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Augmented reality as a future of the education
Case study of MoleQL – educational augmented reality application

Master's thesis

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Author's Declaration of originality

I hereby declare that this thesis is based on my own work. All ideas, major views and data from different sources by other authors were only used as reference and/or for research purposes. The thesis has not been submitted for any degree or examination in any other university.

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Abstract

Technical, economic and social progress is pushing educational systems to restructure and modernize. Every society creates an education system according to their nature and level of socio-economic development. Education transforms and directs the life of society, determines the strategy and realistic conditions of society, turning a "society of today" to "society of tomorrow", and generates new thinking of citizens with a new vision of the meaning of life. Education acts as a development tool for the society which is crucial for the state.

Augmented reality (AR) technology allows supplementing the image of the real world with various virtual objects of computer graphics, and also combine images obtained from different sources of the computer environment. AR is adding additional content to the real world. The technology of augmented reality is already used in various types of human activities, for example, in trade, advertising, military development, tourism, games, entertainment, etc. Moreover, education is considered as one of the most beneficial fields for development of AR.

Augmented reality is the technology of the future which could have a significant impact on the education. By using the technology it is possible visually reproduce processes or objects that are difficult or almost impossible to recreate in the real world and make the learning experience more fascinating and understandable. Moreover, it could affect students motivation and learning outcome by applying five main components of the progressive learning process (high-quality content, object visualization, gamification and game-based learning, real-time performance and interaction).

Nevertheless, the usage of the new innovation technology is challenging. There are the compelling amount of the research about AR technology and education but most of them have a theoretical not practical approach. The effect of augmented reality to the final user requires more examination and testing before massive implementation.

This thesis is written in English and is 69 pages long, including 7 chapters, 4 figures, and 3 tables.

Annotatsion

Tehniline, majanduslik ja sotsiaalne areng sunnivad haridussüsteemi restruktureerimisele ja moderniseerimisele. Iga ühiskond loob lähtuvalt enda iseloomust ja sotsiaal-ökonoomilisest arengust haridussüsteemi. Haridus muundab ja juhib ühiskonna elu, määrab strateegia ja realistlikud tingimused, kuidas "tänapäeva ühiskond" muuta "homseks ühiskonnaks" ja loob uut mõtlemist inimestelt, kellel on on elu mõtte kohta uus visioon. Haridus toimib kui arengutööriist, mis on hädavajalik ühiskonna olemasoluks.

Augmenteeritud reaalsuse (AR) tehnoloogia võimaldab lisada päris maailma kujutisi erinevatele arvuti graafikaga loodud objektidele ning ka kombineerida erinevatest virtuaalsetest keskkondadest pärinevaid objekte. AR lisab reaalsusele täiendavat sisu. Augmenteeritud reaalsuse tehnoloogiat kasutatakse juba erinevates inimtegevuse valdkondades, näiteks kaubanduses, reklaaminduses, militaararengus, turisminduses, mängunduses, meelelahutuses jne. Veelgi enam, haridust peetakse üheks kõige kasulikumaks valdkonnaks augmenteeritud reaalsuse arendamisel.

Augmenteeritud reaalsus on tulevikutehnoloogia, millel võib olla määrav mõju haridusele. Selle tehnoloogia kasutamisel on võimalik visuaalselt taasluua protsesse või objekte, mida on keeruline või peaaegu võimatu teha päris maailmas, muutes õppimise kogemuse paeluvamaks ja mõistetavamaks. Lisaks, sellega on võimalik suurendada õpilaste motivatsiooni ja õpingute tulemit kasutades viite progressiivse õppeprotsessi komponenti (kõrgkvaliteetne sisu, objektide visualiseerimine, mängulisustamine ja mängupõhine õpe, reaalajas sooritus ja koostoime).

Uue ja innovaatilise tehnoloogia kasutamine on kõigest hoolimata keeruline. AR tehnoloogia ja hariduse kohta on olemas arvestatav kogus uuringuid, kuid enamus nendest on teoreetilised ja puudub praktiline lähenemine. Augmenteeritud reaalsuse mõju lõppkasutajale vajab täiendavat uurimist ja testimist enne masskasutusse võtmist.

Antud väitekiri on kirjutatud inglise keeles ja on 69 lehekülge pikk, koosneb seitsmest peatükist, 4 joonisest ja 3 tabelist.

List of abbreviations and terms

AR	Augmented Reality
VR	Virtual Reality
MR	Mixed Reality
IT	Information technology
ICTs	Information Communication Technologies
MARIE	Multimedia Augmented Reality Interface for E-learning
ET 2020	Education and training 2020
VMC	Virtual Multimedia Contact
HCI	Human-computer interaction
MAR	Mixed and Augmented Reality
UI	User Interfaces
HMD	Head Mounted Display
GPS	Global Positioning System
FLM	Flipped Learning Model

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1 Introduction

Education plays crucial role for the society and development of the country. The development of the education in the state is strongly connected to the quality of life and prosperity. In many economically developed countries state remains the primary entity holding the education system and defining the strategic direction and modernization. Nowadays, digital citizens are strongly connected and dependent on e-Governance, e-society, and e-learning. Implementation of new educational approaches and technologies into educational program is one of the most responsible tasks as it can have crucial effect on the society in general.

The main duty of the state is to keep education constantly updated due to the world demand and supply. Currently, the responsibility of the education is critical as educational system needs to prepare a student to the constantly changing world.

E-Society became well-known trend in the society. Currently, it is hard to imagine a day without internet or mobile phone. Nowadays people are dependent on the information.

Each year a lot of money and time are invested into the educational sector but the outcome is lower that it was expected. One of the main problems is that kids cannot understand the difficult subject and give up. They lose their motivation or the concept of the subject. Instead of developing creative thinking, problem-solving and communicational skills schools are killing curiosity and self-esteem of students.

Nevertheless, with the beginning of 21st century, we got a lot of technologies and approaches that could have significant impact on education. One of them is augmented reality (AR) technology. It is a powerful technology combining virtual and real world using 3D models. Augmented reality is a part of e-learning. AR has a potential to change education. The main goal of the Master thesis research is to investigate effects, benefits, and influence of the technology.

1.1. Problem Statement

Nelson Mandela states that: "Education is the most powerful weapon which you can use to change the world"[1]. In it impossible to overestimate the power of the education nowadays. The world is rapidly changing and require adaptation to new processes. Education is a key aspect. Nowadays, education process has a lot of pros and cons, A large number of changes should be resolved to improve the quality of the education and bring it to the new level.

For the last 10-15 years, the area of Augmented reality and education has been acknowledged as one of the most promising fields of human-computer interaction (HCI). The enormous amount of the research has been made in the area of the usage of augmented reality technology and education issues. In spite of that, only a few of them have conducted real-life testing with end users.

Improvement of the education by bringing new technologies should be considered as the main goal of the today's society. Augmented reality is a core of discussions since the technology is new and not used massively. That is why it is hard to predict its effect on educational system and study process. Moreover, interaction between the Augmented reality and kids is an open field. There are a lot of researches about it but most of them are theoretical and not practical. Besides, very often practical researchers concentrate on one comment of the technology with the usage of AR for education, for instance on gamification or educational high-quality content or relevant 3D models but not as on the complementary components of one research.

1.2. Research Objectives

According to Steven K. Feiner and his article: "Augmented reality: A new way of seeing" the prime objective of augmented reality technology is to generate information from the computer to affect sensory perception of final users[2]. It is quite important in the case of

implementing Augmented reality for educational reasons. Moreover, there is a lot of specific in the usage of the technology for different subjects and students' age.

This technology allows to significantly expand the range of data perceived by humans. This expansion of consciousness is achieved by transferring digital information to the real world. The process of forming augmented reality occurs by dint of a smartphone camera, web camera or another device that can process a video signal. A special program will complete the picture with the necessary virtual objects. Video and audio materials, 3D-models, as well as text content can be the elements of AR-technology.

Based on it I would like to highlight the main research objectives for the current master thesis:

1. Collect the opinion about AR experience from kids, parents and teachers. Analyze the data and describe the results.

2. Determine the problems of current education and how AR technology can influence students during their chemistry lesson.

3. Analyze and process the research data outcomes and determine key aspects of successful learning.

1.3. Context of master thesis work

For the beneficial development of the society we need to use resources we have in the 21st century and the main resource is technology. Educational system could significantly benefit from correct usage of technologies. Augmented reality is one of the most encouraging and promising technologies that can be used for education process and its improvement and change.

Having analyzed the immense number of the case study and publications on the AR and the education field, we can conclude that there are five main components that help kids to learn and understand the learning material:

1. The high-quality content of the subject. Well-structured and logically built learning materials and lessons help to improve the understanding of the content[3].

2. Objects' visualization is one of the strongest features that can be used in the education. Design of a visual 3D model of the conceptual framework is a crucial part for understanding the fundamentals of the subject[4].

3. Game-based learning is using games or simulations to achieve a particular learning outcome[5]. In other words, game-based learning is learning through the game. Game-based learning can be used in different ways to increase efficiency in the classroom. Educational games can increase students' motivation, engagement, and learning[6]

4. Gamification is the process of applying or adding game elements to a non-game situation or to existing learning platforms to increase students' interest and motivation. According to the research of Bond University the use of gamification in addition to visualization can improve a traditional teaching approach in the classroom. Gamification enriches engagement by creating challenges; it leads to improving learning process by adding more fun and understanding of the subject[7].

5. Real-time performance and interaction. One of the successful criteria for learning is interaction. According to the report Interaction: Principles and Practice: "Interacting with others or with information can help clarify concepts, improve problem-solving, and enhance retention."[8]

All the components listed above are a part of learning experience but together they set up a new valuable learning approach. Nevertheless, we can find a lot of studies about any of these components separately but there is a lack of the research about their mutual interaction as a part of Augmented reality application and education at the same time. However, the technology of augmented reality rarely used in schools. Mostly it's personal

usage. Furthermore, researchers are concentrated on kids or teachers but not on parents. The viewpoint of parents is crucially important as they can have a big impact.

In the Master thesis research, I would like to examine augmented reality technology as a part of the study process. Moreover, the interaction between AR educational app MoleQL and final users – kids is the main focus of the Master thesis research. Nevertheless, parents are present during the interview and have been interviewed after their kid. Additionally, for the sufficient research outcome observation and opinion of parents and teachers are included.

2 Research Background

This chapter presents an overview of the research background, it provides an overview of the topics under study and helps to find the answers to the research questions. Section 2.1. gives theoretical background and literature overview which consist of subsections. Additionally it is divided into three subsections 2.1.1.Current stage of the education in Europe; 2.1.2. Overview of augmented reality technology and 2.1.3. Augmented reality as a future of the education. Moreover, the conclusion is provided in the second part of the chapter.

2.1. Theoretical background and literature overview

2.1.1. Current stage of the education in Europe on the example of the chemistry subject.

Education is a critical part of the solution to every issue society faces. According to Kofi Annan: "Knowledge is power. Information is liberating. Education is the premise of progress, in every society"[9]. It is impossible to overestimate the importance of the education and its effect on the society. Hence, they need to cooperate and complement each other to have a beneficial impact on the generation.

Education has been elaborated during the centuries. Each country has its own features but in general, there are a lot of common points. Lessons last about an hour. Mobile phones must be switched off and not used. During classes, students should listen to the teacher's explanation and do homework after the class. Afterwards, take an exam or test.

In the European Union, each country is responsible for its own approach to education. EU policy helped to keep education in the right order by harmonizing and developing the learning process. In that way the EU developed a strategic framework called "Education and training 2020 (ET 2020)" for cooperation in education and training. One of the main objectives of ET 2020 is "Enhancing creativity and innovation at all levels of

education"[10]. Higher innovation capacity by developing citizens is one of the top priorities for the EU[11].

On average, 5% of EU GDP is spent on education and training. Moreover, 1 out of 10 students leaves school without a certificate. 2 adults out of 10 have low literacy and numeracy skills [12].

Society has a lot of assumptions about education. The main problem is that this structure of the education was created in a different time and it does not correspond to the current education needs. According to the report of the Innovation Unit: "10 ideas for the 21st century education" Teachers work harder and harder to get kids motivated at school but as children grow older they become less and less interested and engaged [13]. There are a lot of reasons why students dislike school and find it boring. The question is how to change this.

One of the good example of the subject that has not changed much during the centories is chemistry. According to the Javier García-Martínez and Elena Serrano-Torregrosa: "In fact, it is quite surprising how little has changed the way chemistry is taught in the last century despite all the recent advances in chemistry and the numerous possibilities that information technologies offer" [14]. A typical version of a general chemistry lesson is still the same: classroom with students who passively listen to a teacher, reading the book and doing the homework.

