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SEMINARARBEIT IM STUDIENGANG INFORMATIK - GAME ENGINEERING

SINNVOLLE ANWENDUNG VON AUGMENTED REALITY BASIERTEN LERNSPIELEN

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Kurzbeschreibung

Videogames have gotten easier to develop over the timespan of the last few years and augmented reality technologies have become more accessible, which led to a more widespread use. These developments have led to a flood of games lacking in quality, with similar issues might arising in the market of augmented reality-based learning games. This seminar paper wants to answer several questions related to this problem and give a brief overview over related aspects. First, examples for augmented reality-based learning games are given, followed by an overview of different augmented reality technologies and fields in which augmented reality learning games are being used. The reviewed literature is being evaluated and several criteria for a “meaningful” application of augmented reality-based learning games are being formed. Afterwards, the example games are evaluated based on the criteria that have been found. Lastly, different aspects of the development process of learning games that use augmented reality are discussed and an outlook with suggestions on future research is given.

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INHALTSVERZEICHNIS

1 INTRODUCTION

Games have been used in all kinds of educational fields for quite a while now, not only do they have the ability to help their players retain a higher amount of focus for a longer timespan (Barakonyi & Wagner, 2003, p. 335) but their other benefits are plentiful. It has been said by Moldoveanu et al. that "Games offer a true learning platform due to their intrinsic characteristics: a final goal, user's engagement, voluntary actions, decision making, progressive learning, feedback and motivation" (Moldoveanu et al., 2013, p. 107).

An innovative addition to game-based learning has been augmented reality. A simple definition of augmented reality is given by de Freitas et al. as "a technology that combines virtual information onto the real environment in real-time performance." (de Freitas et al., 2010, p.179). While this technology is not exactly new by any means, as it has been in use for well over a decade, it has started to gain public traction in recent years. A big impact on this was with no doubt the augmented reality mobile game "Pokémon Go", which released back in 2016 and has been a gaming hit all around the world ever since. According to Taşkıran, augmented reality "has potential to facilitate learning through enjoyment over learning tasks, engagement and motivation" (Taşkıran, 2018, p. 892). Seeing how augmented reality can transform simple games into something new and exciting (Barakonyi & Wagner, 2003, p. 335), it seems only natural to combine game-based learning and augmented reality technologies in an attempt to take full advantage of their benefits. This leads to several exciting opportunities for educators, one of which, as mentioned by Johnson et al., is the "opportunity to utilize a new highly visual and highly interactive form of learning." (Johnson et al., 2011, 128).

As augmented reality game-based learning is becoming more and more popular on a global scale (Fotaris et al., 2017, p. 181), it is safe to say that several issues will start to show up. With game engines such as "Unity" or "Unreal Engine 4", game development has become more and more accessible in the last few years. These game engines provide an abundant amount of support for their users with tools and functions that make game development easier than ever. Even aspects of game development, like programming, that have been a complex part that cannot be done without, are no longer mandatory. This gives way to a plethora of people from all kinds of backgrounds who want to create games for various reasons. Of course, it is easy to think that this development has only brought about positive changes, but the truth is that just because it is easier to develop games now, does not mean that these games will be of good or better quality. In recent years, game distribution platforms, such as the widely used pc application "Steam", have been flooded with games that are lacking in quality, which not only deliver no value in their gameplay, but also sometimes ignore the most basic game design principles. These games are oftentimes flawed with bugs, performance issues and other problems that keep the enjoyment of their players at bay.

Of course, the serious game market will not be flooded with such games, but it is reasonable to assume that similar problems could develop. It is quite easy for people to think that whatever is being developed, will be made better through the use of augmented reality, and this is a frequent misinterpretation of this technology (Furht, 2011, p.526). This can mean that some augmented reality-based learning games are developed purely because of the developer wanting to use augmented reality, without knowing how it will affect a learning game or if it will affect it in a positive manner at all. In order to be able to avoid such a problematic outcome, several questions have to be answered:

- What is a "meaningful" application of augmented reality-based learning games?
- What has to be paid attention to during the development of a "meaningful" augmented reality-based learning game?
- What problems should the developer be aware of during development?

2 EXAMPLES

In the following section, four examples of augmented reality learning games are being introduced. All of these have varying educational goals that they want to achieve and they all are developed for different fields.

2.1 PATHOMON

The Game “Pathomon”, which was presented in 2018 in the conference paper “Pathomon: A Social Augmented Reality Serious Game” by Bucher et al., is an augmented reality educational learning game that delivers a similar experience to the game “Pokémon GO” released in 2016. (Bucher et al., 2018, p. 1). The goal of the game is to fight viruses in either a group or alone, while also learning more about the viruses themselves.

