quiz task.

IT experts on the role of immersion in AR in the user experience.

- According to numerous studies, as well as responses from IT professionals, immersion in a virtual environment when working with an application increases the engagement in the learning session and often the enthusiasm of the learners (Bowman, 2007). However, immersive experiences do not always improve the learning process and user experience. Sometimes participants in a virtual reality session may experience symptoms of cyberbullying, which prevents them from continuing to use the app (Ravna, 2021).

Master students and experts in pedagogy about peer learning in AR.

- 1) According to the expert interview, the learning approach of peer learning increases the sense of responsibility for the learning process, as when working together students unintentionally constantly compare their skills with their peers, trying to succeed or at least be at the same level (Schunk, 2002). Also, because of the dynamism of peer learning roles, students feel a special responsibility for their competence to ensure successful collaborative work. Co-learning with peers also accelerates the speed of decision-making when sharing responsibility for the output. In the Nevrolens application, studying the 3D model together, students have to jointly address issues that emerge and work together in identifying the anatomical parts, which increases student engagement, interest and responsibility for learning.

- An important positive feature of peer-learning is the psychological factor of facilitating the perception of information from a person who is at a similar level of knowledge as the other students. In addition to simplifying and intuitively perceiving knowledge, the process of explaining material to peers increases confidence in one's knowledge and in the material being learned. When working in the Nevrolens app, students cooperate to solve a learning challenge, as well as switching roles of tutor in a learning session. However, augmented reality learning experts have stated the importance of the teacher explaining and guiding the user in the Nevrolens learning session.

Educators on the importance of self-awareness and confidence

- Students' self-confidence in their knowledge and skills in learning is often shaped by their commitment to the subject. In educational practice, interest usually develops in the process of learning about the educational subject itself and the more engaged the student is in the process, the higher the assessment of his/her knowledge and the more confident he/she is in making decisions. This has been confirmed by psychological research into the phenomenon of self-perception in practical training in medical education (Stojanovska, 2020). Learning in augmented reality inspires students to perceive knowledge with its function, thus increasing their interest and consequently developing their confidence in their own skills.
- Another practical observation of education methodologists is the confidence and determination of students in their decision-making (Driscoll, 2011). When working together in Nevrolens, this was confirmed by a group of experiments where students were more confident and willing to make decisions, feeling more confident from peer support and feeling proud of mastering and working effectively in the application.

5.4 Phase 4 Decision

In the final phase of the research preliminary results were summarised from the data obtained in the previous phases of the study and analysed with the help of relevant sources. After consideration and consultation with the supervisor and an expert from the Kavli Institute it was decided to conduct the final experiment with experienced master neuroscience students and PhD students as well as to collect views on the application and research questions from industry representatives who directly use augmented reality technologies in their professional work in training personnel.

Recruitment and enquiries were made to organisations for expert interviews in order to obtain relevant insights.

5.4.1 A test with neuroscience experts

Three master's students and one postgraduate student of neuroscience were interested in participating in the experiment. This time the test took place in the anatomy laboratory of St Olav's Hospital and together with the follow-up interview took about one hour. Participants read and signed consent to participate in the experiment with guarantees of anonymity and academic conditions of information use and completed a pre-test of neuroscience knowledge. After a short training session, the participants immediately joined the remote session and worked together to explore a 3D volumetric model of the brain. The researcher observed that the participants were vividly engaged in the study and discourse, working confidently on the test tasks. After completing the user scenario, the participants answered post-test questions and gave their feedback in an interview. Figure 28 illustrates the workshop.

Figure 28 Workshop with neuroscience experts

5.4.2 An interview with an industry representative.

Due to the increasing popularity of the usage of augmented reality technology, its application today can be found in a variety of professional fields. From virtual clothes fitting or viewing the house to training surgeons or the military (Freedman, 2023). The expert who wished to take part in the study was a representative of an independent research organisation, where virtual reality applications are mainly used to train employees in various scientific fields.

After a demonstration of the AR Nevrolens app on Hololens 2 and a smartphone and a short collaborative session, an interview was conducted to discuss the main features of using AR in professional training concerning current research questions.

Hence the expert emphasised that cooperation and learning peer to peer is given a high and positive priority after the introductory briefing on the topic of training, but few applications have user-friendly and functional options to ensure efficient work. Nevrolens, according to the expert, is a handy tool for collaboration, since the key functions are present in the app. According to the training experience, employees working in groups succeed faster by learning and exploring material together, and they remember content or experience procedures better. Augmented reality does not give full immersiveness to the experience, so it is difficult to assess the role of this measure in Nevrolens, especially on mobile devices. Nevertheless, the use of the app on Hololens enhances the immersion and presence in the virtual learning environment, especially through the ability to navigate the model in space, to move around oneself, and to manipulate the model with gestures. In other words, the immersiveness of the headsets enhances the educational experience. When asked about the impact of self-assessment on work/learning performance, the expert replied with a smile that competence is coming from confidence and from her experience more confident employees usually succeed faster. When using a well-adapted AR application, people usually increase their confidence based not only on their knowledge and skills, but also on the feeling of using new inspiring technology. Overall, the expert noted the promising learning potential of the app, with a disclaimer on improving the stability of the app, creating voice chat and improving collaborative features.

5.4.3 Results of the experiment

This section presents the results of the masters' tests from the final stage of the study, which are comparable with the discussed answers of the bachelors' tests from the second stage of the research. A comparative analysis and summary of the results of the study is presented in the next part of the work. Figure 29 illustrates relevant findings on the peer-learning.

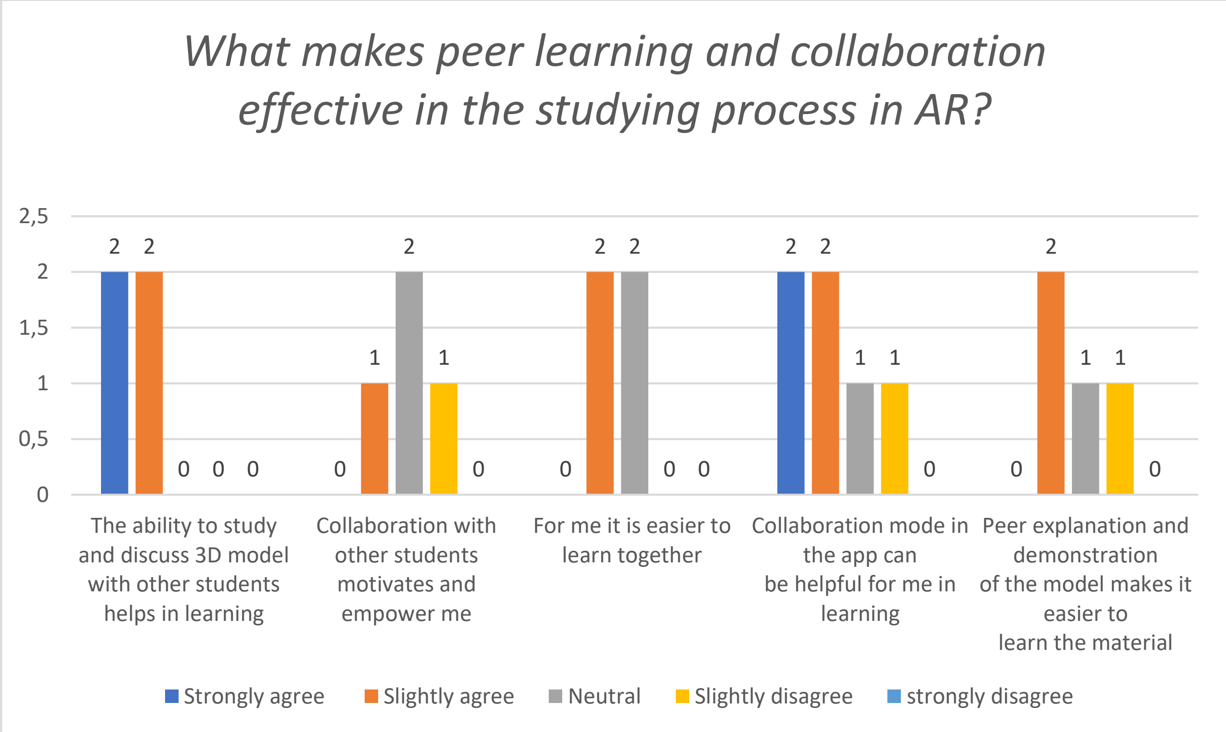


Figure 29 Peer-learning feedback

The participants in the experiment had a generally positive attitude towards working together in AR, but it also depended on the student's personality preferences. However, it is worth noting that during the experiment all participants actively and enthusiastically interacted with each other during the performance of the learning task.