Also, teachers are struggling from the oldness of chemistry program. This is one of factors that provokes teachers to bring the innovations and new approaches by themselves. In the article Empowering Chemistry Teachers' Learning: Practices and New Challenges, authors emphasized that during last 40 years have seen a crucial change of teachers' role: from "consumers" of innovations to "co-producers" of new topics and teaching approaches [15].

Moreover, problems of the education effect results of kids on the state chemistry exam. Final school exams in Estonia are divided on the state and school. State examinations are held once a year and only one day all over Estonia. Final examination papers with questions are prepared by Innove Foundation. Chemistry is not an obligatory subject for final examination. During the chemistry exam in 2016, 704 kids from 202 different

schools were participating. According to the Innov statistic, the hardest for the students were correctly calculated exercises which consist reaction equation as it requires a deeper understanding of chemistry and molecule interaction. The easiest topic was about acids (their name and formulas) [16].

Schools program is too complicated; it is hard for students to comprehend such abstract subjects as Math, Physics or Chemistry. The second problem is a lack of the motivation – kids are getting bored at school. Furthermore, methodologies and approaches are too old.

Nowadays a lot of kids have difficulties with studies. Each year a lot of money is invested into the educational sector but the outcomes are not so great as it was expected.

2.1.2. Overview of augmented reality technology

It is impossible to overestimate progress and development of the society. Human computer interaction (HMI) and the information came to the forefront. The appearance of the computer has changed dramatically the way people live. Technologies are becoming more advanced each year. Evaluation of the computer interaction is shown in Figure 1.

Figure 1. Evolution of the computer interacton [17]

The evolution of the technology is directly connected with human-computer interaction. Moreover, the development of the technologies is progressing rapidly. Carlota Perez in

the book Technological Revolutions and Financial Capital stated that each technical revolution provoked changes in the society which also affecting financial and state stability and development [18].

One of the best explanations what augmented reality is belongs to a technology that superimposes a user's real world view with a computer generated virtual text or image on the user's viewing screen, monitor, helmet face mask, glasses, goggles, head mounted display, a window, or like an automobile windshield.

In 1990, the term "Augmented Reality" (AR) was used by Thomas P. Caudell, a former Boeing researcher. In his research he creates concept of AR and describes the differences between augmented reality and virtual reality [19].

Fundaments of augmented technology existed for a long time. Nowadays we have all required technical resources to develop and integrate the technology. For example, high-resolution cameras and high definition displays on smart devices which help to track and recognize images and objects[20]. Powerful technologies with large memory capacity and enhanced processing capabilities that help to run AR based applications. Strong graphical processing units which help to store, maintain, and use the data are necessary for augmented reality [21].

It is very important to understand the difference between augmented reality (AR), mixed reality (MR) and virtual reality (VR). The general structure is represented in Figure 2. Reality-virtuality *continuum[]*.
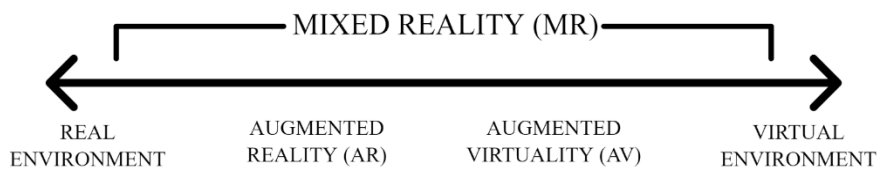

Figure 2. Reality-virtuality continuum[22]

According to Ronald Azuma AR technology combines real-time interaction, 3D, the combination of real world and virtual reality [23]. VR – brings you to fully 3D generated virtual world. Mixed reality is often explained as hybrid reality. Augmented reality is part

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of the mixed reality (Eng. Mixed Reality), where real objects are integrated into the virtual environment. Mixed reality is an environment where there is a combination of real and virtual scenes and objects.

According to Ronald Azuma, augmented reality systems are characterized by three properties [19]:

- Combine real and virtual objects in the physical environment.
- Align real and virtual objects with each other.
- Real-time interaction.

M.Moode in 1989 emphasized that augmented technology naturally supports learn-content interaction which is based on real-time interaction of the technology [24]. AR is close to the real world. Mainly the technology is adding computer-generated objects into physical world.

In the case of the Mixed and Augmented Reality Reference Model represented in the Figure 3, we can see that Augmented and Mixed reality (MAR) build imposed connection between the user and physical world by adding virtual objects and interacting with them.
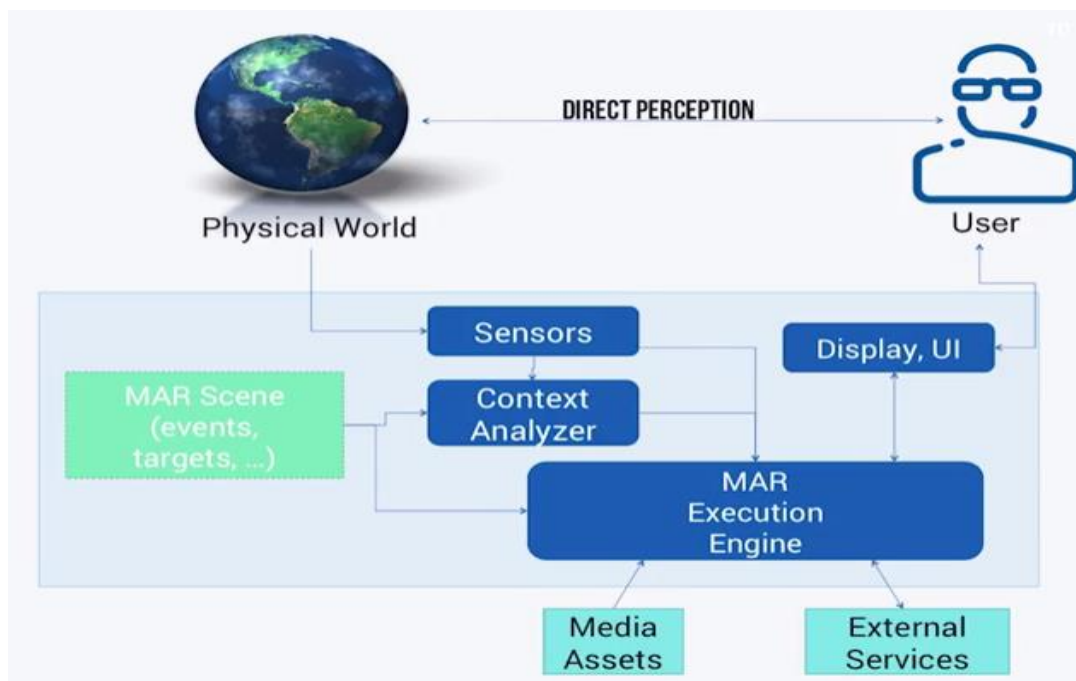

Figure 3 Mixed and Augmented Reality Reference Model[25]

Sensors, cameras, GPS, microphones, head mounted display (HMD), mobile devices, etc. help to build the connection with the physical world. The data received through the sensors is analyzed by Context Analyzer and transferred for MAR execution Engine which is the system brain. The engine controls all the data it receives and displays them according to the programmed functions. Moreover, it manages the communication with additional sensors and presents the final results to the user. Furthermore, the user can interact with the system through a user interface (UI) by using HMD, smart phones or any device with the camera [26].

The technology of augmented reality has its own critical limitations one of them is a stable internet connection. It is hard to imagine a day without internet but nevertheless, there is a lot of coultries where internet connection is quite low. Moreover, it is not always present in schools or educational institutions [27].

Moreover, augmented reality application is usually have high system requirements and using a lot of memory space. Additionally, AR programs affecting batteries lives. Despite the technological progress, it is still hard for the system to maintain AR applications. Development of the augmented reality application has downsides [28]. One of them that technology is quite new and requires a lot of system changes and updated all the time. Moreover, the release of new AR software versions is usually delay.

2.1.3. Augumented reality as a future of the education

Nowadays, the technology of augmented reality is rapidly developing and progressing. We can see the use of the AR technology in various fields such as advertising and promotion, architecture, gaming, navigation, medicine, military arts, etc. Nevertheless, usage of augmented reality applications in the education is at the early development stage.

Technology and its effect on the society provoke a lot of discussions and opinions. Melvin Kranzberg in his publication for the annual meeting of the Society for the History of Technology said: "Technology is neither good nor bad; nor is it neutral". Technology

interacts with the society on different levels and it can have different results when introduced into different contexts or under different circumstances [29].

A good example of the article that combines technical and educational part of AR in the e-learning field is published by the University of Sussex: "Multimedia Augmented Reality Interface for E-learning (MARIE)". During the research project called the Virtual Interactive Teaching Environment, the MARIE system that combines computer-generated information and computer-human interaction technologies were taken into consideration which is possible to observe in Figure 4. Mainly we can see that architecture of the AR system connects real world and augmented world by using video camera.
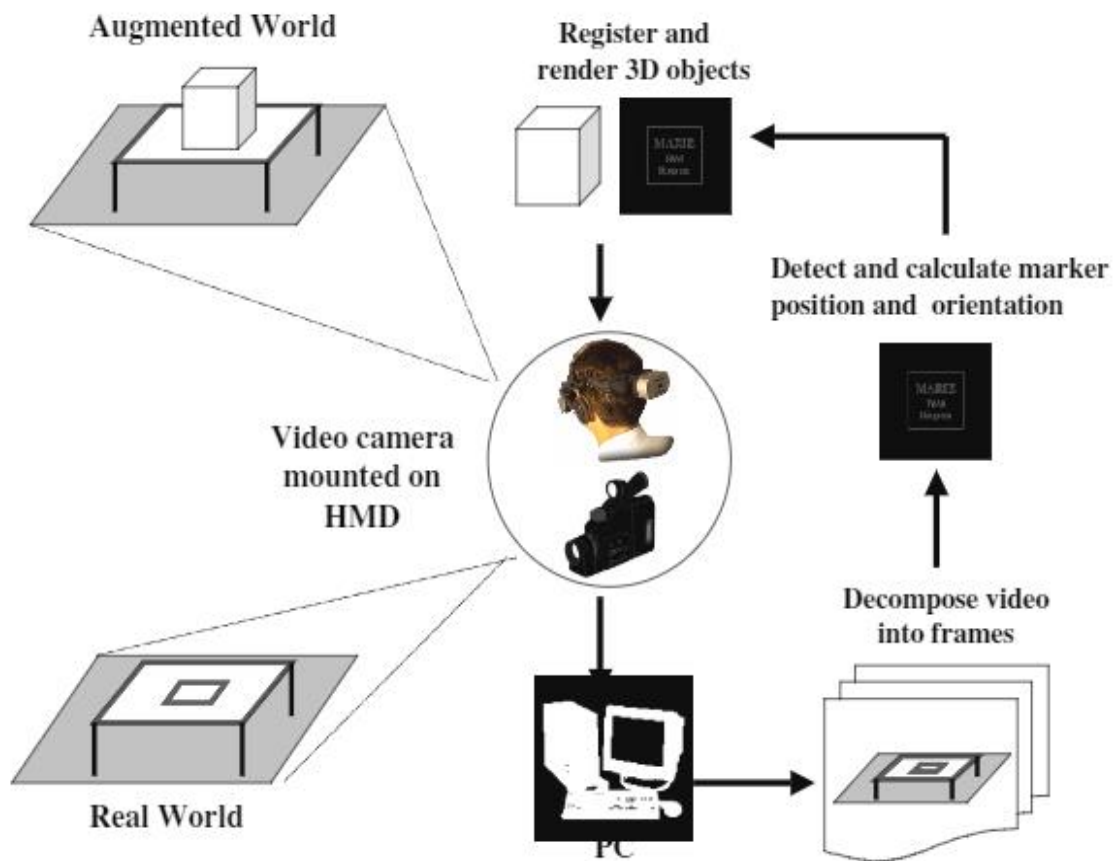

Figure 4. Architecture of the Augmented reality system 30 *below*

The research shows that students are learning more effectively thought of Virtual Multimedia Concept (VMC). Furthermore, authors emphasized that the main advantages are low-cost and real-time augmented presentation [30].

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The research shows that students study more efficiently thought Virtual Multimedia Concept (VMC). Furthermore, the authors emphasize the main advantages being low-cost and real-time augmented presentation [31].

By using augmented technology as a part of the educational process the user gets an idea of the surrounding space with the help of a large set of sensation. AR technology as intermediate system between a person and augmented reality should create a signal for person sensation. Thus, according to the type of information representation the augmented reality systems are divided into [32]:

1. Visual. They are based on the visual perception of a person. The task of such systems is to create an image that will be used by a person. Since the image for a person is more informative and understandable, this kind of systems is more common.