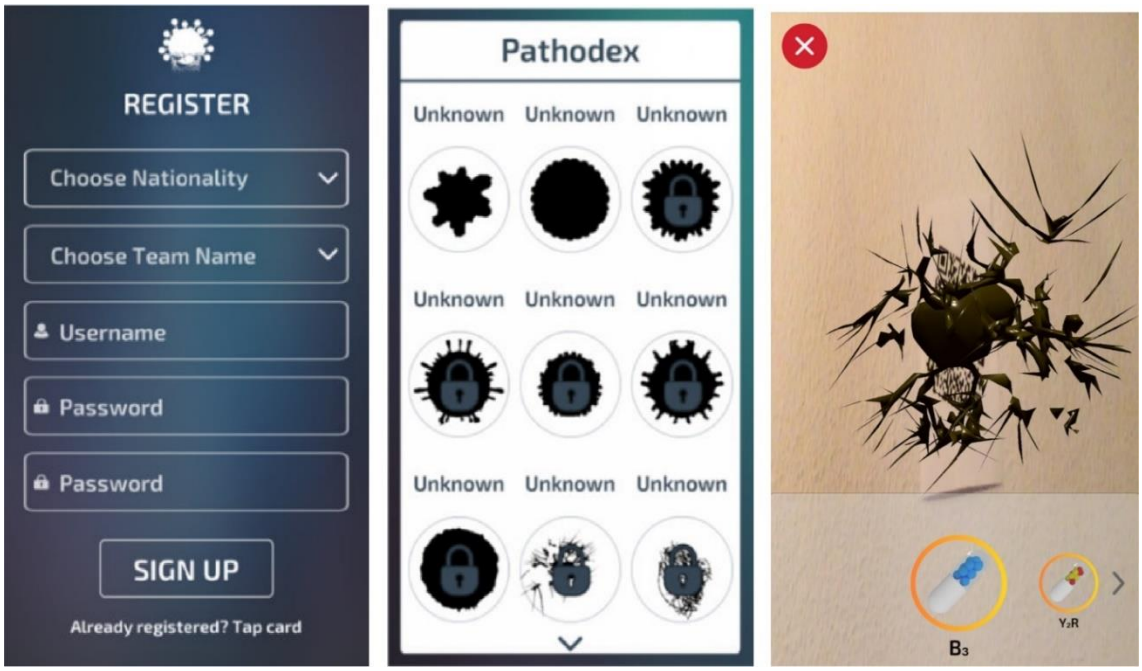

FIGURE 1 DIFFERENT SCREENS OF THE GAME "PATHOMON"

The gameplay structure of the game is described in the paper. The job of the user is to find QR-Codes within the playing area and scan those with their smartphone or tablet. When the player scans a QR-Code, either a 3D augmented reality representation of a virus or an ingredient will appear on the screen of their device. (Bucher et al., 2018, p. 1). The ingredient can be used with other ingredients by the player to craft an antidote, which can be used to fight a virus, but only if the kind of antidote the player has crafted is, in fact, the right one for the specific virus that is being fought. Each destroyed virus grants the player experience points, which are used the reach higher levels within the game. By reaching higher levels, the player unlocks additional kinds of antidotes, which are then used to fight and destroy stronger viruses. Additionally, the players have a chance to accidentally spread the virus onto visited QR-Codes, this, in turn, is implemented to try and simulate the real-life attributes of viruses. (Bucher et al., 2018, p. 3).

Each virus found by the player unlocks an entry about that individual virus, which contains information like associated symptoms, physical size, how it is spread among infected people and

a realistic 3D-representation of the virus. (Bucher et al., 2018, p. 3). By using this information or working together in a team and sharing the found knowledge, the correct antidote can be crafted. The game also includes more resilient viruses apart from the "normal" ones. According to Bucher et al., the partaking players need to work together in order to fight those more resilient viruses. (Bucher et al., 2018, p. 1).

In their conference paper they also mentioned that they conducted a user study. The results of this user study are summarized by Bucher et al. (2008):

> "The results of the Ingame Questionnaire are quite favourable as the game seems to evoke feelings of immersion and positive affects while not being tensioning or bringing out negative emotions. […] Additionally, the players did not have the feeling that their actions would influence the actions of the others in a considerable way according to the the low values for Behavioural Involvement'. An explanation for this could be that the players might have focused on their own progress, thereby overlooking their influence on the others." (Bucher et al., 2018, p. 4).

This user study only examined the effects on the player that occurred during the play session and neither the effects of the game on the player's knowledge shortly after or in the long run were investigated.

2.2 THE TABLE MYSTERY

"The Table Mystery" is a game made by Costas Boletsis and Simon McCallum in 2013 that got developed for the Science Center of Oppland county in Norway. (Boletsis & McCallum, 2013, p.88). It makes use of marker-based tracking and the camera of an iPad in its implementation of augmented reality. In their conference paper, published in 2013, Boletsis and McCallum describe the goal of the game as follows:

> "The ultimate goal of the Table Mystery's gaming experience is to provide a positive association between chemistry and learning as part of the suit of educational experiences provided by the Science Centre. That means that the game should focus on providing a pleasant and memorable experience around science, through educational content." (Boletsis & McCallum, 2013, p. 88)

"Table Mystery" additionally features a narrative story. At the centre of the game's story is a man that has lost most of his memories and is currently in a hospital, because of that he needs the player's help to cure his amnesia and get his memories back. All of his currently remaining memories are related to chemistry.