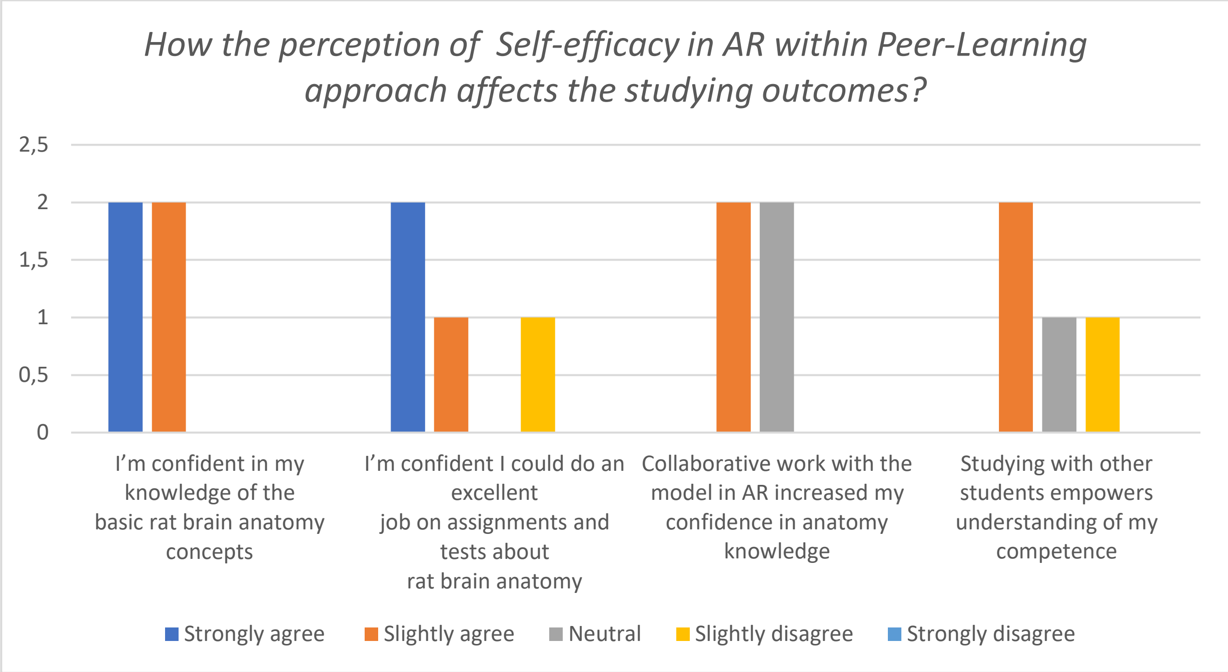


Figure 30 Self-efficacy within AR

Based on the findings, the confidence of Master's students in their competences is significantly higher than the Bachelor's, which can reasonably be explained by higher competence and experience in neuroscience. Also, even in the small group of participants a positive tendency can be seen to assess the impact of cooperation on increasing confidence in their competences. Figure 30 highlights the relevant self-efficacy points.

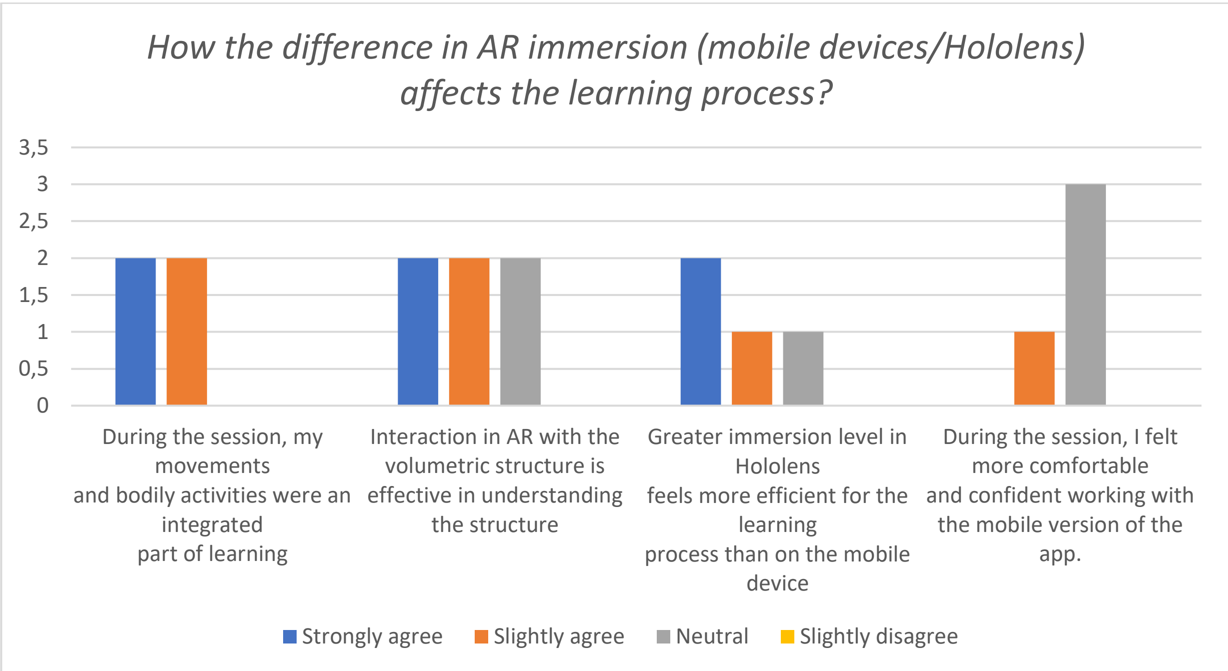


Figure 31 Immersion assessment

When discussing the importance of immersive experiences, students noted the importance of gesture control and the higher effectiveness for learning using the Hololens headset. Figure 31 illustrates the assessment of immersion.

CHAPTER 6 THE EVALUATION SUMMARY

This part summarises the findings of the research. It considers the relevance of the data acquired during the research to the aims and objectives of the study, and summarises the research questions. Moreover, the chapter presents a discussion of the limitation in the research project and how they can have affected the produced results.

6.1 Research goal and research questions

The main research goal of this thesis is to evaluate the learning potential of peer learning and immersion in AR. This goal was formed during the consultation phase in cooperation with the Kavli Institute and the iPear Project. For an educational institution that has very recently developed the augmented reality application Nevrolens together with the IMTEL VR Lab NTNU, it is important to obtain a qualitative assessment of the educational function of the application. This means that the existing application corresponds to its intended purpose as an interactive and useful neuroscience learning tool. For the iPeer project, which investigates the application of augmented reality technologies in collaborative learning, the evaluation of the educational potential of the new Nevrolens app is a useful contribution to the theoretical framework of the research. Combining the requests of the two scientific communities the aim of this Master's thesis was formulated.