2. Audio. Such systems are oriented on auditory perception by accompanying actions by sounds.

3. Audiovisual. This is a combination of the two previous types, though audio here is only of auxiliary nature.

According to the Yoyuneyong G. and Johnson E.: " AR has vast potential implications and numerous benefits for the augmentation of teaching and learning environments". Moreover, researchers summarized potential of the usage of augmented reality [33]:

(a) engage, stimulate, and motivate students to explore class materials from different angles;

(b) help teach subjects where students could not feasibly gain real-world first-hand experience;

(c) enhance collaboration between students and instructors and among students;

(d) foster student creativity and imagination;

(e) help students take control of their learning at their own pace and on their own path;

(f) create an authentic learning an environment suitable for various learning styles.

Johnson stated that: "AR has strong potential to provide both powerful contextual, on-site learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world" [34].

Lee Kangdon in this work about augmented reality in education and training said: "Augmented Reality (AR) is one technology that dramatically shifts the location and timing of education and training" [35]. A lot of researchers predicted beneficial usage of the AR technology as a part of the education.

According to the article: „Impact of an augmented reality system on students' motivation for a visual art course" authors investigated that AR technology has a positive impact on the motivation of middle-school students [36]. For the research, the ARCS motivational model has been used, which is the part of the motivated learning process and includes: Attention, Relevance, Confidence, Satisfaction (ARCS) [37]. Moreover, the usability research investigated that AR technology is not mature enough to be used massively in education. Researchers were studying the effect of two scenarios to the school lesson. During the first scenario, the teacher was using slides and the second one – usage of augmented reality. According to the observation, the scenario with the usage of augmented reality shown higher motivation and learning outcome. Moreover, students remarked as a positive experience to have control over study process by themselves. Furthermore, a real-time interaction was highly emphasized [36].

Nilgun Tosun from the Trakya University stated that augmented technology will have imercive effect for Flipped Learning Model (FLM). He can see the posibility of AR usage. Moreover, augmented reality technology can be used in in classroom in trafitional fase to face learning or out-of-class activities. The mobility of the technology increacec with the development of the technology. Student can use the technology for self-learning and being not dependent from the teacher or the place. He stated that: "Supporting distance education based on the flipped learning model, which is one of the most suitable learnign models for digital native students" [38]. Moreover, the author emphasised that FLM is the future of educational approach and in cooperation, with AR technology it could increase the usefulness of the learning.

Gamification and game-based learning is amusing and motivating way to learn. The main purpose for playing games is to train and stimulate activities. Games have been used as a part of the learning experiance back 5000 years when the Chinese invented the was game for Wei-Hei. Towardays games are used iin different arias for studing and preasure[39].

Despite, benefits of the usage of augmented reality there are limitations and challenges. The novelty of the augmented reality technology may detract from the learning experience. Users are focused on novation of the technology rather than learning objectives and learning content. AR applications may widen the social divide between the users. Social interaction could be damage in the not correct usage of augmented reality technology [28]. Social discrimination could occur As the usage of AR technology requires modern technologies that sometimes can not be provided by the family of the user [40]. Moreover, AR interaction might be prohibited experience for some users because of mental conditions [41].

2.2. Conclusion

Schools and the educational sector have big responsibility for new generations of kids. In the 21st century the world and technology are developing so quickly that schools need to prepare kids for the position that do not exist yet. We can see a positive tendency in the educational sector: a lot of schools try to change educational approach and methods by bringing technology into education.

The problem of education is well-known and a lot of steps have been made for solving the issue. During centuries a lot of things have changed. People got new technologies around them: the internet, e-books, mobile phones, laptops but nevertheless pupils have difficulties with learning.

Augmented technology that allows supplementing the image of the real world with various virtual objects of computer graphics, and also combine images obtained from different sources of the computer environment. AR is adding additional content to the real

world. It is an enormous tool that can enrich the future of the education. It can help to see and interact with the things from a different perspective during the study process.

During the educational process, the user is getting information represented as a visual, audio and audiovisual which can also be used as a part of the educational experience. Today, to complement physical reality with additional digital objects, it takes a little - special glasses, a smartphone or a helmet.

Augmented reality and mixed reality are an additional Layer of reality between the user and physical world. A significant difference between the augmented and the virtual reality is the preservation of the physical world as a context. virtual reality is completely abstracted from the physical world to put the user completely in the virtual world. Augmented reality is brining 3D objects into a physical world. Virtual and augmented reality are parts of mixed reality.

The technology of augmented reality helps to visualize things or visual additions to augmented objects - newspapers, booklets, magazines, geographic maps, etc. Augmented information can be in the form of text, image, video, sound, three-dimensional objects. With the help of special programs and devices augmented objects can be scanned and viewed.

Gamification and game-based learning with augmented reality applications have many benefits over traditional games. For example, the ability to input animation and other multimedia effects can not only add interest to the game but can also be used for learning.

Augmented reality as a part of the education system has not been studied enough Researchers can be sure about the downside of the technology and its effect on the user. Moreover, AR technology was a lot of technical challenges and limitations that could make it hard or not convenient to use.

3 Case study research method adaption

The chapter represents an adaptation of case study research to the main goal of the master thesis work. Moreover, it includes framework and focus of the research. The first section describes the acquaintance with the chapter. The section 3.2 consist of research questions, section 3.3. Explaining data sources, section 3.4. Includes hypotheses of the research, section 3.5 Replicate analysis procedure and the last section, consist of the conclusion.

3.1. Introduction

To analyze and proceed with the Master thesis, the case study research method was adopted. Moreover triangulation is used as a part of the case study research.

Qualitative research has been used to identify the motivational aspects of the respondents' behavior, personal expectations, perceptions, values, etc. They focused on the study of a wide range of the object's manifestations. It allowed respondents to express themselves, which helped to reveal their inner values and experiences, stimulate their creative potential and creative thinking.

For the data collection interviews were conducted. An interview is a targeted socio-psychological communication of an interviewer with a respondent on a certain subject. In addition to it, live demo testing and surveys were analyzed and processed.

3.2. Research Questions

The main questions of the Master thesis are: How can education system benefit from the usage of augmented reality technology?

The technology of augmented reality is developing incredibly fast, nevertheless, there are a lot of concerns about it. In my Master thesis I would like to explore the impact of AR

on kids and education in general. My research will take into account the following groups: parents, kids, and teacher.

I will use augmented reality educational app for learning Chemistry called MoleQL for the research. The app belongs to the *Subatomic* company – an Estonian based company with the main focus on e-learning and augmented reality. Development of the app started in March 2016. During the development period a lot of research and testing was made. Based on the outcome a lot of lessons have been learned and conclusions made. In the Master thesis, I would like to structure and process the obtained data and share the research results.

From the main research question, the following three sub-questions are derived:

1. How kids, parents, and teachers will react to the usage of the augmented reality technology as a part of the learning process?
2. How will augmented reality technology help to enrich educational and learning process?
3. How will AR help to cover five main components of the progressive learning process (high-quality content, object visualization, gamification and game-based learning, real-time performance and interaction)?

3.3. Data sources

There are two main strategies for case study research: inductive and deductive. Induction can be defined as a method of transition from the knowledge of certain facts to general knowledge. It starts from observation and defined certain patterns, followed by structuring the hypothesis and finally linking them to existing theory [42]. Deduction is a method of knowledge transfer to the general laws of its individual manifestations. In the case of deductive strategy, the process is opposite to the inductive one. First of all, it starts from the existing theory upon which the hypothesis is built, after the researcher observes and confirms or rejects the hypothesis [43].

In current work, inductive strategy approach is used. According to it, the theory, research questions, objectives and hypothesis were formed at the beginning of the work. The research started with building up a theory and making observations afterwards.

3.4. Hypotheses

The solution of a scientific problem begins with settling a hypothesis. The scientific hypothesis is a statement containing an assumption about the solution of the problem. They are strongly connected to the research questions and help to structure data collection. Moreover, it helps to define better the concepts and measures to be used during the study [44]. Based on the research question and goal of the Master thesis the following hypotheses were formed:

- IF AR technology app can help to enrich educational and learning process THEN it would motivate and encourage kids to study
- IF to use augmented reality technology in addition to educational program THEN kids will learn and understand fundamentals of subjects in more clear and amusing way.
- IF to use augmented reality in different counties THEN kids would have different expectations and learning experience.
- IF AR technology is used as a part of learning experience THEN it could cover five main components of the progressive learning process (high-quality content, object visualization, gamification and game-based learning, real-time performance and interaction)
- IF augmented reality technolody helps kids to learn the material THEN parents and teachers would be willing to use it as a part of the learning process.

3.5. Analysis procedure

Analysis procedure is a decisive part of the research. It includes steps that should be taken to obtain and proceed with the data collected.

Data analysis emphasizes the tasks of organization and description. Important to understand reflections on what processes exist and what their results are. It is a task for theoretical assumptions, interpretations, and hypotheses. The fact that data has been studied carefully leads to the emergence of ideas about causal relationships. It is important to clearly classify conclusions based on assumptions, interpretations or hypotheses.

It is important to establish study focus during the analysis procedure. There are four steps for it and the fist one is to be clear of the research purpose. Second, define the scope of studying. The next one is to develop research questions and objectives based on the purpose and main focus of the study. The last step is to build a theory and hypothesis as a part of one learning process. Afterwards, it is critical to keep the focus on the main purpose of the studies as it will result in positive outcome from analyzing procedure [45].

After the study focus is settled there is a time for data collection and analysis. Interview and surveys were used in the present Master thesis. Since qualitative data were enormous it was crucial to set correct priorities for the analyzing procedure. The last step of the research is to build an objective and transparent connection between the research outcomes.

Coding was used to process the data in combination with thematic analyze. Coding has been made by using Nvivo tool. The program helped to analyze the collected data and to process it for the future usage. Afterwords, thematic networks were built between the codes.

To increase impartiality results of the case study research, the triangulation method has been used. Each method represents the data from one perspective. Triangulation can help to observe and study the data from different views which will also increase the validity of the research. Triangulation encompasses four different types: [44]:

- Data Triangulation refers to the usage more than one source of the data.

- Observer Triangulation is using more than one observer or reviewer during the research.
- Methodological Triangulation represents a combination of different types of data collection methods, for example, qualitative and quantitative methods.
- Theory Triangulation stands for using different viewpoints and theories for the same data.

Observer and methodological triangulation have been used during the research. They assisted in viewing the collected data from different points and perspectives.

3.6. Conclusion

To conduct the master thesis work the case study research method has been used. Qualitative research has been used for data analysis. It provides detailed information on the user psychology, its values, outlook, underlying motive. Qualitative research helps to focus on the user motivation and attitude.

In addition, the triangulation has been used. Its increasing validity and transparency of the Master thesis work by viewing different sides and methods on the research. Observer and Methodological types of triangulation have been chosen.

The research started with developing the research questions and theory which were adjutsed with hypothesis for the research. Afterwords, interviews, live testing and observation took a part. The data was collected and structured for analyzing. Data analysis was processed by coding the collected data and building a thematic network between them. Moreover, data was discussed and reviewed with observer to increase preciseness of results.

4 Data collection

It is described in this chapter how the data for the Master thesis was collected and processed. The data is gained from the interviews, live testing, the perception of multiple observers who participated in the testing and surveys sent to the participants. The chapter includes six sections. 4.1 Introduction with the general remarks about the process, 4.2. Planning of the data collection, 4.3. Collecting and preparing the data for future usage. 4.4. Preparing the data for analysis, 4.5. Coding and storing the data from interviews. Moreover, this chapter also includes the description of the data storage. And the last section is 4.6. Conclusion which includes a short overview of the chapter.

4.1. Introduction

Data collection is the process of collecting and measuring the information for set variables and systematic ways to respond to urgent issues and evaluate the results. The aim of all data collection processes is to select high-quality data which will correspond to the main goal of the research. The methods vary depending on the discipline and focus of the work. The main idea of the adaptation of suitable data collection method is to provide accurate and truthful information which will fulfill objectives of the research questions and have direct connection with hypotheses.

The purpose of Qualitative Research in general, is exploration. Using qualitative data collection methods researchers can understand the underlying reasons, problems, opinions, and motivations of users. In current Master thesis, the qualitative data collection method has been used along with triangulation. Combination of different methods helps to validate the research results from different perspectives.