The basic gameplay structure is relatively simple: The players are first split into different groups, all of those groups are made up of three people, each of who has a very specific role (technologist, researcher and investigator) in the game. (Boletsis & McCallum, 2013, p. 90). Each Level in the game consist of a riddle, which can be solved by finding the correct element on a large physical print of a periodic table and then using the iPad's camera to scan the element. The important thing here is, that each individual member of the group works together and successfully fulfils their assigned role in order to solve the riddle. Once a correct element is scanned, an item that is associated with the element is displayed on the device's touchscreen, e.g. a hot-air balloon for the element helium. For each solved level the player is rewarded with recovered memories of the man in the hospital. After the entirety of the levels has been successfully solved, all three players have to take a quiz in order to obtain a key code, this key code can then be used in combination with the key codes of the other teams to completely

recover the last bit of the man's memories, finish the story line and complete the game. (Boletsis & McCallum, 2013, p.90).

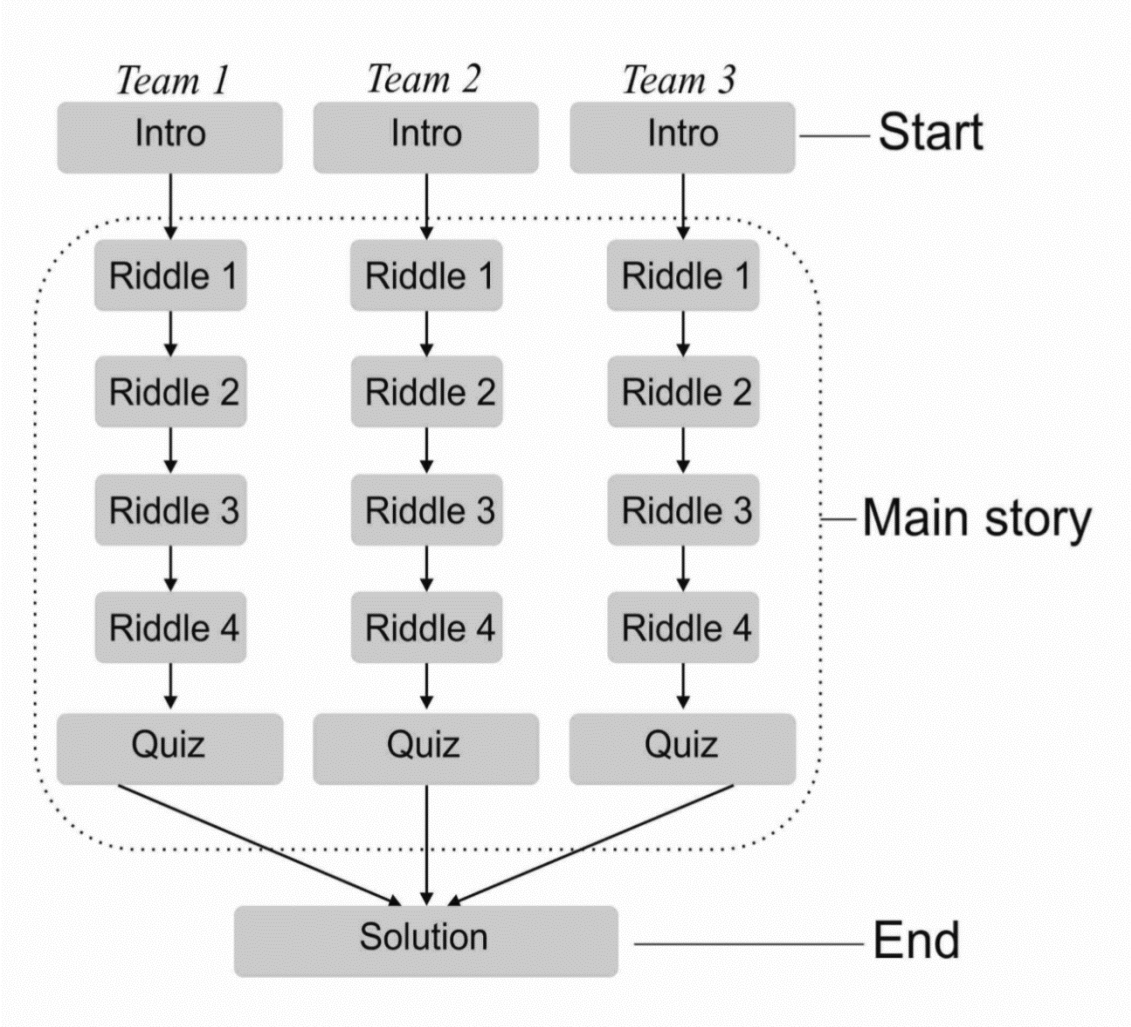

FIGURE 2 GAME-FLOW OF THE GAME "TABLE MYSTERY"