The research method was based on a design thinking model, which is consistent with the mixed methodology of interdisciplinary research. The research method determined the strategy used and the design of the topic. In addition to detailed research of existing relevant sources on the topic, the research has an extensive empirical basis. It is in the synthesis of practical findings and theoretical foundation of the research results the final conclusion of this Master's thesis is formed. The final conclusion of the study will be summarised after consideration of the research questions.

RQ 1 How peer learning and collaboration in AR affect the studying process?

The positive impact of peer-learning on learning has been highlighted throughout the work in many parts of the study. This concept is also one of the main points of the popular and widely used constructivist educational theory. Despite the popularity and sustainability of the concept, its application in the collaborative use of augmented reality technology has not been measured.

In the interdisciplinary study combining new technologies and classical educational methodology, the learning potential of peer interaction in augmented reality was measured by a neuroscience knowledge test before and after the collaborative use of the Nevrolens AR app. The test is available in the app and a representative selection - in Figure 32 is shown below.

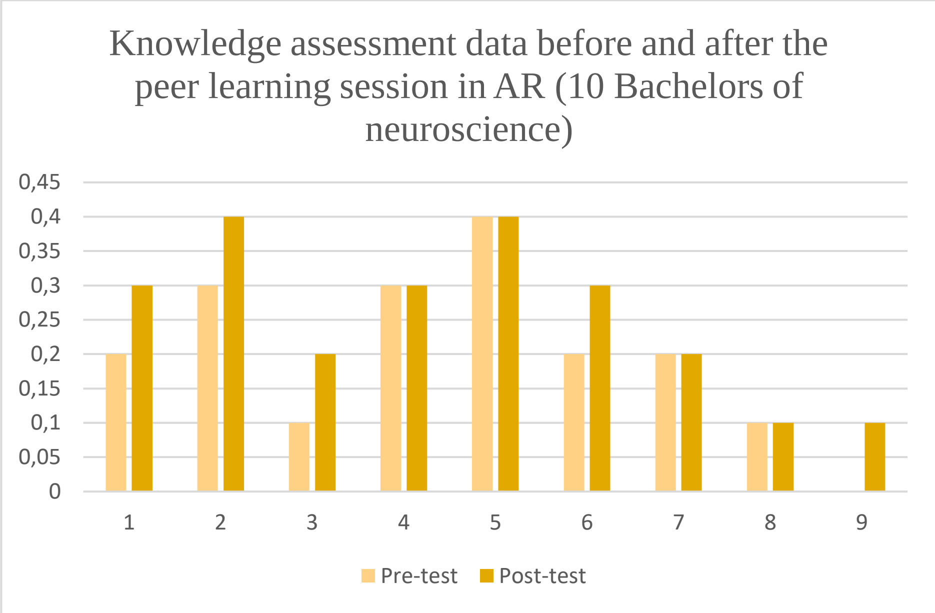


Figure 32 Bachelors knowledge test

A description of the test, as well as the main findings, is described in section 5 in the second phase of the study. The graph illustrates the results of the anatomical test consisting of 9 questions, visualising the sum of the number of correct answers of the bachelor neuroscience students taking part in the experiment. The obtained results indicate that the use of the Nevrolens application in collaboration with peers could have a positive learning effect for some of the users. However, the difference in the mean score between the knowledge test of the pre- and post-test was not significant. Therefore, it cannot be stated that the Nevrolens application can contribute to a significant increase in the knowledge level of the users. This result can be caused by the features not facilitating learning of neuroanatomy to a sufficient extent. At the same time, learning is a complex process that often requires repetition over longer periods of time. Many students likely require longer and repeated learning sessions in order to learn neuroanatomy from using the application. Additionally, as the expert stated in Section 4.2.3, students need to learn how to use the application and the HoloLens before they can start focusing on learning neuroanatomy. Moreover, the limited time of the experiment and the lack of opportunity to repeat the test with these users is an evident limitation of the study.

Despite the lack of significant change in knowledge scores, most respondents were positive about their experience and progress in working together in AR with their peers. These results are presented in the discussion of the first experiment in the second phase of the study. Summarising the findings, 40% reported a significant positive impact of collaborating with other students during the study session and 70% reported increased confidence and motivation from working together. Overall, over 60% reported an improvement in their educational experience when interacting with the peers.

The data obtained after the final test with Masters and PhD students in neuroanatomy are almost identical. Figure 33 shows the master students assessment.

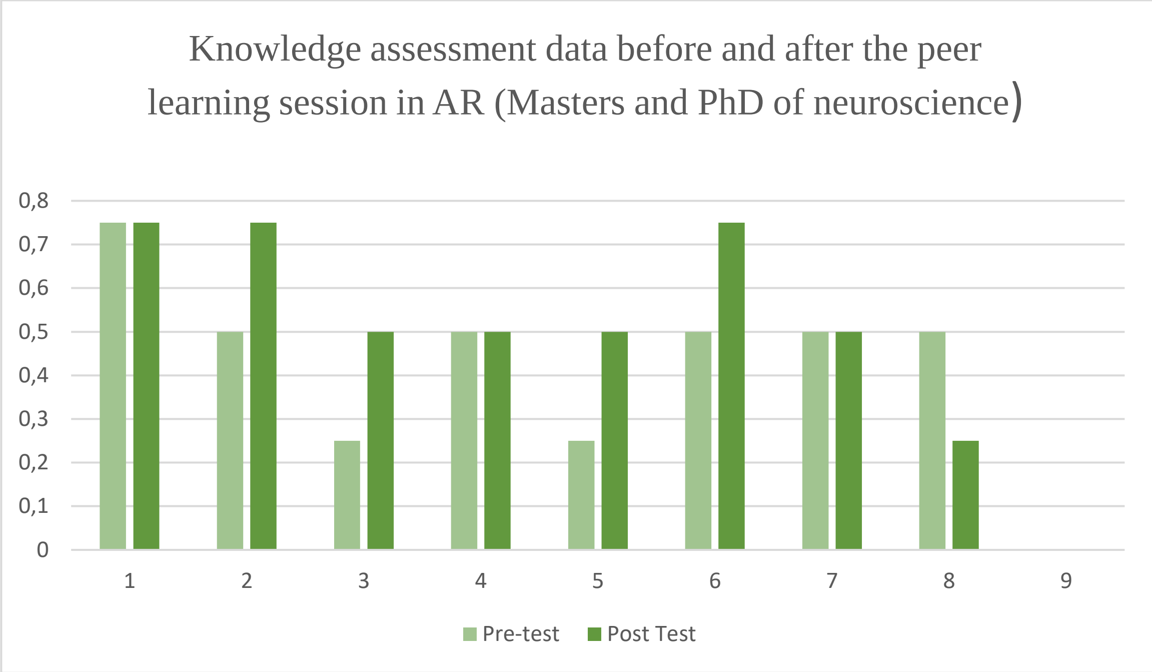


Figure 33 Knowledge assessment data before and after the peer learning session in AR (Masters and PhD of neuroscience)

In general, there is a slight increase in the correct answer rates. The results of the test with the more academically advanced neuroanatomy students show a slight positive dynamics in the improvement of knowledge from the use of the Nevrolens AR app in a collaborative mode. Also based on the post-interview it is worth to mention the students' statements about the increasing interest in the learning process and the easier decision-making together with other students.

During the third phase of the study, which is described in detail in the section, the IT and pedagogy students and experts who took part in the second demonstration and discussion of the app did not complete the neuroanatomy knowledge tests. however, from the experts in creating augmented reality apps, the importance of arranging collaborative sessions to accelerate learning was emphasised and the IT students pointed out that one important factor for the success of the collab app is its ability to encourage users to cooperate (Andrade H., 2019). These features are present in Nevrolens and therefore the experience of collaboration with the model was considered a success by the pedagogy masters. They noted that the app, with the exception of some administrator functions, provides an absolutely equal experience of participation and implies equal distribution of learning roles when working together. This encourages and discreetly pushes the participants to cooperate, which is the key to a successful learning process (Azevich, 2019).