4.2. Planning of data collection

Data collection is the accumulation of information in order to provide sufficient completeness to uncover a targeted objective. For more efficient and clear outcome of the research, data collection is divided into two phases:

First of all, interviews and live testing with kids and parents. During the private testing, the phone with the augmented reality application was given to a kid under the parents' observation, which helped to increase clearness and overview of the child activity. During the second phase five kids and five parents from four different countries with different school background and experience were interviewed. Names of the kids and parents where changed due to private issues but the countries and gender remain the same. Kids and parents from the following countries participated in the interview:

Table 1. List of the interviewed participants and their countries of residence

Country	Name of the kid	Name of the parent
Estonia	Triin	Anette
Poland	Yan	Igor
Sweden	Arina	Stefan
Ukraine	Christy	Irina
Ukraine	Andrii	Vira

The second phase, testing and observation of the MoleQL augmented reality-based application in Tartu gymnasium with the kids from 8 to 12 grades who currently are the main focus group for the research. After the testing, the survey forms were sent to kids, parents, and teachers for data collection and future processing. Moreover, the observation of the live testing has been done in cooperation with a Subatomic team which is the owner of the MoleQL application. In addition, testing was conducted during Chemistry class

where the teacher was represented as an observer. Afterwards, the observations of the participants were recorded and analyzed.

4.3. Collecting and preparing the data.

For the first phase of the data collection process, interviews were chosen as the main source of the data. Four out of five interviews were handled directly with kids and parents and one via Skype. In the case of remote interview via Skype, the kid and parent had the earlier experience with the augmented reality app – MoleQL. All interviews were recorded and processed for future analysis.

At the beginning of each interview, the demo of the app was shown to the kids and parents. Kids had direct interaction with the app – they could observe and explore augmented reality using MoleQL application. Meanwhile a parent was observing the kid and his/her behavior. Parents were asked not to help the kid with the usage of the app and to emphasize their own opinion for the clear and transparent outcome of the research. Furthermore, parents had time to try the app by themselves after the interview with the kid. Afterwards, the interview was handled with the parent.

The interviews with the live testing of the augmented reality app lasted approximately 1.5-2 hours. During one testing session two interviews were handled (kid and parent). Questions for the interview are attached in Annex 1 and 2.

For the second phase of the data collection process, the live testing was performed in Tartu gymnasium during Chemistry lesson. Card reaction of carbon dioxide, 3D web-based chemical models and chemistry card game were shown to kids and the teacher.

The reaction of carbon dioxide was shown with the usage of mobile phone and two cards with augmented images. One of the cards was with the image of carbon (C) and the second – with oxygen (O). By scanning the card with carbon a user can see the model of a molecule of carbon on the screen of the mobile device.

When the user puts a card with carbon and oxygen next to each other the interaction between cards starts and the user can see the carbon dioxide reaction (CO_2).

3D web-based chemistry models were shown personally to each kid. The kids could try by themselves to interact with the models via a mobile device and see different layers and sides of models.

The educational card game was played using cards with chemistry elements. The main purpose of the game is to teach students how the interaction between molecules happens at the molecular level.

Also, all interviews were recorded in mp4 format and stored for future analysis and validation. Furthermore, all participants agreed to be recorded and knew the purpose of the interview. All the collected data stored in two cloud storages (Google Drive and Dropbox), additionally audios are stored in the laptop. The voice memo application on mobile phone was used for the recording.

4.4. Preparing the data for analysis

Data analyze is one of the most crusial step of the research. It required a lot of preplanning and investigation before the data is collected. Moreover, the quality and quantity of the data have a big impact on the final results of the research. For the better structure of the process the following stages were followed:

First of all, collect and gather the information. The process of data collection is taking place after the objectives, propositions and hypotheses have been defined and structured. Research methods, literature and data sources are important components of the process.

Second, an organization of collected data. To organize the data that was gathered during the research is challenging part as it will affects analyze and conclusion. All audio files with interviews of kids, parents and observers were saved, re-listened and rewrote into text files. Furthermore, Coding structure was designed.

During the third stage, the collected and organized data was analyzed and visualized. For qualitative analyses of the data Nvivo11 program was used. All the coding and structuring of the information have been done with the usage of the program.

In the last stage, results of the collected and processed data were formed and described. In this stage crucially important to make right conclusions which will correspond to research questions, objectives, propositions and hypothesis.

4.5. Coding and storing the data from interviews

Data which is collected by using qualitative methods is usually voluminous. Analysis of qualitative data is a creative process. It requires intellectual discipline, analytical rigor, and effort. Since different people used to do intellectual work in various ways, there is no single way of organizing, analyzing and interpreting qualitative data. For processing received information from interviews the researcher needs to do an operation in which collected data is split into pieces, proceeded and reconnect in a new way. This operation called coding, which is the central process for considering research theories and objectives.

Coding data is a technical technique by which data are categorized in a specific way of presenting the received information in the form of symbols, signs, numbers, for the convenience of its use for a computer or other processing.

Coding was made by using NVivo is computer software for qualitative data analysis (QDA) and mixed methods research [46].

Moreover, after the coding method of thematic networks has been used. The method helps to streamlines results for qualitative research. The main purpose of thematic analysis - selection of the main topics contained in the qualitative data, their grouping and display easy to understand researcher and reader[47]. The result of such groups is spider network, which shows all the coded themes and the relationship between them.

4.6. Conclusion

Quantitative research is a descriptive research aimed at strict standardization and formalization of the process of information collection and processing, which enables the company to obtain accurate data. One of the most efficient ways to collect comprehensible data for quantitative research is personal testing, interviews, and observation.

Data collection was conducted in two phases. The first phase consisted of collection of the interviews with kids and their parents. The second part included the live testing of the application built on the technology of augmented reality – MoleQL, 3D chemicals models, and educational chemistry game. Moreover, the testing was conducted under review of observers who were additionally interviewed. In addition, surveys were sent to all participants, teachers, and parents.

The collected data was reviewed by the researcher and coded using the Nvivo tool. The software allows the researcher to classify and sort obtained information, study interactions between the data, and combine analysis with a formation, search and modeling.

5 Data analysis

This chapter represents the analysis of the data received during the two phases of data collection. Section 5.1. consists of an introduction, 5.2. describes interviews' analysis which is referred to at the first phase of the data collection, and section 5.3. contains survey and testing analysis – linked to the second phase of the research. The Chapter is summarized in section 5.4.

5.1. Introduction

Data analysis involves performing consistent, logics and interpretation actions for the data collected. It helps to analyze the data obtained during the research and build a transparent conclusion.

Qualitative research does not end with the data collection. The culmination of the whole work is rather not the conduction of the interview, but the analysis, interpretation, and presentation of the results to the readership. The challenge is to find the corresponding meaning in the mass of the materials collected that will help to investigate the hypothesis and reflect objectives of the Master thesis.

The data was collected during two phases and represented in the separate sections. Nevertheless, some data was combined from interview and surveys for a complete representation of the data. Moreover, several outcomes from the data analysis were reviewed with other researchers who work in the same field.

The methodology of qualitative research includes not only qualitative methods of collecting information but also qualitative methods of analysis. The method of thematic networks is used for the data consolidation. It consists of four main steps. The first one is coding. The second is sub-themes identification. Then sub-themes form themes and build a thematic network. The last step is description and explanation of the thematic network.

5.2. Interviews analysis

Qualitative research conceptualization is an important part of data analysis. Determination of correct research themes is a critical part of the arranging and structuring the qualitative data. Coding is a technical part of the research which arranges raw data by breaking it into parts and combining along with creating a theme and new sense. It frees the researcher from confusion in the details and leads to higher levels of thinking about them. Codes also encourage researchers to test the hypothesis and theory of the research.

The method of thematic networks was used for grouping the codes into the themes and for visualizing them. This method helps to represent the data as a spider web grouped by themes. Five main themes were consolidated after the codes analysis:

- Interactive leaning
- Filling educational game
- Augmented reality experience
- Motivation and encouraging of a kid
- Self-driven learning

Each of the themes includes subthemes generated from the coding. Visualization of the themes and sub-themes is represented in Annex 3. The themes are interconnected. Moreover, they are connected with five components of the learning progressive process being important part of the study experience.

Additionally, coding made for the usage of the MoleQL – augmented reality application during the learning process. Coding is based on the combined answers from interviews and open questions from the surveys. The result of the coding is illustrated in Annex 4.

Moreover, in addition to the interview participants were asked to rate five main progressive learning components in the scale from the most important to the least important. The results give us a clear picture what major and minor priority in the learning process is. The consolidated results of the answers are shown in Table 2.

1 – Insignificant; 2 – Unimportant; 3 – Neutral; 4 – Important; 5 - Highly Important

Table 2. Rating of the five main components of progressive learning

Country	Name of the Intervied	High-quality content	Visuali-zation of objects	Gamifi-cation	Game-based learning	Real-time performance and interaction
Estonia	Triin (kid)	2	4	5	3	1
Estonia	Anette (parent)	5	3	2	1	4
Sweden	Arina (kid)	1	2	5	4	3
Sweden	Stefan (parent)	5	1	3	2	4
Ukraine	Andrii (kid)	1	2	4	5	3
Ukraine	Vira (parent)	4	5	3	1	2
Ukraine	Christy (kid)	1	2	4	3	5
Ukraine	Irina (parent)	4	5	1	2	3
Poland	Yan (kid)	2	1	3	5	4
Poland	Igor (parent)	5	2	1	3	4
Sum of kids evaluation		7	11	21	20	16
Sum of parents evaluation		23	16	10	9	17
Total		30	27	31	29	33

Based on the results received we can conclude that the total priority is gamification. Nevertheless, we can see different patterns of evaluation by kids and by parents. As for kids the major priorities are gamification and game-based learning, at the same time for parents – high-quality content.

After analyzing the data collected during the interview we could summarize the general attitude of parents and kids towards augmented reality experience as a part of the learning process. The results are shown in Table 3.

Positive – interested and exciting towards AR technology. Finding it beneficial for the learning.

Neutral – indifferent about the technology. Finding it neither good nor bad.

Negative – against the augmented reality technology as a part of the learning process

Table 3. Attitude towards augmented reality application as a part of the study process

Country	Name of the Intervied	Attitude towards augmented reality
Estonia	Triin (kid)	Positive
Estonia	Anette (parent)	Positive
Sweden	Arina (kid)	Neutral
Sweden	Stefan (parent)	Neutral
Ukraine	Andrii (kid)	Positive
Ukraine	Vira (parent)	Neutral
Ukraine	Christy (kid)	Positive
Ukraine	Irina (parent)	Positive
Poland	Yan (kid)	Positive
Poland	Igor (parent)	Positive

5.3. Survey and testing analysis

Company SUBATOMIC OÜ which is the owner of MoleQL augmented reality application used to perform its own researches and testings. One of them was handled in Tartu gymnasium. The testing has been made for carbon dioxide reaction, 3D chemical models and chemistry card game. Additionally, survey forms were sent to kids, parents, and teachers. The outcome of the surveys are shown in Appendixes 5, 6, and 7.

Twenty-five students participated in the survey, 44% of them were girls and 56 % - boys. All kids study at Tartu gymnasium. Kids from the 8th grade till 12th grade were eligible to participate. 64% of the kids answered the question whether they liked studying that they like school but sometimes it is hard to study, 20% - like school and find it interesting, 12% of kids do not like school, and only 4% find it boring. According to the results, majority of the kids find Chemistry hard and difficult to understand and 20% like Chemistry and it is easy for them. Surprisingly, only 4% of the kids use educational apps on the daily basis and 48% - sometimes. Moreover, 48% of kids do not use apps at all. Nevertheless, we can see the enormous interest of kids towards educational games, 92% of the kids would like to learn through playing games.

The survey that was sent to parents showed that most of the parents are in the age of 31-40 having 2 or 3 kids. In addition, 40% of the parents think that one of the crucial problems of the educational system is that school program was not updated frequently. What is more, lack of financing and equipment affects the educational process. Besides, the majority of the participants stated that kids have low interest in studying and they do not have any motivation which causes problems. Moreover, 20% of the parents find school program complicated. Additionally, parents showed extensive interest in the educational apps that can help kids to study.

The survey was also sent to teachers, and 46 participants replied thereto. Age of the interviewed varies from 26 to over 65. Moreover, 90% of them have experience of being a teacher for more than 10 years. In response to a question about problems of the educational system 39% of the participants emphasized low interest of kids in studying, for the majority of the interviewed financing and lack of materials are the significant

problem. Additionally, a minority of teachers mentioned social and family factors as a negative aspect which affects educational system. More than half of the teachers consider visualization to be one of the best ways for explanation learning materials and only 4% found it not efficient. Nevertheless, 94% of participants would use app that helps to visualize chemical elements and reaction during Chemistry lessons. The overall response to the question about educational games was surprisingly acceptable as all two-thirds of the participants found it beneficial for the learning experience. Moreover, one-third has a neutral attitude towards educational games. Nevertheless, 87% commented that they would allow students to play educational games during the class.

Moreover, in Annex 8 difficult and simple chemistry topics are shown. The coding was made separately based on open questions from the survey and interview questions. The image includes chemistry topics for 8th and 9th grades.