2.3 DENTAL SURGICAL SKILLS TRAINING

In the year 2010, Dailey et al. showed off an augmented reality serious game for training dental surgical skills. While talking about conventional dental training methods, on either plastic teeth or live patients, Dailey et al. said, that "The limitations of this approach include a lack of real-world cases and concerns for patient safety" (Dailey et al., 2010, p. 97) and then goes on to explain that the users can repeat different tasks and experiences, while also making mistakes as often as they want to in virtual simulation-like environments, like augmented reality. (Dailey et al., 2010, p. 97).

The game uses a marker-based tracking approach, runs on a head-mounted-display (HMD) and makes use of a haptic device, which makes it possible for the users to get feedback about the hardness of a tooth and allows them to interact with the tooth in different ways, like drilling and cutting it. (Dailey et al., 2010, p. 97). Furthermore, players have the ability to use a virtual dental mirror, in order to help them complete their assignment. This virtual dental mirror in the augmented reality simulation is tracked by placing a small printout of a marker on a real dental mirror. (Dailey et al., 2010, p. 98)

A preliminary evaluation of the augmented reality simulation was conducted by a dental instructor. Comparing it to a previous virtual reality version of the serious game, Dailey et al. said, that the expert found it to be “much closer to a real clinical setting” (Dailey et al., 2010, p. 98). It is also mentioned that accurate depth perception was an issue as the HMD used only had a monocular camera instead of a stereo one. (Dailey et al., 2010, p. 98).

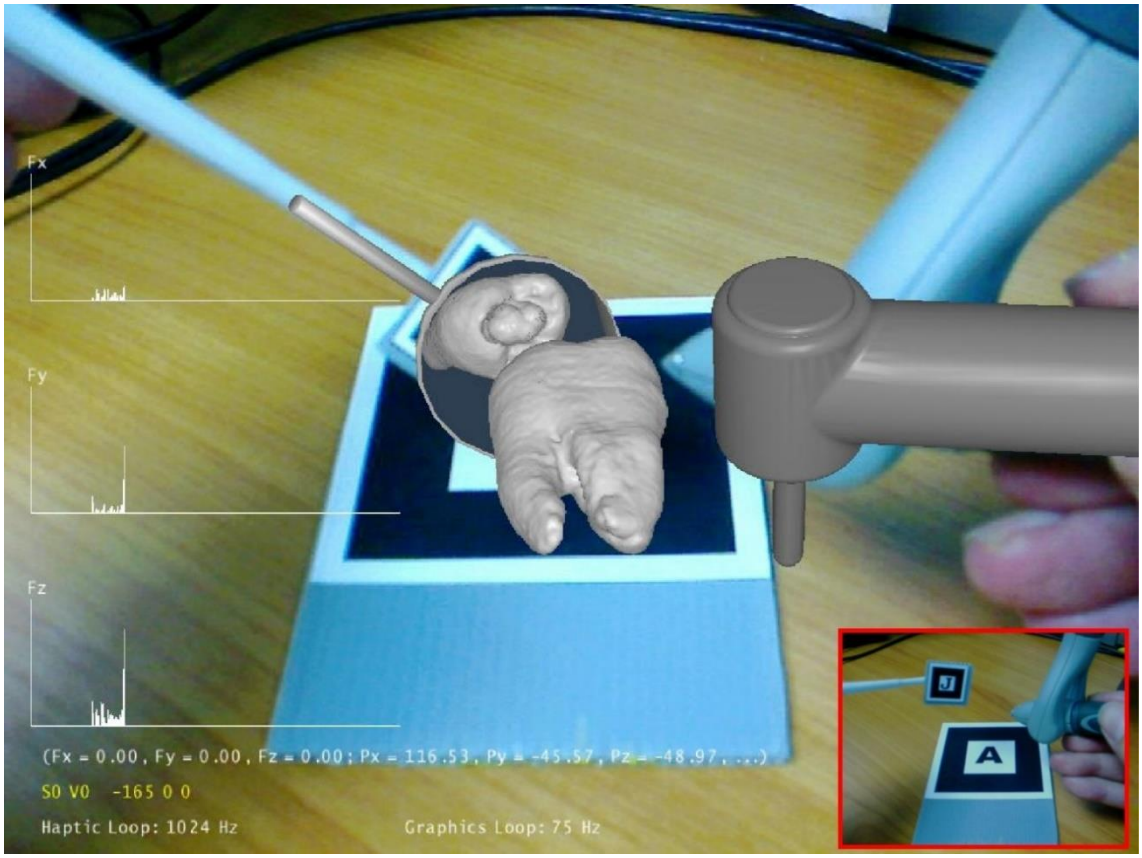

FIGURE 3 VIEW OF THE PLAYER THROUGH THE HMD IN THE DENTAL SURGERY SIMULATOR

2.4 HELLO

“HELLO” is a game developed by Tan-Hsu et al. and presented by them in 2007 in the conference paper “2D Barcode and Augmented Reality Supported English Learning System”. HELLO stands for “Handheld English Language Learning Organization”. (Tan-Hsu et al., 2007, p.5). The game’s goal is to improve the student’s English language capabilities and allow them to do so anywhere and whenever they want. (Tan-Hsu et al., 2007, p. 5).