The first question of this study can therefore be summarised as follows: Based on three tests with different groups of students, working with peers in an augmented reality setting slightly improves knowledge scores, increases confidence and motivation to master a subject, and is an important component of the psychological side of learning and the creation of a productive learning environment.

RQ 2. How the difference in AR immersion (mobile devices/Hololens) change the learning experience?

Augmented reality is not a fully immersive technology; virtual reality objects are overlaid on a physical setting. Nevertheless, the experience in AR in HMD Hololens 2 and on mobile devices cannot be characterised as the same. Hololens gives the feeling of 'being there' when working with the app, bringing it closer to a mixed reality (MR) experience (Makransky, 2020).

Participants of all tests were able to try out the Nevrolens app on mobile devices and in the HMD. Although there were technical problems with some of the Hololens launches of the app, the biggest challenge for the participants was getting to know the handling, which requires adaptation. Based on the results of the surveys and interviews, the following findings were obtained.

80% of undergraduate students stated that they had preferred to use the Hololens app for learning AR because of the immersiveness of the experience. They cited immersiveness as a factor that was more inspiring and supportive for learning. However, in terms of usability and interaction with the model, more than 70% referred to the mobile version of the app. This inconsistency is possible due to the limited user experience with HMD, the complexity of management and the emerging bugs in the application. Discussions highlighted the importance of an immersive, hands-on learning session as this brings the experience closer to the real one.

During interviews with masters and postgraduate students in neuroanatomy, the importance of performing physical actions when examining a model, such as dissection, was highlighted. By virtually gesturing upon the model, perception of the volumetric structure of the brain is strengthened, which will be useful when memorising the internal structure and preparing for a real laboratory dissection. This group of users unanimously chose Hololens for AR, which may, however, be due to the lower number of technical difficulties when working on Hololens.

Neuroscience experts noted the convenience and accuracy of the reproducible 3D brain model, but several noted that if the model overlaps with real-world objects, this overlap is distracting and prevents focus on the study session. Once again they highlighted the manual complexity and instability of the app.

In general, the immersiveness on Hololens HMD is the preferred educational option, which might, however, be described as attractive and entertaining rather than a defining educational experience (Parong, 2020). Nevertheless, according to the given data most users will prefer the immersiveness of Hololens when using the application.

RQ 3. How self-assessment affects studying outcomes?

Self-efficacy refers to one's perceived capabilities for learning or performing actions (Schunk 2016). In a meta-analysis of Sitzmann stated that computer-based simulation games can increase self-efficacy by 20% Sitzmann (2011). Several empirical studies investigating the effect of AR-based lessons on self-efficacy have also identified positive effects (Petersen G. B., 2020) Immersive simulations can increase self-efficacy through immediate high-fidelity feedback on one's actions and choices, As self-assessment is often shaped by the perception of receiving approval from significant, as the situation requires, assessors. In learning, this evaluator is the teacher, and when working with the app, the algorithm that evaluates the user's actions.

For practical answers to the question of correspondence between research on self-efficacy in neuroscience and work in the Nevrolens AR app, the following collection of results was made. The figures 34 and 35 below show data for participants in the two experiments, with the numbers of participants on the horizontal line indicating the level of knowledge self-efficacy, the vertical line indicating the generalised knowledge test score, and the lines showing the dynamics and dependence of student performance before and after the study session.

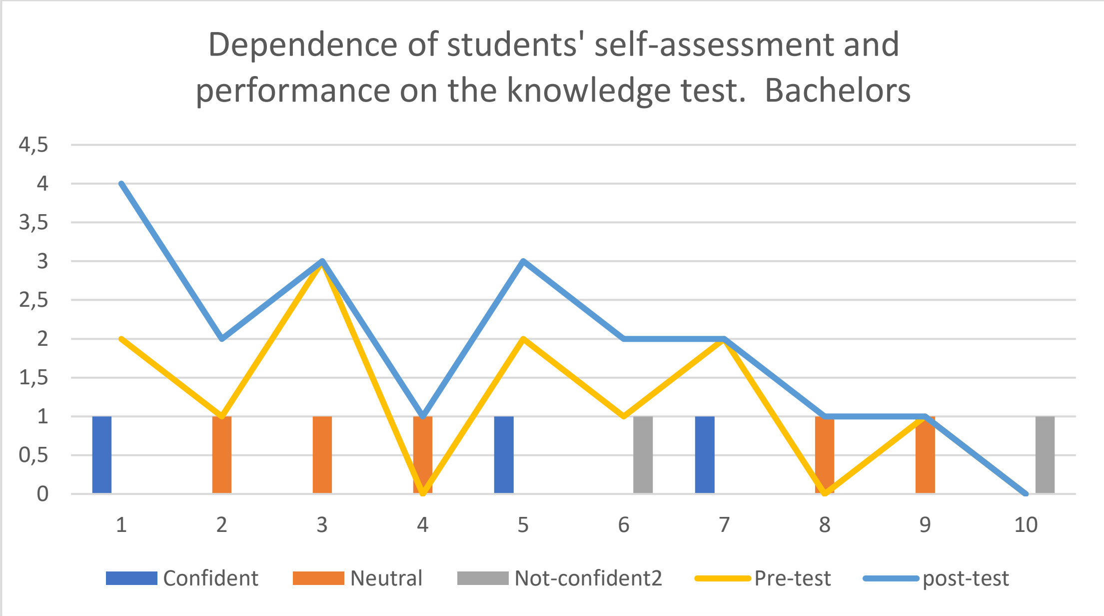


Figure 34 Dependence of students' self-assessment and performance on the knowledge test. Bachelors

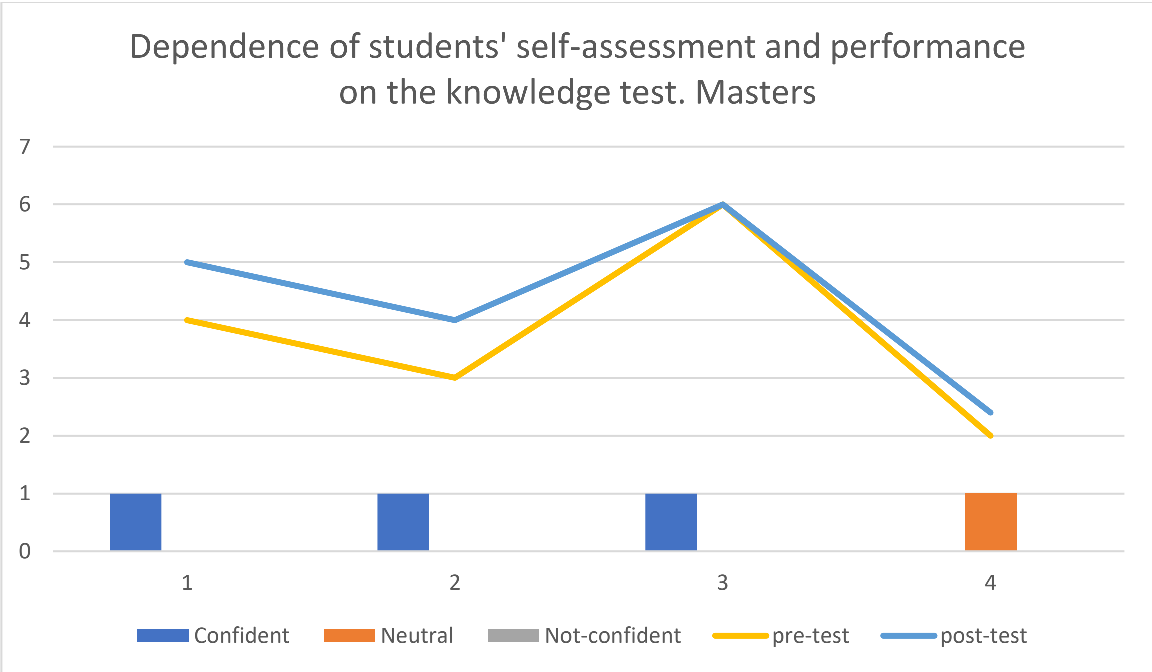


Figure 35 Dependence of students' self-assessment and performance on the knowledge test. Masters and PhD

The graph visualises the correlation between self-assessment and the knowledge test, showing that students who were initially confident in their knowledge improved slightly as a result of the post-test. According to feedback from pedagogy experts and industry representatives, confidence in personal knowledge and skills improves the learning experience, as confident students tend to work more enthusiastically on a subject, make better decisions and adapt more easily to changing circumstances. The limitations of this finding are the experimental setting of the data collection, as in the unfamiliar environment of the VR lab, some students may have felt uncomfortable and nervous about the novelty of the study session. Moreover, it is important to consider the personal characteristics of the student when collecting and reviewing the results.