5.4. Conclusion

The research has an exploratory approach with qualitative data collection method, which allows concentrating on the experience and motivation of the user, seeing benefits, disadvantages, and problems of augmented reality technology as a part of the learning process. Moreover, triangulation was used as a part of the validity of the research.

The research consists of two phases: interviews with kids and parents and live testing in the school with the kids and teacher during Chemistry class. By dividing research into two phases data was collected which gave wider and precise information about the augmented reality technology as a part of the learning process. Moreover, it helped to include observer and methodological triangulation methods. Analysis of the interviews is represented in the first phase, in the second phase – observation and analysis of the surveys are displayed.

The method of thematic networks is used for analyzing interviews and open questions in the surveys. The method is a convenient way of qualitative analysis. It allows analyzing

big amount of data of different types. Moreover, it is easy to visualize research results and build connections between the data with the help of thematic network.

6 Validation and limitations

This Chapter presents study validity and limitations of the research. The overview of those factors shows the influence and effect of the exposition to the research. The chapter is divided into four sections. The first one is introduction, the second represents the study validation, while the third section shows study limitations, and conclusions have been made in the last part of the chapter.

6.1. Introduction

Case study research is an exploratory research. It helps to explore feelings, a way of thinking and motivation of the participant. Moreover, it helps to investigate the deep purpose and reason of the research.

In a qualitative study, the data collection is a beginning for analyzing and processing the data, checking the quality of the interview obtained, coding, making the conclusions, etc. The next stage is the classification of data in accordance with the hypotheses, interpretation and analysis of the results obtained, the generalization of data, checking the numerical values of variables and the corresponding hypotheses of the study.

6.2. Study validation

For conducting the research the qualitative analysis was chosen as the main approach to the research. The decision was based on the goal and objectives of the master thesis research. Qualitative research gets deep and detailed information about the feeling and internal motivation of the participant. It answers the question "how" and "why". It is mainly oriented on finding out more in-depth information.

In the case of the research, it was important to have detailed and private interviews with the final user as it helps to concentrate and get the feeling of the participant towards AR

technology and education. Moreover, flexibility of the selected method helped to see the results from a different perspective and develop hypotheses and ideas.

For the validity and objectivity of the research the following criteria were followed:

- Subjectivity and confirmability of the collected and proceed data. The main focus is to display data in terms of participants by using individual approach. The main task of the researcher was to reflect the view of the participant.
- Credibility and transparency, after the data collection, the review of the results has been made in cooperation with the Subatomic team for the information transparent display. Furthermore, during the interviews and AR application testing parents and teachers played the role of the reviewer of the kids' behavior and motivation. In addition, data has been audited for checking misrepresentation and deviations in the procedure of data collection and analysis.

The triangulation has been used to avoid redundancy and develop transparent approach. According to the authors of the book of case study research for software engineering: "It is important to ensure that there is sufficient coverage of sources of data as this will support triangulation of data and therefore enhance the reliability and validity of the findings of the study" [44].

The master thesis consists of a combination of different methods of analysis and emphasizing their complementary with sufficient comprehension of data sources. During the research the observer and methodological types of triangulation have been used.

The observer triangulation type of methods is often based on comparing data collected by qualitative methods with data obtained by quantitative methods.

The methodological type of triangulation uses several observers or analysts. It helps to reduce the potential bias that occurs when data is collected by one person and represents an effective means of direct assessment of the data reliability and validity. Observers' triangulation provides an offset check when collecting data. Moreover, it was used to review the conclusions received from the observer triangulation.

6.3. Study limitations

One of the main targets for the researcher has to reflect collected and analyzed results as much transparent and precise as possible. The data was analyzed from different angles and reviewed by several observers. But nevertheless, the research faced study limitations.

One of the main problems was enormous amount of the data collected during the interviews, live testing, and surveys. The scope of the research surpassed all estimations. It required a lot of efforts for the data analysis and replication. On the other hand, it helped to investigate broader picture of user experience. In each report large amount of information collected by the researcher must inevitably be omitted. Focusing on the report should be in the first place. The researchers risk to lose the main purpose of the work by trying to include the immense mass of materials into the report. Very often the decision about what to include and what to disregard is made hard and becomes one of the most painful steps in the entire study. The better the research questions are, the easier it is to keep track of the goal of the research.

The use of triangulation methods has its downsides. One of the most crucial is the comparison of qualitative and quantitative data received during the research. This process of comparison is not always a straightforward process since qualitative and quantitative methods answer different questions, and their answers are not easily combined to form a holistic picture. Moreover, engagement of different observers and researchers for the data collection and processing will bring chaos into the research.

Adjustability of the case study research makes it difficult to concentrate and focus on the main points. During the research, the objectives and purpose of the Master thesis were constantly changing and improving. It was hard to keep the focus on the initial goals. Nevertheless, after setting up the research objectives and linking them with hypotheses the research was shaped into a clear framework.

Trustiness and reliability of the sources used for the research was the background due to various interpretations of the information. Each researcher in his paper reflects data from his perspective. Research background requires a lot of reading and investigation to view the transparent and impartial information.

Validity and applicability of the used information about augmented reality technology. As AR technology frequently develops and progresses, it is challenging to keep track of the latest updates and usage of the augmented reality technology in the educational field. Moreover, usage of augmented reality varies from one region of the Earth to another, for example, the occupation and style of AR in China differs from European. Sometimes it differs from country to country.

6.4. Conclusion

For the researcher, it is challenging to conduct transparent and efficient analysis for case study research as the amount of the data collected and processed is huge. It is important to keep focus and concentration on the main objectives of the research. In order to facilitate the preparation of the conclusions, it is considerable to return to research questions and to concentrate on them.

Each research method has its pros and cons. Selection of the method that will be adopted for the Master thesis work is based on the estimated purpose of the studying. Nevertheless, the combination of different research methods reflects the received results from different sides. The procedure of combining various methods is called triangulation. Two types of the triangulation have been used – observer and methodological.

The reliability of the research method is under the constant attention of critics since it largely depends on the experience and the chosen strategy of the encoder conducting the analysis. To improve the reliability and validity of the method, it is recommended to have data processed in parallel by several observers, which was done in cooperation with the Chemistry teacher and Subatomic team. Moreover, combination of different types of data collection methods was included. In the research, a qualitative method is a primary method and quantitative is an additional one. The representation of the data from different perspective is called triangulation. The observer and methodological triangulations were used during the research.

7   Conclusion

7.1. Summary of findings

At present, the education system is undergoing significant changes. The role of information in life of society is increasing, which leads to increase in the requirements for the education level. Nowadays schools have an important mission to prepare kids for the new world which is rapidly changing and progressing. It is impossible to increase the efficiency of studies without the use of the latest technical training tools.

Augmented reality technology in our time is very rapidly developing and can be applied in many areas. One of the most beneficial usages of the augmented reality technology is education.

The results of the analysis of qualitative data rarely contain unexpected conclusions. But even information that seems obvious requires proof. The research showed positive attitude towards AR technology. Nevertheless, there are a lot of concerns about the future use of the technology as a part of the learning process. Moreover, full digitalization of the education could have a backside which is hard to predict. In the case of any innovative technology, it is uneasy to forecast the outcome for the future, as there is general over-excitement about the technology from the beginning.

Generally, kids were more broad-minded and excited about the technology while parents and teachers were more tolerant and circumspect. Moreover, teachers and parents stated they could assume the future usage of augmented reality as an additional for the school program but not as its replacement.

As interview included kids from different schools and countries so their attitude and expectations of the school and chemistry class were different. For example, kids from Ukraine and Poland dislike school education but at the same time they like going to school because of their friends. The kid from Estonia was more discreet in comments about the school, the attitude is more neutral. Meanwhile, the kid from Sweden likes school classes more than other interviewed kids, the main reason is that during classes they have a lot of

teamwork and it is perfect time for communication and interaction with friends and classmates, in addition, they have a lot of outside activities (excursions, games, walks).

All kids replied that more experiments and chemistry labs would make chemistry class more interesting for them. Moreover, kids mentioned that they do have a few chemistry labs during the study year. But most of them is in introductory level. Moreover, Arina mentioned that during chemistry labs they do not have the possibility to do all schools labs by themselves. Usually, teachers is only one who is going them and showing to the class.

Chemistry topics are different, so kids understand not all of them. Some of them are challenging and some of them are not. By analyzing the data collected during the interviews we summarized five hardest and easiest chemistry topics for kids in Annex 8. As we can see, the hardest part for the kids is to understand the Chemistry questions and connections between elements and the easiest one – the theory and periodic table. Moreover all the kids interviewed stated that sometimes they do not understand the teacher and would like to have more personal approach during the classes.

According to the results of the coding about MoleQL augmented reality application (Annex 4), it is clear that user experience and interaction with the application are beneficial for the user. Moreover, the researcher can conclude that the MoleQL application includes five main components of the progressive learning. Nevertheless, they all are at the early stage of development and need to be improved before the application release.

Interesting was answer for the question about kids expectation of the class in the future. As kids from Ukraine and Poland emphasized digitalisation of school books and classes when a kid from Sweden pointed out the remote education. The contrast between kids from different countries is significant huge as the educational approach.

As the study has shown, kids and parents have different expectations from the school and education. According to the table 5, kids and parents were asked to evaluate five components of the progressive learning. For kids, a top priority was game-based learning and gamification features while for parents - high-quality content. During interviews, kids

were more interested in the gamification of the MoleQL application and reactions while parents were searching for educational content and correctness of 3D models.

According to the research observation of the Subatomic team, kids enjoyed playing with the MoleQL app, the majority of the kids emphasized positive experience with the app, nevertheless, a few prototype bugs and UI problems were defined in the app. The main concern of the kids was that app does not have enough reactions to play with and it should have more additional content. Comments from the teacher were that it should include more information about the reaction and detailed explanation, though he found it interesting and entertaining for the kids. The testing of the chemistry card game was a bit more complicated to the kids as it required understanding of the chemistry reactions.

Chemistry game was difficult for understanding and engaging in the same time. The game requires strong basic of chemistry knowledge and time to learn the rules. It cost around 20 min to explain the game but then kids were motivated to play. The Subatomic team should simplify the game, since the game rules are not clear for users.

The real-time interaction with the models was the best past of user experience. In addition, models included enough of the learning content. Kids loved to interact with models and see different layers and sides of chemical objects. Nevertheless, there were small inaccuracies in one model were pointed out by the teacher.

Augmented reality have shown the mobility and self-driven learning of kids in the class. Most of the kids were learning and exploring chemistry without the help of the teacher or observers. By using the technology of augmented reality as a part of the education kids could learn not only in the class with the teacher but also my themselves in any place.

7.2. Implications

Augmented reality is a technology that allows combining a layer of digital reality with physical environment. It is a powerful tool that can enrich the future of the education. It can help to see and interact with the things from a different perspective during the learning process.

However, the technology of augmented reality is rarely used at schools. But it is impossible to overestimate the potential of the technology. By using the capabilities of augmented reality in education it is possible to visually reconstruct the processes that are difficult or almost impossible to reproduce in the real world and make learning interesting and understandable.

The research helps to understand the attitude of the user towards augmented reality technology as a part of the learning process. The obtained research is beneficial for the future development of the AR technology represented in the MoleQL application.

Moreover, five components of the progressive learning designed by the researcher emphasize the main points that are crucially important for the successful and valuable learning outcome. Furthermore, they help to keep the focus on the most important parts of the learning process. Components are taken into consideration for the further development of the MoleQL application. Furthermore, the research has shown that application with the usage of augmented reality technology has a combination of one of several progressive components. Meanwhile, they all should be connected to one application.

The research showed that augmented reality has a unique value for the education and future development of the school programs. Nevertheless, each technology it has pros and cons. The researcher recommends to use AR technology in addition to the existing school learning program but not as a replacement of the current study process. The main concerned of the researcher is that Augmented reality technology is an innovational technology which has not been used massively, it is hard to predict the effect on kids and society in general. The monumental usage of the technology should be carefully implemented into the education under constant observation of specialists.

7.3. Future work

Rapid development of technologies, which took place over the past few decades, has led to the fact that in some countries educational system has catastrophically fallen behind.

Currently we can only imagine how the process of perception and memorization of learning material would improve after implementing the augmented reality technology. It is these modern interactive technologies that bring visualization, game elements, activate the interaction of participants in the learning process, and develop spatial thinking and new learning approach. Owing to augmented reality, students have unlimited possibilities for learning new things.

We live at the age of information and rapid development of the technology. Changes in the environment affect society and future of the state. By adopting new and innovative approaches to be used in the educational system the government could increase the intelligence and conversance of the society. Augmented Reality is the most efficient way of exploring the surrounding environment and space. However, at the moment there is no single methodology for applying the augmented reality technology in the educational environment. Moreover, the usage of the AR needs more line testing for long term prospective.