It uses marker-based augmented reality tracking in the form of 2D barcode that is placed in a variety of different areas around a school called “learning zones”. (Tan-Hsu et al., 2007, p. 6). The players are equipped with a PDA that has access to a camera and can use a wireless connection to retrieve and sent data to the HELLO server. (Tan-Hsu et al., 2007, p. 6).

FIGURE 4 A STUDENT PLAYING THE GAME "HELLO"

According to the conference paper by Tan-Hsu et al., in which this game is presented, the gameplay looks something like the following. The students go from one location to the next location, which are classified as learning zones on the PDA. These learning zones can be found through using the map integrated into the game running on the PDA. (Tan-Hsu et al., 2007, p. 6). The English language topics that are covered in each learning zone are directly related to their real-life location within the school. Once the users reach a learning zone, they are expected to find and scan the 2D-barcode found somewhere within it. (Tan-Hsu et al., 2007, p. 6). When the 2D barcode has been scanned, data is sent to the PDA from the HELLO-server and a virtual learning partner appears on the screen of the PDA in form of an augmented reality presentation. (Tan-Hsu et al., 2007, p. 6). This virtual learning partner can then be talked to, as the game offers the ability to use voice commands and recognition to its users, in order to complete the player's task. (Tan-Hsu et al., 2007, p. 6-7). Additionally, the game can be used to read English articles and news, play English songs and write in English. (Tan-Hsu et al., 2007, p. 7). It is also mentioned that students can get direct feedback of their pronunciation and so on in form of a graph that compares their sounds to the correct sounds of the virtual teacher. (Tan-Hsu et al., 2007, p. 7).

3 DIFFERENT KINDS OF AUGMENTED REALITY

Augmented reality can be achieved with multiple different kinds of tracking technologies. These tracking technologies can be roughly divided into two different groups, marker-based tracking and marker-less tracking. Location-based tracking, though it is a part of marker-less tracking, will be talked about separately. All of these augmented reality tracking technologies have their own advantages and disadvantages when it comes to being used in an educational setting. The

following section will try to give a brief overview of each of those augmented reality technologies while also taking related research into account.

3.1 MARKER-BASED TRACKING

Marker-based tracking, like the name suggests, uses markers that are placed in the real world to track an object in virtual space. Applications using this technology require optical sensors, such as a video camera, that are oftentimes found attached to computers and imbedded into mobile devices (Godwin-Jones, 2016, p. 10). An example for a marker used in marker-based augmented reality can be seen in figure 5 below.

FIGURE 5 2D-BARCODE MARKER AND PDA USED IN THE GAME "HELLO"

Markers are usually predetermined during the development of an augmented reality application and can nowadays frequently been seen in the shape of basic, often colourless, images. Since they are mostly predetermined, these images can only be selected by the developer and rarely by the end user. QR-Codes and barcodes can also be used as markers, as these can be easily seen and tracked by the software. It is stated by Tan-Hsu et al. that "2D barcode has many advantages including large storage capacity, high information density, strong encoding, strong errorcorrecting, high reliability, low cost, and ease of printing". (Tan-Hsu et al., 2007, p. 6). While most of these advantages are not exactly useful for your average augmented reality application, a few, such as high reliability, low cost and ease of printing, are. The most significant aspects of a suitable augmented reality marker are for it to have the highest amount of feature points possible, as these help the application to recognize and position the objects

projected onto the marker. (Martinez et al., 2013, p. 377). An example for the feature points of an image can be seen in figure 6.

FIGURE 6 SHOWCASE OF FEATURE POINTS ON A PICTURE, CREATED WITH THE SOFTWARE "VUFORIA"

The advantages of marker-based augmented reality technology are as follows. All that is required of a mobile device, head-mounted-display or computer, for it to be compatible, is to have a camera that is able to supply the software that is being used with a high-quality video-feed of the camera's view. Another advantage is given by Godwin-Jones: "The easy processing means that this kind of AR activity can be accomplished on devices without a lot of processing power" (Godwin-Jones, 2016, p. 10). As long as the marker has been well chosen, which means easy to recognize for the application, the tracking is mostly flawless, with the only responsibility of the user being, that he as to keep the marker in good view of the device's camera. Markers can also be incorporated into the game's design, as in the game "The Table Mystery" mentioned above. In it, the name of an element on a periodic table is used as a marker for augmented reality. (Boletsis & McCallum, 2013, p. 89). The fact that markers are so versatile, can, as stated by Godwin-Jones, also be used to further increase the engagement of students through involvement in the creation of markers for a marker-based augmented reality project. (Godwin-