To summarise the third research question, this study obtained empirical evidence stating a positive effect of positive self-efficacy on learning experiences and performance. Nevertheless, due to the limited amount of data obtained, it is important to extend the study with more participants. The Nevrolens app is lacking of any mechanism of user approval for performing correct actions, so the findings on this research question can be considered a recommendation for future improvement of the app's features or in the design of a new one.

6.2 Reseaech limitations

This section presents some of the limitations of this research project that can have negatively affected the process or the results. These limitations are limited resources, challenging recruitment of users, limitations of the learning outcome test and user interview, potential influences on the qualitative analysis.

- Limited Resources

One of the main challenges of this research project is that it has been conducted with limited available resources, such as restricted time and limited experience within interdisciplinary research within pedagogical and technological fields. The limited experience meant that the researcher had to spend time at the beginning of the project to learn the necessary methodology and technology.

- Challenging Recruitment of Users

Another main challenge of this research project has been to recruit users from the intended user group to participate in different activities during the research project. These users include neuroscience, medical and anatomy students and personnel from the Kavli Institute. It was challenging to recruit a sufficient number of participants for educational sessions which can have affected the results in a negative way. One of the reasons behind the challenge of recruiting students was likely that the test and interview were performed at a time in the semester when the students were busy practicing for their exams. The limitation in the number of participants means that the overall results may not be representative.

- Limitations of the Learning Outcome Test and User Interview

To mitigate the challenge of recruiting students to participate in the learning outcome test and user interview, the length of these activities was restricted to one and a half hour. This restriction meant that there was limited time to execute the different steps of the test and the interview. The participants only got to use the Nevrolens application for approximately 45 minutes which limits the amount of time available for learning neuroanatomy. This limitation can affect the quantitative analysis of the learning outcome discussed in Section 8.2. Learning is a process that requires time, so if the participants were given more time to work together with the application they could have performed differently on the knowledge test of the post-test.

- Potential Influences on the Qualitative Analysis

The researcher plays an active role during thematic analysis and might thus influence the results. For this research project, the researcher played an active role in the thematic analysis of the user interviews and the coding of the expert interview and demonstration feedback. Therefore, the presented results from these activities might have been influenced by the views, knowledge, and goals of the researchers.

The researcher identified three main aspects that might have influenced the results of the activities mentioned above. Firstly, the researcher is a student herself and have some pedagogical experience. As a result, the reported information might reflect the view on anatomy learning and learning preferences as student. Secondly, the author conducted a literature review and four iterations of the design thinking process before collecting and analysing the data. Due to these activities, the knowledge about AR was acquired and its use in anatomy education, advantages and disadvantages with AR, and recurring themes within these areas. also, some insight into the perspectives of the user groups was gained. This knowledge and insight might influence viewings and readings of the data. Lastly, the research goal and questions were defined before the analysis started and, as stated in Section 4.2 , the thematic analysis focuses on aspects connected to the research goal. The knowledge of the researcher about which research questions were supposed to be discussed and answered might have influenced the reported results.

CHAPTER 7. CONCLUSION

The main objective of this interdisciplinary study is to evaluate the learning potential of peer learning and immersion in AR which is a multifaceted task requiring a creative and multidimensional research. For this reason, adaptation of the Double Diamond Design Thinking model and qualitative and quantitative analysis of the findings were chosen as the research method to fully and comprehensively address the objective. The design research method was chosen to fully address research questions from different scientific fields: pedagogical methodology, technological design and psychological factors of educational theory harmoniously combined in the concept of measuring peer learning experiences in augmented reality. The study consisted of 4 broad phases, each of these phases being subdivided into separate stages in order to reveal the topic of the study in different ways. At each phase, after the collection of relevant data and feedback, a further research strategy and design was undertaken by analysing the findings, focusing on the collection of additional data that expanded and refined the research findings.

To answer the goal of this research project, three research questions were defined. The first question was aimed at finding how peer learning in the Nevrolens AR app affects the educational experience. In order to answer this question, the results of a series of knowledge tests with different groups of neuroscience target users were analysed, and the results showed a small positive dynamic in student knowledge of rat brain parts after a joint session in AR. Data from interviews with participants and neuroscience professors emphasised the importance of collaboration with other students during the study, emphasising increasing motivation and engagement. Especially when using immersive and encouraging AR technology.

The second research question focused on focusing on the role of the immersive technology feature of augmented reality and its impact on learning. As users tried the app in two versions on mobile devices and in the Hololens 2 headset, the difference in immersion was apparent to them, as the experience of using Hololens is closer to mixed reality. Despite the technical issues that emerged, most users preferred to use the app in the headset, as the ability to gesture control the 3D model gives a better understanding of the volumetric structure of the brain, and is also generally a more engaging learning experience.

The third research question focused on examining the impact of students' self-assessment on the educational process. Based on the analysis of data on learners' self-efficacy and their learning performance in knowledge tests, it was noted that more confident students had a slight positive dynamic in tests. This fact was also confirmed by pedagogical and industry experts, who noted that psychological positive self-esteem helps to more easily cope with difficulties experienced, helps to make better decisions more quickly, and is also related to interest in the subject being studied.

Therefore, having considered the main aspects that constitute the phenomenon of peer-learning in AR from a variety of experiences: methodological-educational, personal-psychological and the application of a suitable digital technology, it can be stated that the research objective has been successfully fulfilled. However, some of the limitations detailed in the part can affect the result, so for the most accurate and complete study in the future it is worth expanding the methodology and the data base.

7.1 Future Research and Recommendations

During the research project there has been identified some potential for future work that involve research on the Nevrolens application. This potential include further evaluating the learning potential of the application within different learning approaches. The tests should be performed with an increased number of participants to ensure that the evaluation of the features can be based on several perspectives and thus be more representative of the intended user group.

While working on the current research project, it has been observed that professors and students have expressed a desire for getting access to the Nevrolens application to support the teaching or learning of anatomy. Nevertheless, they also had some suggestions and user requirements for improving the learning scenario. One of these improvements involves implementing the Voice chat feature to allow students to collaborate remotely on their mobile devices.

The peer-learning method is a versatile and creative approach to learning. Due to the limitations of this study, a single, slightly changing learning scenario was used to measure the learning potential of the method when using the application. For a more accurate and complete evaluation, more diverse scenarios should be adapted to the AR learning session to reveal other aspects of this learning approach.

ACRONYMS

2D - two-dimensional.

3D - three-dimensional.

AI – Artificial intelligence

AR - Augmented Reality.

CT - computer tomography.

DH – Digital humanities

HMD - head-mounted display.

IMTEL - Innovative Immersive Technologies for Learning.

IoT – Internet of things

iPEAR - inclusive peer-to-peer learning with AR tools.

MR - Mixed Reality.

MRI - magnetic resonance imaging.

NTNU - Norwegian University of Science and Technology.

VR - Virtual Reality.