In future works the researcher would like to concentrate more on the methodology for applying AR technologies at schools. Moreover, integration of AR into the educational program is challenging task which needs to be tested and investigated in the future. Furthermore, better understanding of the usage of augmented reality technology and its effect not only on the user but on the education in general have to be studied. Currently, a lot of practical researchers were studying the effect of AR on the user but not on the education system.

In addition, most of researchers are focused only on one or few components of progressive learning but not on all of them at the same time. The question of AR application that will include five components of the progressive learning and be integrated into the study programme is considered for the future research

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Appendix 1 – Interview questions for interviews (Kids)

1. How do you feel about school? Why do you like school?

2. How do you feel about chemistry classes ?

1. Why you like and dislike chemistry classes? What topics are the hardest to understand? What topics are the easiest to understand?

2. What would make you more excited about chemistry lessons?

3. How do you understand your chemistry teacher?

4. What additional materials do the teacher use to explain chemistry?

5. How many chemistry labs do you have at school?

6. How do you use mobile phone during the class?

7. How do you feel about educational games? Would you like to play them during the class?

8. Are pictures and videos help you to understand materials better? Do you use them during the class?

9. How do you feel about MoleQL app?

10. How do you understand the reaction? Why does the reaction happen?

11. Would you like to use MoleQL app during the class and why?

12. How would you improve the app?

13. What additional features and topics would you add to the MoleQL app?

14. What would make you more excited to use the app?

15. How do you see the class of the future?

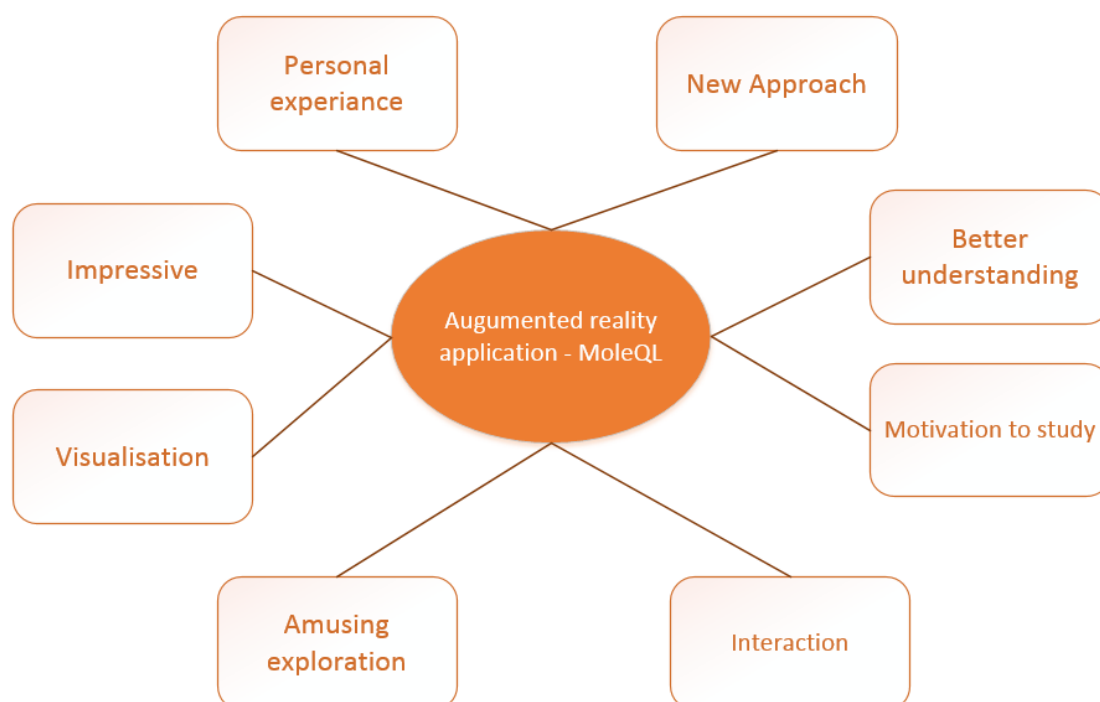16. How do you see perfect class?

Appendix 2 – Interview questions for interviews (Parents)

1. How do you feel about educational system ?

2. What is your opinion about the school that your kid is attending?

3. Why your kid like and dislike school?

4. How much time your kid spends for studying ?

5. How do your kid concerns to chemistry classes?

6. How do you feel about educational apps?

7. How do you usually find out about new educational apps?

8. Would you pay for educational app that helps your kid to study and get better understanding of school subject?

9. How do you feel about educational games? Would you allow your kid to play them?

10. How do you feel about MoleQL app?

11. According to your observations, how kids reacted to MoleQL app?

12. In your point of view, how MoleQL app affect learning outcome?

13. Would you like your kid to use MoleQL app?

14. What additional features would you add to the MoleQL app?

15. What would make your kid more excited to use the app?

16. What would make you more excited to use the app?

17. How would you improve the app?
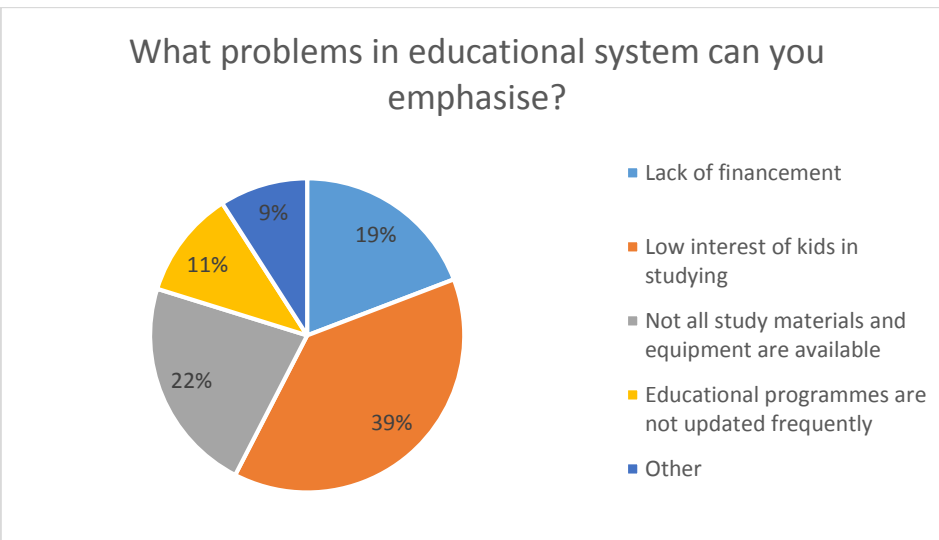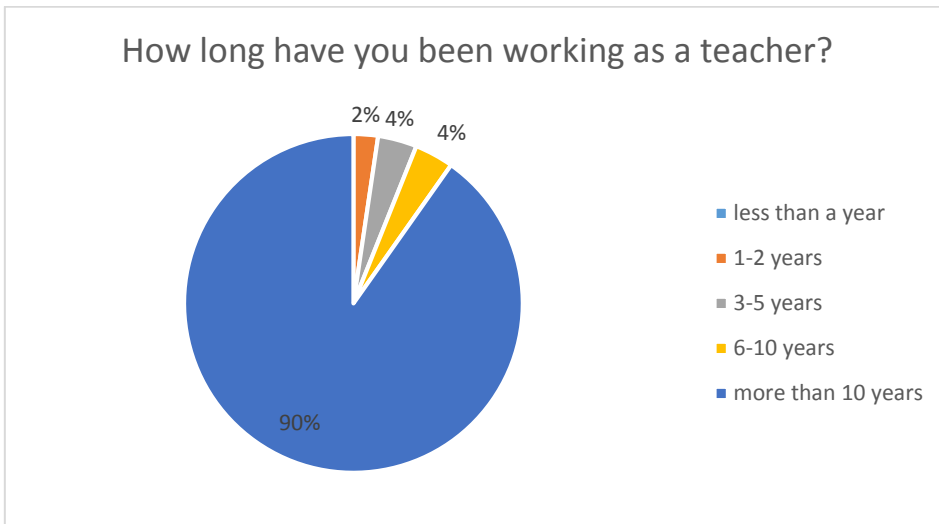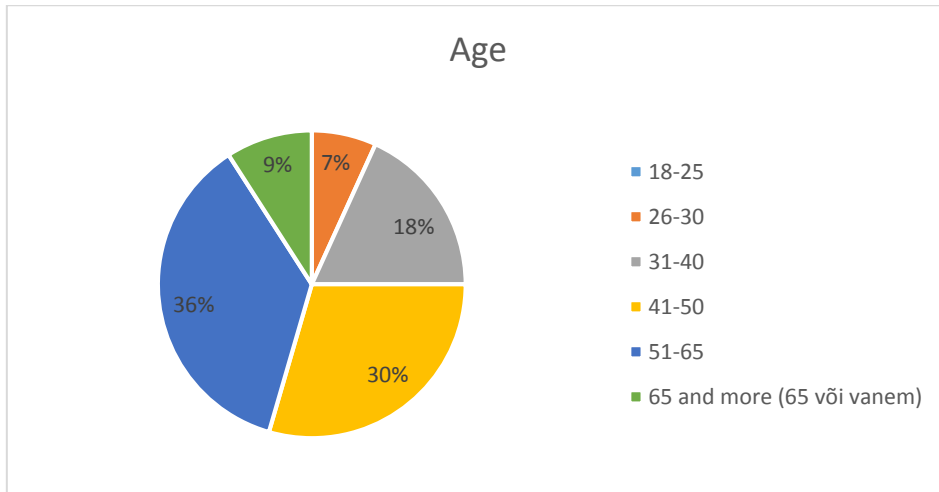18. How do you see the perfect class for your kid? (How do you see the class of the future?)

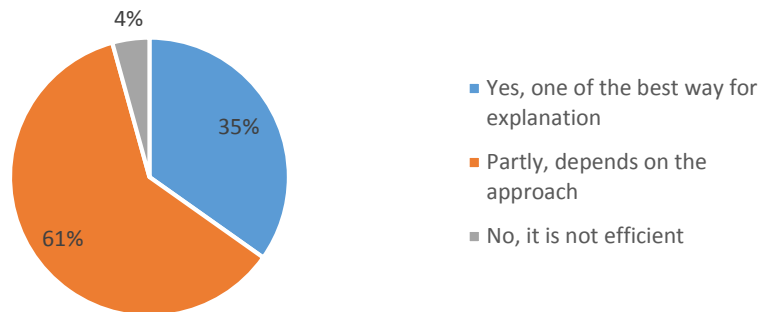# Appendix 3 – Thematic networks of themes
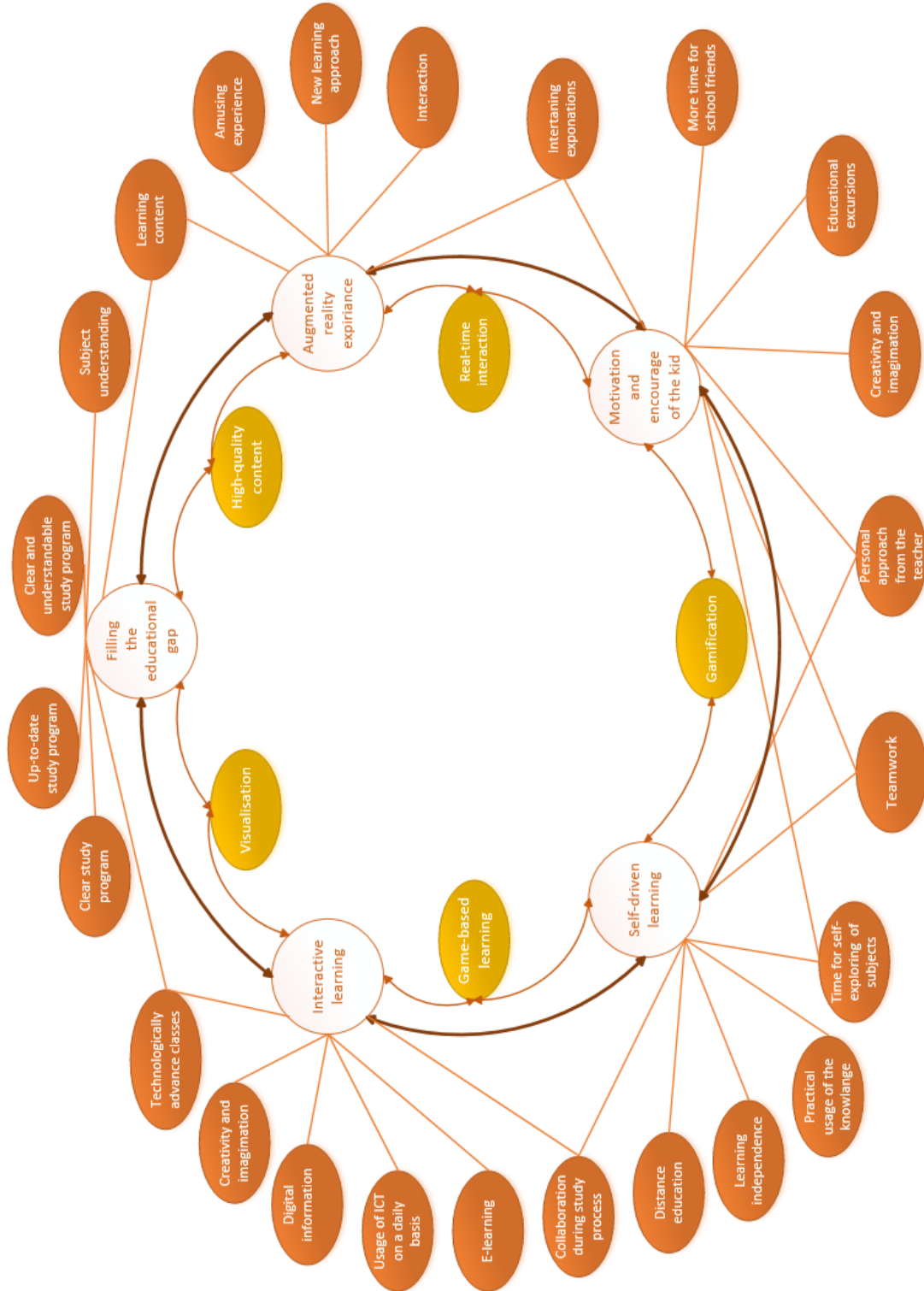
Appendix 4 – Coding for Augmented reality application - MoleQL