Jones, 2016, p. 11). Godwin-Jones goes even further and lists a few examples for usage of markers in everyday life:

> "It is easy to imagine how marker-based AR could be used in community or study abroad projects. Students, for example, could explore the linguistic landscapes of their surroundings, capturing signs, menus, graffiti, or billboards to explore topics such as urban multilingualism or neighborhood profiles." (Godwin-Jones, 2016, p. 11)

A downside of marker-based approach is that it requires the user to have a version of the marker available, be it virtual or physical in the form of a picture, printout, sticker or inside a textbook. This can add additional cost, work and waste to educational AR games. Furthermore, markers can be prone to tracking issues and inaccurate tracking when used in suboptimal lighting conditions.

The use, in the majority of augmented reality games and applications, is pretty straight forward for the most part, as Godwin-Jones explains: "When an AR app recognizes that a marker has come into view through the user's camera, an action is generated, such as displaying text, showing an image, or playing a sound clip" (Godwin-Jones, 2016, p. 10). Fotaris et al. recommends markers for the use in educational purposes, as they are currently providing a better learning experience to students, compared to most marker-less tracking methods. (Fotaris et al., 2017, p. 188). In addition to that, it has also been found by Ferrer et al., that using an augmented reality application that is based on a one-marker design can have benefits over the use of multiple markers. (Ferrer et al., 2013, p. 7).

Marker-based tracking was used in the majority (roughly 89%) of the educational augmented reality games that have been looked at during the research for this seminar paper, which makes it the most commonly used one. Naturally, this is not that conclusive, since a relatively small amount of educational AR serious games has been examined, but it is a similar finding to what Fotaris et al. have found in their literature review on the topic of augmented reality game-based applications in primary education (52% of reviewed studies used marker-based AR-technology). (Fotaris et al., 2017, p. 188).

3.2 MARKER-LESS TRACKING

Marker-less tracking for augmented reality has been around for a while. It uses different methods to track 3D space in a real-life environment. These technologies include GPS-tracking (also called location-based tracking) and tracking through algorithms combined with depth-cameras and sensors. Since location-based tracking will be discussed separately, the following is relating to marker-less tracking through algorithms combined with depth-cameras and sensors. This method brings quite a few benefits with it. For one, in most cases it does not require the end user to setup the environment beforehand and therefore can be used almost anywhere in the nick of time. Additionally, it saves cost as markers do not have to be printed.

On the other hand, augmented reality tracking with this method can be flawed sometimes, as it can suffer from issues like tracking inaccuracy and other limitations. In addition to that, a high amount of processing power is required in most cases compared to tracking through a GPS or markers-based technologies. This also means that the price for portable all-in-one solutions is usually quite high.

Two commonly used devices for this are the Kinect and HoloLens, both developed by Microsoft. Microsoft's Kinect is a small system that can be used in augmented reality like a webcam with good results while also being relatively cheap. On the other side, Microsoft's HoloLens is an all-

in-one head-mounted display with a high price but state-of-the art marker-less augmented reality tracking technology.