WDP - Windows Device Portal.

XR - Extended Reality.

REFERENCES

‘NSD’, N. -N. (2023, 3 15). NSD. Retrieved from https://www.nsd.

3D4Medical. (2023, 3 25). The world’s most advanced 3D anatomy platform. Retrieved from https:

Andrade H., V. A. (2019). Promoting learning and achievement. Oxford University Press.: Theory Into, 19-24.

Aranova, S. V. (2018). Intellektual`no graficheskaya kul`tura vizualizacii uchebnoj informacii v kontekste modernizacii obshhego obrazovaniya. vestnik Chelyabinskogo gosudarstvennogo universiteta, 5-16.

Arnold, E. (2023, 04 28). Digital Humanities: Is it Research or is it Service? Retrieved from Digital Humanities: Is it Research or is it Service?: https://dhmuc.hypotheses.org/2834

Auernhammer, J. R. (2021). "The Origin and Evolution of Stanford University's Design Thinking: From Product Design to Design Thinking in Innovation Management". Journal of Product Innovation Management. 38 (6):, 623-644.

Avramenko, A. (2019). Dopolnennaya real`nost` v yazy`kovom obrazovanii: e`tapy` raz-. Ucheny`e zapiski Nacional`nogo obshhestva prikladnoj, 23-27.

Azevich, A. (2019). Vizualizaciya pedagogicheskoj informacii: uchebnometodicheskij podhod. Vestnik Moskovskogo gorodskogo pedagogicheskogo universiteta. Seriya «Informatca obrazovanya, 115-134.

Bailenson, J. (2018). Experience on demand: what virtual reality is, how it works, and what it can. NY: W. W. Norton & Company.

Billinghurst, M. (2021). Grand challenges for augmented reality. Frontiers in Virtual Reality, vol. 2.

Bland, M. (2018). An Introduction to Medical Statistics. Medical Studies, 25-33.

Bork, A. L. (2020). The effectiveness of collaborative augmented reality in gross anatomy teaching: A quantitative and qualitative study. Anatomical Sciences Education, vol. 14, no. 5, 590-604.

Bowman, D. A. (2007). Virtual reality: How much immersion is enough? Computer, 40(7),, 36-43.

Braun, V. a. (2016). Using thematic analysis in psychology. Qualitative research in psychology, 77-101.

Brew, A. (2013). Towards Autonomous Assessment: Using Self-Assessment. Buckingham.: The Society for Research into Higher Education & Open University Press, 171-196.

Browne, C. (2023, 03 17). A Comprehensive Guide for UX Designers. Retrieved from https://careerfoundry.com/en/blog/ux-design/what-is-an-empathy-map/

C. W. R., U. (2023, 3 25). Learn faster, understand more. Retrieved from https://case.edu/holoanatomy/

Cassidy, S. (2016). Developing employability skills: Peer assessment in higher education. . Education & Training, 48(7), , 508-517.

Cooley, S. V. (2023, 4 26). ‘About hololens 2’. Retrieved from Microsoft: https://docs.microsoft.com/en-us/hololens/hololens2-hardware

Coopersmith, S. (1967). The Antecedents of Self-Esteem. San Francisco: W. H. Freeman & Co.

D'Andrea, A. (n.d.). VR architecture . A PhysX-based Framework to Develop Rehabilitation using Haptic and Virtual Reality. Taipei, Taiwan.

developer.microsoft.com. (n.d.). MR.

Dorst, K. (2020). Design beyond Design. ournal of Design Economics and Innovation, 127-135.

Drew, C. (n.d.). 31 Major Learning Theories in Education, Explained. 31 Major Learning Theories in Education, Explained.

Driscoll, M. P. (2011). Psychology of learning for instruction (2nd ed.). Needham Heights: MA: Allyn & Bacon.

Elamany, R. (2021). The art of design things. O'Reilly .

Emaliana, I. (2017). Teacher-centered or student-centered learning approach to promote learning? Jurnal Sosial Humaniora, 2-5.

eucen. (2023, 04 05). i Pear. Retrieved from i Pear: http://www.eucen.eu/projects/i-pear

Ferrer-Torregrosa, J. T. (2017). ARBOOK: Development and assessment of a tool based on augmented reality for anatomy. Journal of Science Education and Technology, vol. 24, no. 1,, 119-134.

Freedman. (2023, 04 22). 5 Best Augmented Reality Use Cases. Retrieved from 5 Best Augmented Reality Use Cases: https://www.business.com/articles/best-augmented-reality-uses/

Garzon, J. K. (2020). How do pedagogical approaches affect the impact of augmented reality on education? a meta-analysis and research synthesis’. Educational Research Review, vol. 31, 100-134.

Grabinger, S. A.-B. (2017). Instructional design for sociocultural learning environments. W-Journal of Instructional Science and Technology, , 10-22.

Haugum, M. V. (2022). Facilitating Different Approaches to Learning Anatomy in an AR. Trondheim : NTNU.

Havens, N. S. (2020). A case report about anatomy applications for a physical therapy hybrid online curriculum. Journal of the Medical Library Association, vol. 108,, 2.

Hawrylycz, M. B. (2011). Digital atlasing and standardization in the mouse brain. PLOS Computational Biology, 7(2):, 1-6.

HIVE, T. (2023, 3 25). HOLOBRAIN 2.0. Retrieved from https://hive.med.ubc.ca/projects/holobrain/

John-Steiner, V. &. (1996). Sociocultural approaches to learning and development: A Vygotskian framework. Educational Psychologist, 31(3/4), 191-206.

Kang Y-N, C. C.-H.-C.-N. (2019). Development of a short and universal learning self-efficacy scale for clinical skills. PLoS ONE 14(1).

Kozulin, A. (1990). Vygotsky’s psychology: A biography of ideas. Cambridge: MA: Harvard University Press.

Liang, S. (n.d.). AR. Research Proposal on Reviewing Augmented Reality Applications for Supporting Ageing Population.

Logeswaran, C. M. (2021). The role of extended reality technology in healthcare education: Towards a learner-centred approach. Future Healtcare Journal, vol. 8, no. 1, 79-84.

Mackenzie, S. K. (2006). Research dilemmas: Paradigms, methods and methodology. Research dilemmas: Paradigms, methods and methodology, 193-205.

Makransky, G. P. (2020). The Cognitive Affective Model of Immersive Learning (CAMIL): a Theoretical Research-Based Model of Learning in Immersive Virtual Reality. Educ Psychol Rev 33, 937-958.

Marques, A. T. (2022). A critical analysis on remote collaboration mediated by augmented reality: Making a case for improved characterization. computers & Graphics, vol. 102,, 619-633.

McLeod, S. A. (2016). Lev Vygotsky. Simply Psychology. Retrieved from www.simplypsychology.org/vygotsky.html

Milgram, H. T. (2011). Augmented reality: A class of displays on the reality-virtuality continuum. Telemanipulator and Telepresence Technologies, 282-296.

Miller, P. (2011). Theories of developmental psychology (5th ed.). New York: NY: Worth Publishers.

Miot, H. (2017). Assessing normality of data in clinical and experimental trials. journal Vascular Brasilero, 2-7.

O’Donnell, A. &. (2000). Cognitive perspectives on peer learning. Mahwah: Lawrence Erlbaum Associates.

Oates, B. J. (2016). Researching Information Systems and Computing. SAGE Publications.

Papp, E. K. (2014). Waxholm space atlas of the sprague dawley rat brain. NeuroImage,, 374-386.

Parkay, F. W. (2000). Curriculum planning. Needham Height: MA: Allyn & Bacon.

Parong, J. &. (2020). Cognitive and affective processes for learning science in immersive virtual reality. Journal of Computer Assisted Learning.

Parr, J. &. (2020). Environments, processes, and mechanisms in peer learning. International Journal of Educational Research, 37(5), 403-423.