Appendix 5 – Survey for teachers

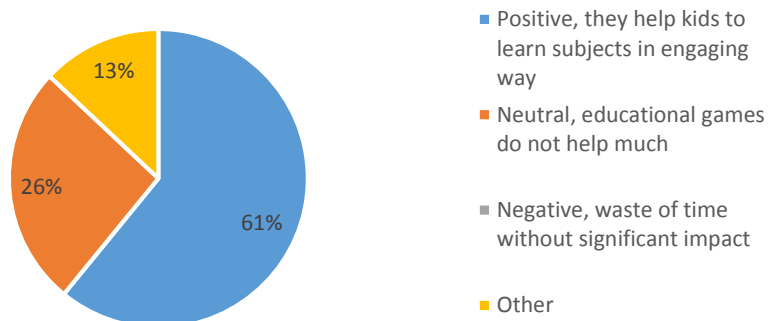## Age

- 18-25
- 26-30
- 31-40
- 41-50
- 51-65
- 65 and more (65 või vanem)

7% — 26-30
18% — 31-40
30% — 41-50
36% — 51-65
9% — 65 and more

How long have you been working as a teacher?

- less than a year
- 1-2 years
- 3-5 years
- 6-10 years
- more than 10 years

2% — 1-2 years
4% — 3-5 years
4% — 6-10 years
90% — more than 10 years

What problems in educational system can you emphasise?

- Lack of financement
- Low interest of kids in studying
- Not all study materials and equipment are available
- Educational programmes are not updated frequently
- Other

19% — Lack of financement
39% — Low interest of kids in studying
22% — Not all study materials and equipment are available
11% — Educational programmes are not updated frequently
9% — Other

Do you consider that visualisation helps kids to learn?

- Yes, one of the best way for explanation
- Partly, depends on the approach
- No, it is not efficient

4%
35%
61%

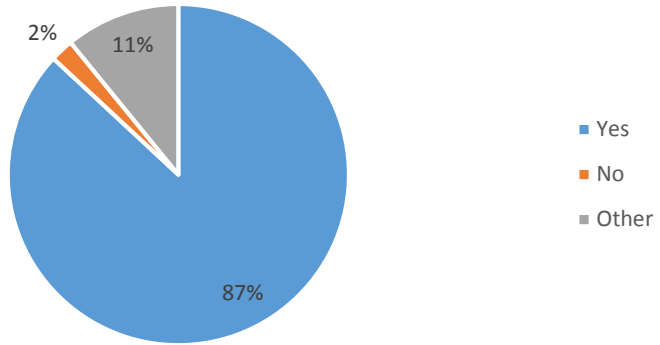## Would you use app which helps to visualize chemistry elements and reactions during chemistry lessons?

- Yes
- No

6%
94%
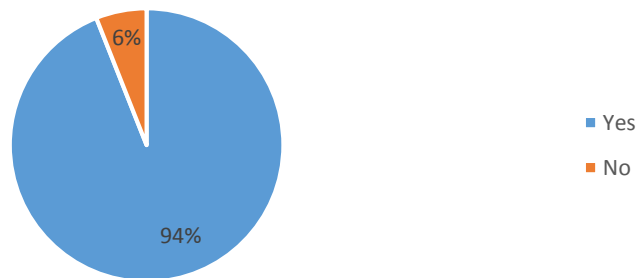
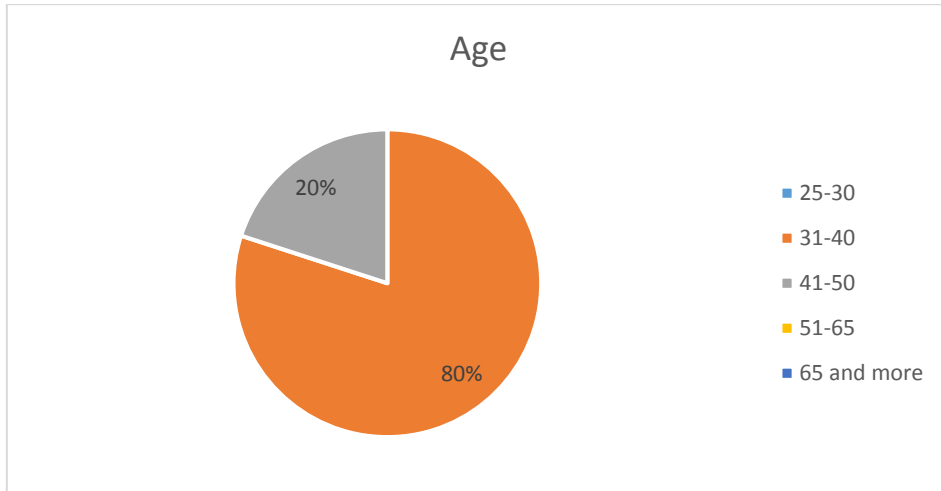## What is your attitude towards educational games?

- Positive, they help kids to learn subjects in engaging way
- Neutral, educational games do not help much
- Negative, waste of time without significant impact
- Other

13%
26%
61%

Would you allow students to use educational games during the classes?

2%
11%
87%

- Yes
- No
- Other

Appendix 6 – Survey for parents

Age

- 25-30
- 31-40
- 41-50
- 51-65
- 65 and more

20%

80%

How many kids do you have?

- 1
- 2
- 3
- 3 and more

20%

40%

40%

How old is/are your kid(s)?

- 5 - 7 years
- 9 - 11 years
- 12 - 15 years

27%

55%

18%

What problems in educational system can you emphasise?

- Lack of financement
- Low interest of kids in studying
- Not all study materials and equipment are available
- Educational programmes are not updated frequently
- Other

15% 15% 20% 10% 40%
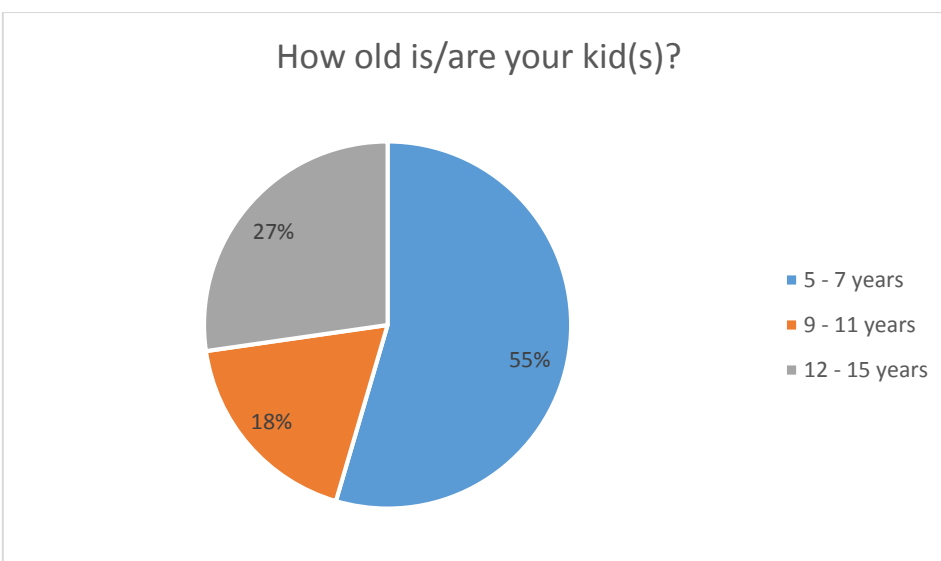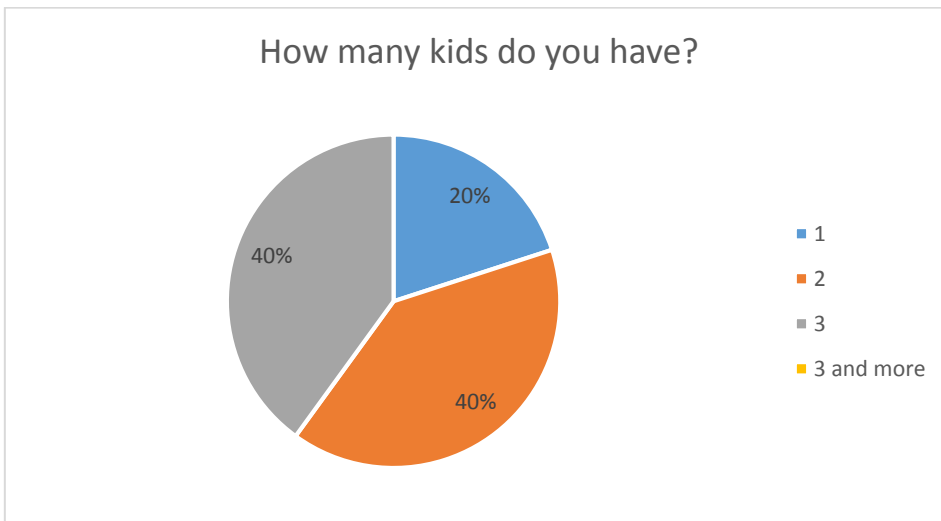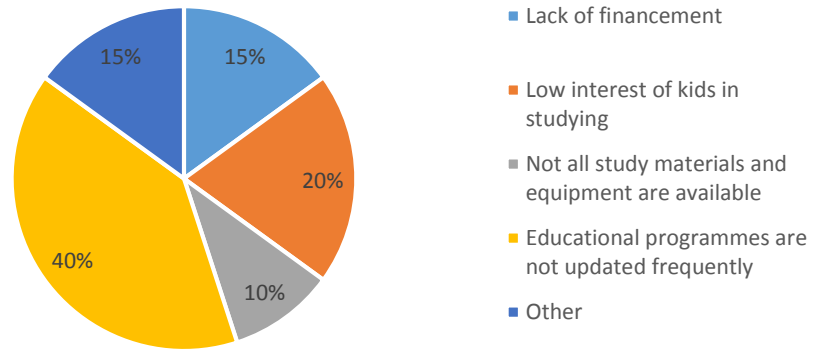
Do your kids use educational apps?
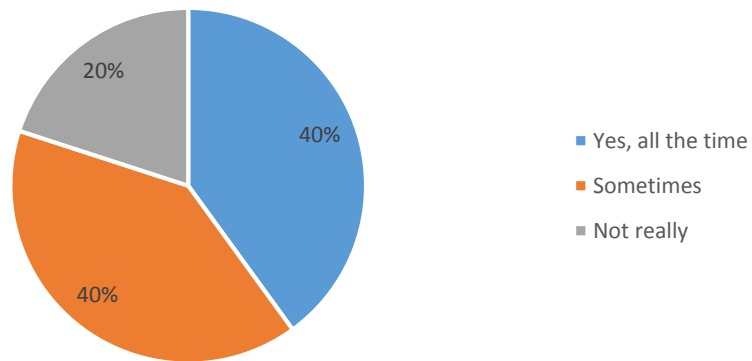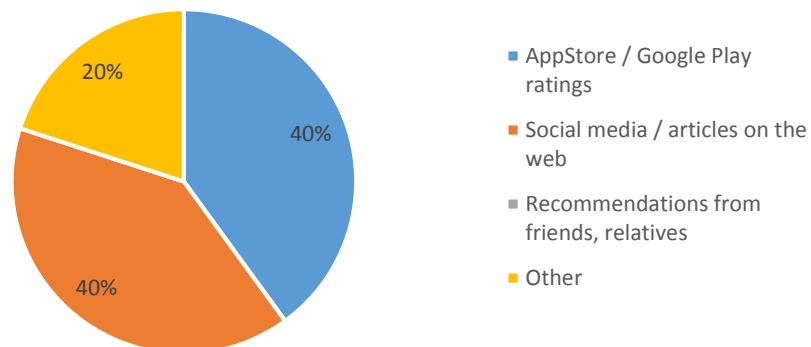
- Yes, all the time
- Sometimes
- Not really

20% 40% 40%

How do you usually find out about new educational apps?