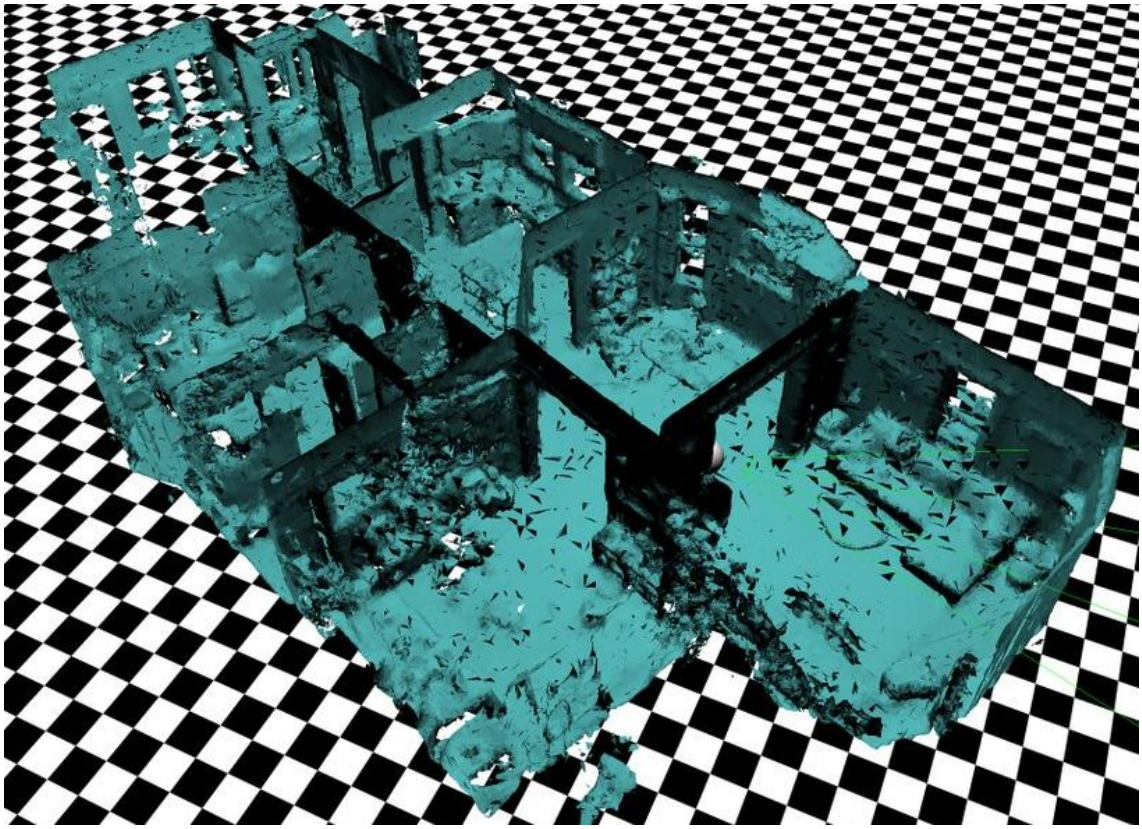

FIGURE 7 MESH GENERATED THROUGH SPATIAL MAPPING WITH THE HOLOLENS, USED FOR MARKER-LESS TRACKING

3.3 LOCATION-BASED TRACKING

Location-based tracking most commonly makes use of the GPS-technology featured in most mobile devices nowadays to track the players movement in the real world. Most people will probably be familiar with this approach due to it playing a big part in the popular augmented reality mobile game "Pokémon GO".

This technology is frequently used in applications that want to integrate the global position of the user, in order to present them with contextual information based on their current location. When this is used in combination with the integrated camera of devices like smartphones, it can be especially useful when it comes to the educational topics of history and culture, as it can be used to create digital tours that guide the application's user through historic sites or places of cultural significance.

Devane et al. say that "AR games seem ideally suited for giving players a depth and appreciation for place that is otherwise difficult to obtain." (Devane et al., 2007, p. 278) while Mingfong and Squire also say that "games offer opportunities to tie goals to particular places" (Mingfong & Squire, 2007, p. 9). Moreover, Devane et al. state that:

> "Physically, place-based approaches resituate us in our physical environs (field sites, communities, cities) that are frequently at the basis of academic disciplines (such as environmental science, history, or geography). Responding to student and academic critiques of education as removed from personal experience and social consequences (thus removing from participation in social life), place-based approaches seek to

connect students to the history, culture, and social life of places, making learning consequential for its participants." (Devane et al., 2007, p. 267)

This means that, since location-based tracking can be easily tied into specific places and used to transfer information and knowledge about those places to the user, it can be a perfect fit for learning games.

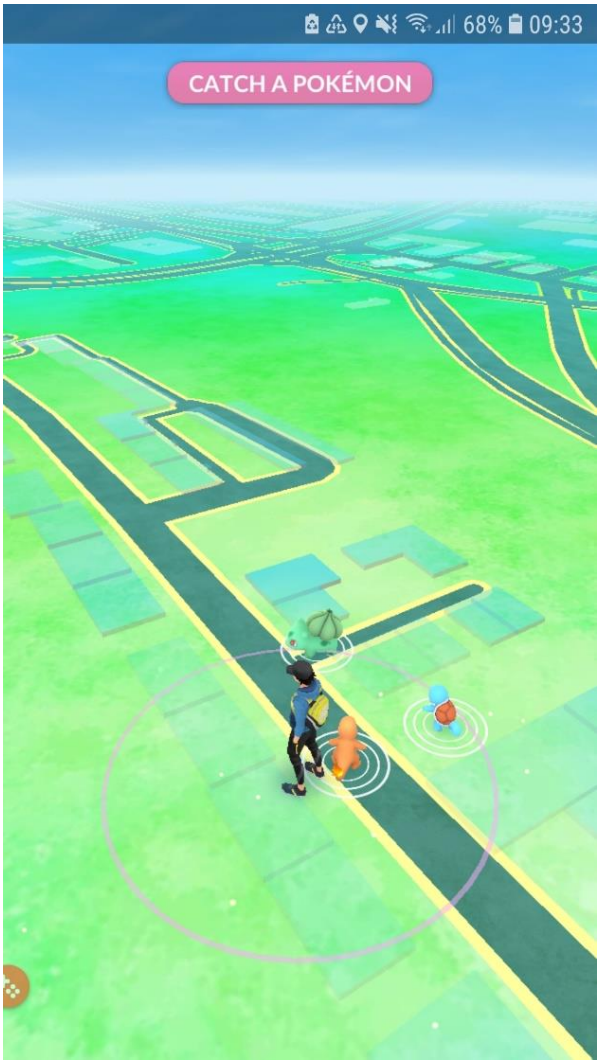

FIGURE 8 LOCATION-BASED AUGMENTED REALITY IN THE GAME "POKÉMON GO"