Petersen, G. B. (2020). The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education. British Journal of Educational Technology., 51(6), 298-311.

Petersen, G. B. (2022). A study of how immersion and interactivity drive VR learning. Computers & Education, 179,.

Puntambekar, S. (2018). Scaffolding. Education.com. Retrieved from http://www.education.com/reference/article/scaffolding/

Race, P. (2021). Briefing on Self-, Peer, and Group Assessmen. York.:, 51-53.

Radianti, J. M. (2021). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers and Education, 147.

Ravna, O. V. (2021). 'Towards teaching neuroanatomy in collaborative augmented reality',. Trondheim: NTNU.

Schunk, D. (2002). Learning Theories An Educational Perspective. Pearson.

Scott. (2015). The futures of learning 3: What kind of pedagogies for the 21st century? Education Research and Foresight,, 1-27.

Scott, S. &. (2017). Sociocultural theory. Education.com. Retrieved from http://www.education.com/reference/article/sociocultural-theory/

Shaffer, D. (2000). Social and personality development. Belmont: CA: Wadsworth/Thompson Learning.

Shiratuddin, K. W. (2015). Utilising mobile-augmented reality for learning anatomy. Procedia - Social and Behavioral Sciences, vol. 197,, 659-678.

Stojanovska, G. T. (2020). Mixed reality anatomy using microsoft hololens and cadaveric dissection: A comparative effectiveness study. Medical Science Educator, vol. 30, 173-178.

Thurston, A. V. (2017). Peer learning in primary school science: Theoretical perspectives and implications for classroom practice. . Electronic Journal of Research in Educational Psychology, 5(3), 477-523.

Topping, K. &. (1998). Peer-assisted learning. Mahwah: Lawrence Erlbaum Associates.

Tullis, J. G. (2020). Why does peer instruction benefit student learning? Cogn. Research 5, 15 .

Tullis, J. G. (2020). Why does peer instruction benefit student learning? Cogn. Research 15, 117-126.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge: MA: Harvard University Press.

Walker, A. (2020). British psychology students' perceptions of group-work and peer assessment. Psychology Learning and Teaching, 1(1), 28-36.

Watson, S. L. (2018). The learner-centered paradigm of education. Retrieved from In R. West (Ed.). Foundations of Learning and Instructional Design Technology.: https://lidtfoundations.pressbooks.com/chapter/systemic-change/

Wish-Baratz, A. C. (2020). Assessment of mixed reality technology use in remote online anatomy education. JAMA Network Open, vol. 3,.

TABLE OF FIGURES

APPENDIX 1

User Pre-test

To which gender identity do you most identify?

- Male
- Female
- Other
- Prefer not to answer

Which degree are you taking?

- Bachelor’s
- Masters
- Doctorate/PhD
- Other/Please specify the degree you are taking:

I prefer to work individually
- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

I feel more confident studying withother students
- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Usually, self-assessment of my competence affects my performance:
- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Did you have neuroanatomy courses during your study?

- Yes
- No

How do you assess your knowledge about the rat brain structure?

- Very Poor
- Poor
- Acceptable

- Good
- Very Good

Have you used AR (Augmented Reality) technology and/or VR (Virtual Reality) technology ?

- Never used it
- Tried once
- Have a basic understanding
- Use it often
- Experienced user

Do you have an experience of rat brain dissection?

- Yes
- No, but I have participated in one with another type of brain
- No

APPENDIX 2
User scenario for AR collab session

Write your participant number

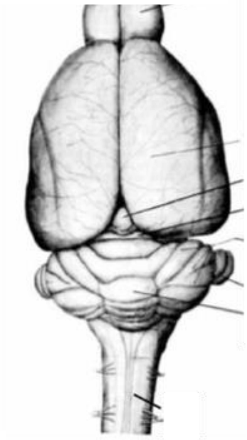
<u>Individual task</u>

Identify the location of the

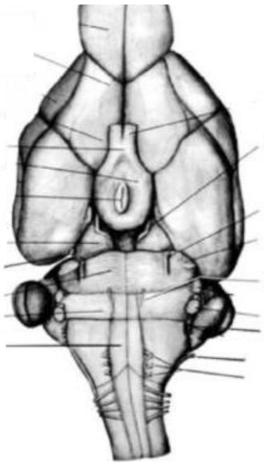
1. hypothalamus
2. cortex
3. spinal cord
4. basal forebrain
5. cerebellum
6. brainstem
7. olfactory bulb

on the dorsal and ventral view of the rat brain.

dorsal



ventral



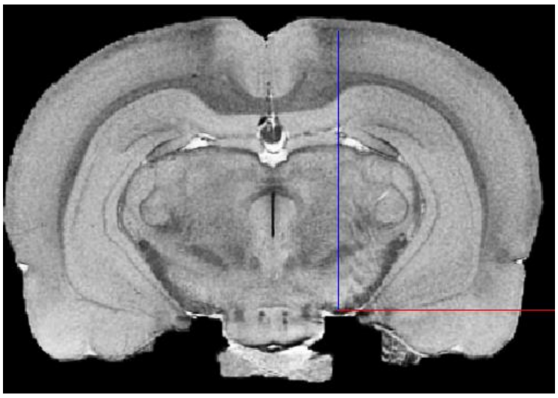
Collaborative tasks

- Identify the location of the

1. hypothalamus
2. cortex
3. cerebellum
4. brainstem
5. hippocampus

on the coronal and sagittal sections of the rat brain shown below

Note that not all brain area are visible on all sections



- Few brain areas are layered in the mammalian brain.

1. Please identify which regions are layered
2. Discuss what being “layered” means

APPENDIX 3
Post-test 1

During the session, my experiences and actions were under my control:

○ Strongly agree
○ Slightly agree

- Neutral
- Slightly disagree
- Strongly disagree

During the session, I felt more comfortable and confident working with the mobile version of the app.

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

It was easier to control the rat brain model on the phone

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Working with the model in Hololens feels more efficient for the learning process than on the mobile device

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Non-Intuitive controls on Hololens made it difficult to focus on learning

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

In the future, I would prefer to work with augmented reality glasses for an effective immersive learning experience

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Augmented reality mobile apps are more suitable for learning

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

It was difficult for me to focus on learning because of the difficulty in mastering augmented reality

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

During the individual work in the app, I felt confident and wanted to explore as much as possible

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

When working individually with the app, I was bored

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

I feel more confident and focused on learning when I work alone

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

The ability to move and separate parts of the brain was useful for learning

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

During the session, my movements and bodily activities were an integrated part of learning.

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

The ability to move in space helped me understand the material more easily

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Collaboration with other students motivates me in learning

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Peer explanation and demonstration of the model makes it easier to learn material

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

I need teacher guidance to learn efficiently in the AR environment

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Collaboration mode in the app can be helpful for me in learning

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Collaboration mode can be helpful for exam/assignment preparation.

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

For me it is easier to learn together

- Strongly agree
- Slightly agree
- Neutral

- Slightly disagree
- Strongly disagree

Performing tasks together helps me to understand better

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Competition in quizzes in the app motivates me to studies

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Working in a group makes me feel lost and bored

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

Actions of other students in collaboration mode disturbed me

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

The approach of peer-to-peer learning combined with AR tools was useful for me

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

I was interested in teaching each other and sharing content in AR.

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

The Peer-to-peer learning approach makes me feel more responsible for learning

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

I think the peer-to-peer learning model will be useful in other courses

- Strongly agree
- Slightly agree
- Neutral
- Slightly disagree
- Strongly disagree

APPENDIX 4

Questions for the expert interview.

1) How is neuroanatomy mostly taught today?

- What kind of teaching materials are mostly used in training?

- Do you use mobile applications in teaching?

- What do students mostly have difficulties with?

2) Do you think an augmented reality app can help with a better understanding of volumetric structure?