- AppStore / Google Play ratings
- Social media / articles on the web
- Recommendations from friends, relatives
- Other

20% 40% 40%

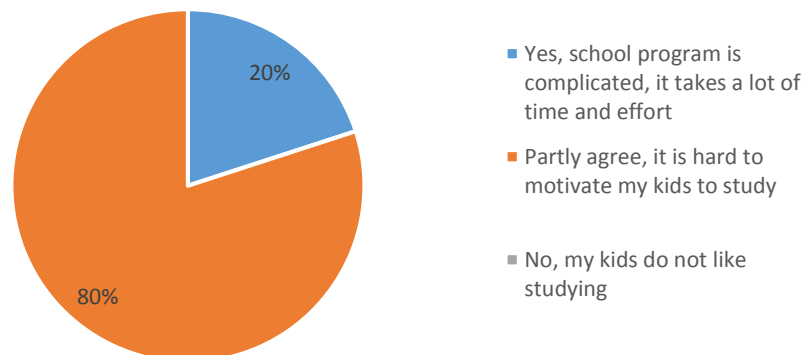## Would you pay for educational app that helps your kid to study and get better understanding of school subject?

- Yes — 80%
- No — 20%
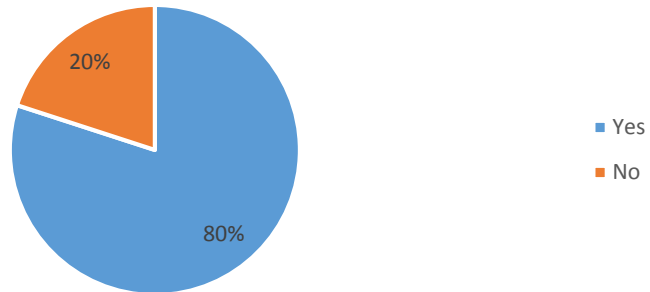
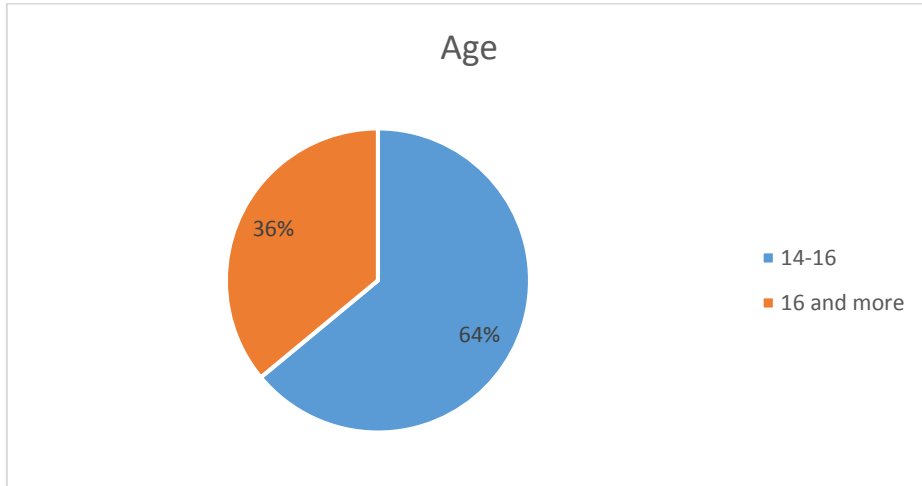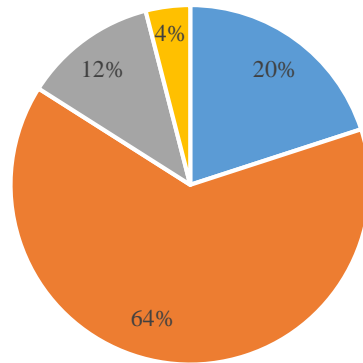## If "Yes" how much would you to pay?

- 1-3 Euro — 60%
- 4-7 Euro
- 8-10 Euro — 40%
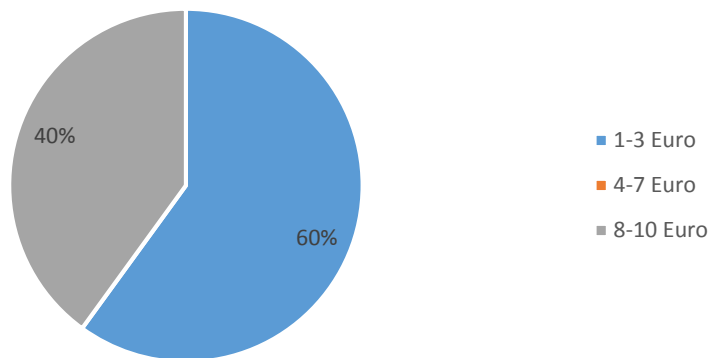
Do your kids spend a lot time for studying?

- Yes, school program is complicated, it takes a lot of time and effort — 20%
- Partly agree, it is hard to motivate my kids to study — 80%
- No, my kids do not like studying

Appendix 7 – Survey for students

Age

36%

64%

- 14-16
- 16 and more
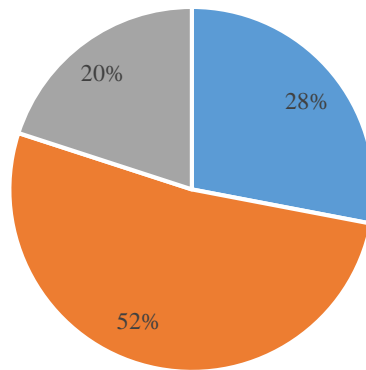
Gender

44%

56%

- Male
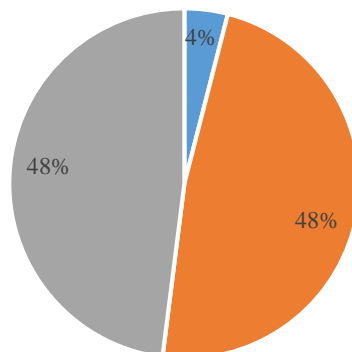- Female
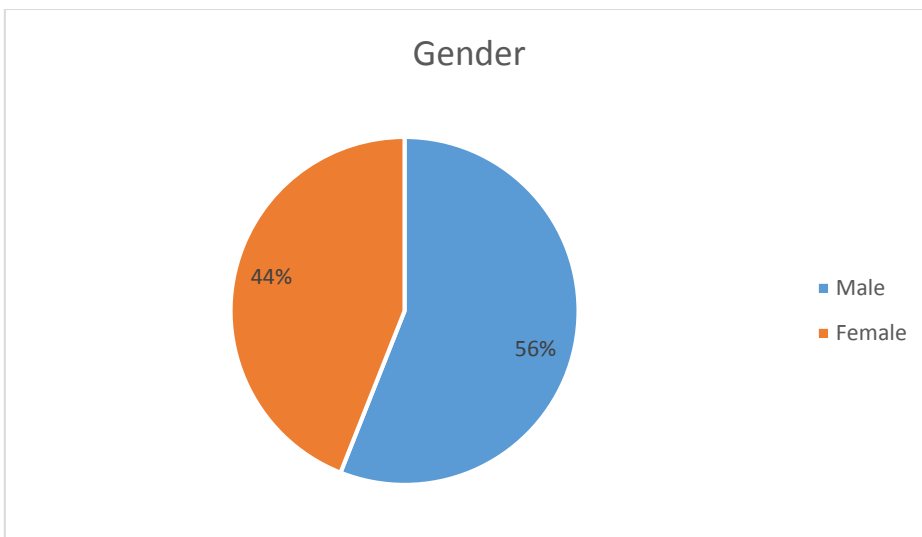
Do you like studying?

- I like school. It is very interesting to study
- I like school but sometimes it is complicated to study
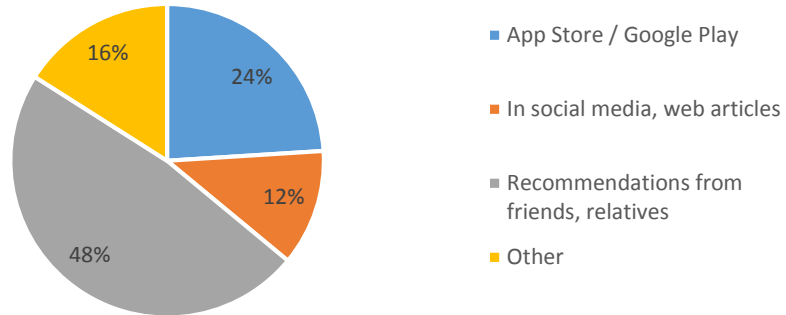- I do not like school. It is hard to study
- School is boring

20%
4%
12%
64%

Do you like chemistry?

- Yes, it is easy to understand
- Mostly, sometimes it is hard to understand
- No, it is complicated subject

28%
20%
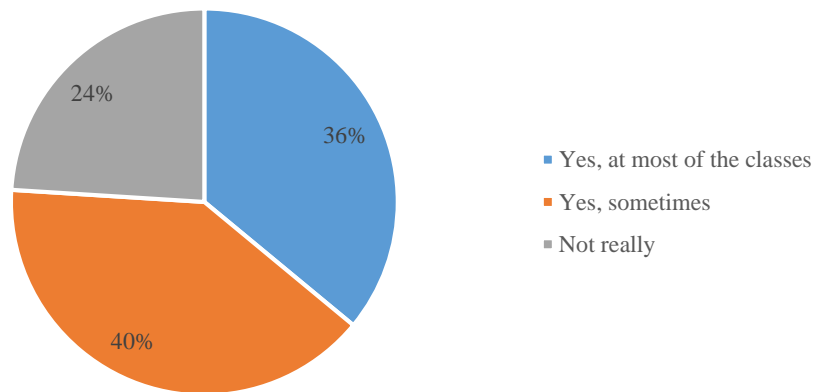52%

Do you use educational apps ?

- Yes, all the time
- Sometimes
- Not really

4%
48%
48%

How do you usually find out about new educational apps?

- App Store / Google Play — 24%
- In social media, web articles — 12%
- Recommendations from friends, relatives — 48%
- Other — 16%

Do you use mobile devices during the classes?

- Yes, at most of the classes — 36%
- Yes, sometimes — 40%
- Not really — 24%

Would you like to play educational games in the classroom?

- Yes, definitely — 80%
- Yes, if it won't distract me — 12%
- No, I do not think it would be useful — 8%
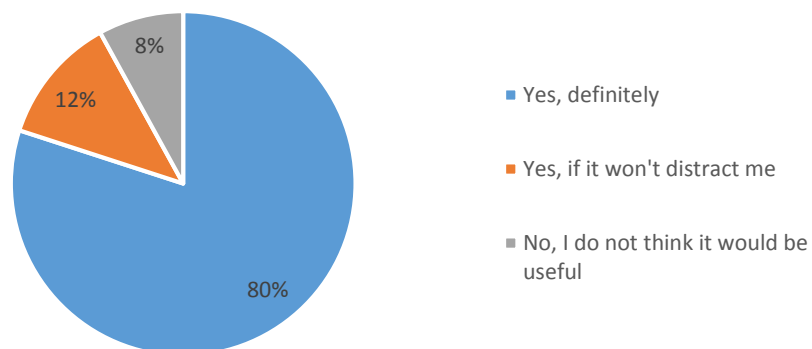
Appendix 8 – Difficult and simple chemistry topics

Difficalt to understend
- Chemical Equation
- Valence of electrons
- Molecular structure
- Compounds
- Effect of conditions on reactions

Chemistry Topics

Simple to understend
- Theory
- General structure of periodic table
- Chemical Equations
- Finding the number of Protons or Electrons in an Atom
- Valance of electrons