- What do you think about immersive learning experiences in virtual reality?

3) From your experience, do students prefer to work individually or in groups?

- How does work in groups take place?

- How do students share responsibilities when working together?

4) Have you noticed a difference in the results of more confident students?

- In your opinion, does the self-efficacy assessment affect the learning process?

APPENDIX 5
Consent form

Taking part in the research project
″Immersive Technologies for Learning and Training″

This is an inquiry about participation in a research project where the main purpose is to to explore the potentials and limitations of Immersive Technologies (virtual/mixed/augmented reality, VR/MR/AR) for learning and training in different areas, as a part of master student projects at Innovative Technologies for Learning (IMTEL) VR lab. To conduct this research, we will need to investigate the development and use of immersive technologies for learning and training in various contexts, including learning of language and mathematics, virtual field trips, remote learning in COVID-19 context, visualization of climate change, immersive visualization of lab experiments, workplace training, visualization of medical procedures and anatomy and other projects. In this form we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

To conduct this research, we will need to analyze the use immersive technologies for learning and training in various contexts, including learning of language and mathematics, virtual field trips, remote learning in COVID-19 context, visualization of the climate change process, immersive visualization of lab experiments, visualization of medical procedures and anatomy and other projects. The goal is to develop innovative learning methods and tools using immersive technologies.

Who is responsible for the research project?

NTNU, Department of Education and Lifelong learning is the institution responsible for the project.

Why are you being asked to participate?

You are asked to participate because you are a potential user of educational applications developed as a part of this project and have visited our lab/expressed interest in immersive technologies. Your feedback is important for develop innovative learning methods and tools.

What does participation involve for you?

You will be ask to test immersive applications for learning and training purposes and then give feedbacks in the form of questionnaires and interviews/group interviews. We might take some anonymized photos/videos (with faces partly hidden behind the VR/AR headsets) during the testing sessions.

Participation is voluntary

Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act). Any data that can be traced to individual participants will be kept confidential and anonymized before being used for research purposes. Parts of the sound recordings will be transcribed (written down) and stored electronically. All source data will be handled and stored in accordance with the existing regulations by NTNU as the responsible institution and only persons associated with the project (IMTEL VR lab research personnel and master/bachelor students) will have access to them.

What will happen to your personal data at the end of the research project?

The project is scheduled to end 31.12.2022. All data will be anonymized at the end of the project, e.g. audio and video will be deleted when transcripts and analysis of data are completed, except for selected video and photo material to be used for research purpose. These and anonymized recordings from the inside of the virtual environments may be used for demonstrations in research context in such a way that no information will be linked to individuals. Scientific reports and presentations from this study might contain recordings from the VR/MR/AR sessions, questionnaire results, anonymized photos/videos from the sessions and anonymized citations from the interviews.

Your rights

So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent.

Based on an agreement with NTNU, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:

- Ekaterina Prasolova-Førland (Department of Education and Lifelong Learning, NTNU)
- phone: +47 99 44 08 61, email: ekaterip@ntnu.no
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

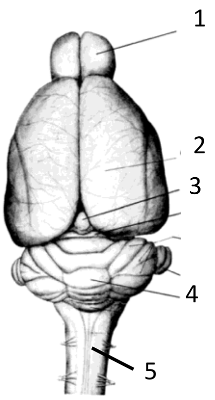
Consent form

I have received and understood information about the project Immersive Technologies for Learning and Training and have been given the opportunity to ask questions. I hereby declare my consent that my data in relation to Immersive Technologies for Learning and Training may be stored, documented and used for research and educational purposes as described above. I give consent for my personal data to be processed until the end date of the project, approx. 31.12.2022

(Signed by participant, date)

APPENDIX 6

Neuroscience Test knowledge



Name the numbered brain parts on the image below

Dorsal view of the rat brain

1

2

3

4

5

Ventral view

1

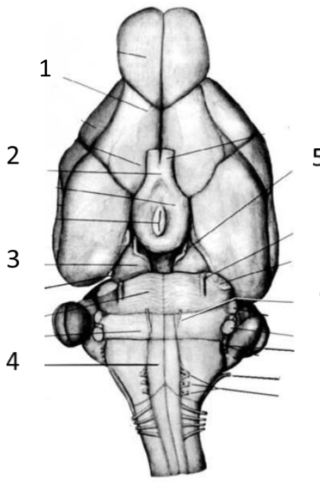
2

3

4

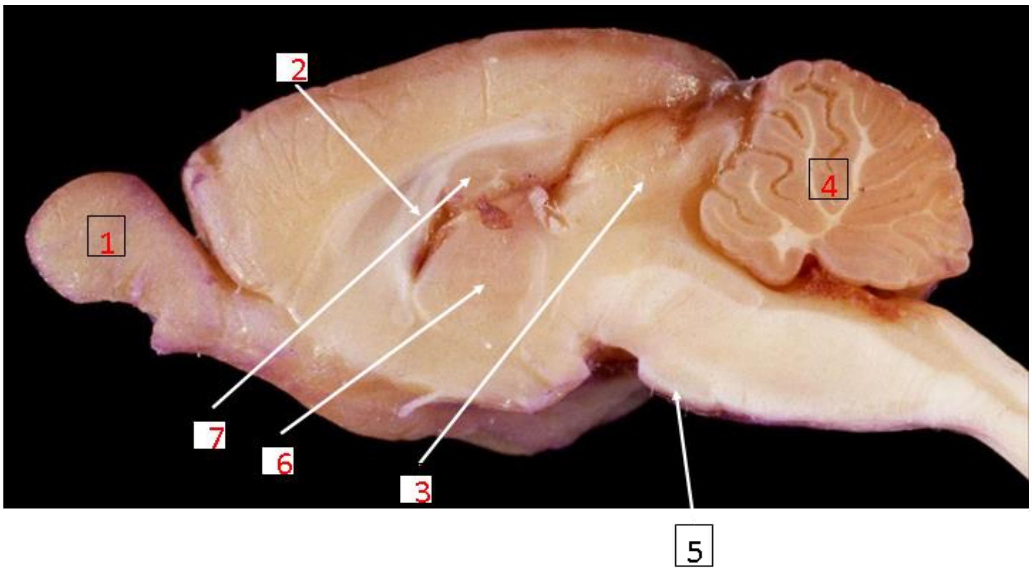
5

6



Name the numbered brain parts on the image below

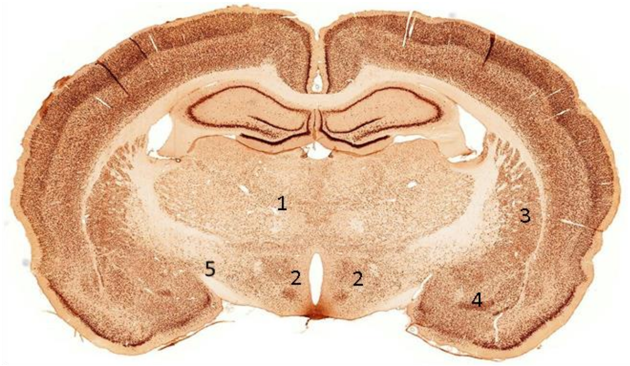
Rat brain - subdivisions

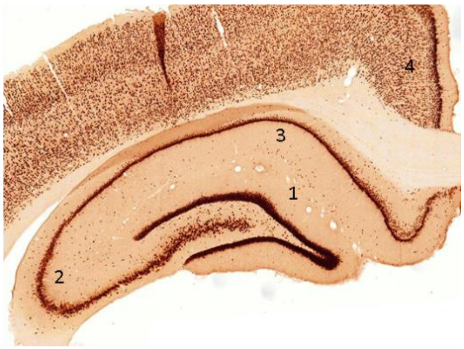


[Text answer]

This is a coronal section through the

This is a section through the


1
3
5
2
2
4


4
3
1
2


1
2
3