While this approach to augmented reality can have the upper hand when implemented in an educational game, since for example, based on Devane et al., it "encourages students to connect academic content to lived experiences, particularly via place" (Devane et al., 2007, p. 273), there are also a few disadvantages. One of those disadvantages is that it requires the user to be outside in most cases, since the GPS in most devices is not accurate enough to work flawlessly inside comparably small places (e.g. a classroom). The play area is also required to be a decent size, so that the game can be played without any tracking-errors. Another big issue of location-based AR that arises from these limitations, especially when used in a school-environment with young children and teenagers, is that the players can be so highly focused on

the game that they lose track of their surroundings and therefore might walk into oncoming traffic or similar dangers. (Johnson et al., 2011, p. 128).

4 EXAMPLES OF FIELDS IN WHICH AR LEARNING GAMES ARE USEFUL

Nowadays its common for the military to use game-based learning scenarios as a fundamental part in their training exercises. (Devane et al., 2007, p. 265). Naturally, this includes augmented reality approaches as well. According to Müller and Sommerauer, the use of augmented reality in the fields of teaching and learning has advanced significantly during the duration of recent years. (Müller & Sommerauer, 2018, p. 1). Müller and Sommerauer go on to say that augmented reality can be used to "deliver persuasive learning experiences in formal teaching (e.g., in classrooms) and in informal learning environments (e.g., museums)" (Müller & Sommerauer, 2018, p. 1). While augmented reality learning games are commonly used in the development of basic competences in a young audience, a widespread adoption for training teenagers & adults in their workplaces is also currently taking place. (Martinez et al., 2013, p.376).

Johnson et al. say that "It cannot be denied that AR applications have tremendous potential for all fields where rapid information transfer is critical" (Johnson et al., 2011, p. 124) and that that is particularly the case in the field of education. (Johnson et al., 2011, p. 124). A reason for this is given by Moldoveanu et al., as they say that mediating enhanced visual and cognitive perception is an attribute of augmented reality that can be used in education. (Moldoveanu et al., 2013, p. 105). Seeing how augmented reality-based learning games can be used in such a broad spectrum of different educational fields and are implemented into fields that have such a wide variety of age groups, the following examples, namely the fields of language learning, school education and medicine, have been selected to cover the different age groups and fields alike.

4.1 LANGUAGE LEARNING

Being able to speak a second language, like English or Spanish, is almost mandatory in today's world. Not only is it required to be somewhat fluent in English when you are applying and working in most jobs related to science and technology (e.g. programming) but it is also extremely helpful in most people's day to day life. While e-learning is already commonly used in English education projects in most colleges in order to prepare students for the requirements of their future workplace (Tan-Hsu et al., 2007, p. 5), augmented reality is relatively uncommon addition to these projects. Tan-Hsu et al. mention that "how to construct an English learning environment in college to increase students' learning motivation and improve their English level is a priority to be solved" (Tan-Hsu et al., 2007, p. 5). Augmented reality-based learning games might be the answer to this, as Godwin-Jones said in 2016 that:

> "Through its ability to use add-on digital assets to explore and expand scenes and locales from the real world, there is an obvious connection between AR and current theories of second language acquisition which emphasize localized, contextual learning and meaningful connections to the real world." (Godwin-Jones, 2016, p. 9)

Similar to this statement, memorising vocabulary might also be supported through augmented reality's ability to establish a visual link to an item. (Godwin-Jones, 2016, p. 10).

4.2 SCHOOL EDUCATION

The first thing most people will probably think about when they hear the terms “learning” and “education” is probably a classic school environment and classrooms. This is association is convenient, as in 2013 Fonseca et al. said:

> “So we could say that AR technology, by providing new interaction possibilities, promote active student participation in its own knowledge construction. Thus, it becomes a suitable medium to be used in the classroom.”

In addition to that, it is stated by Fotaris et al., that augmented reality-based learning games “can potentially influence the students’ attendance, knowledge transfer, skill acquisition, hands-on digital experience, and positive attitudes in laboratory experimental exercises for different courses” (Fotaris et al., 2017, p. 182).

Science and Social Sciences are the two fields in school that augmented reality has been used in the most. (Fotaris et al., 2017, p. 189). A big advantage of augmented reality game-based learning in the field of science is stated by Fotaris et al., they say that “it offers the ability to bring to life invisible, abstract, and complex concepts in 3D or to visualise scientific phenomena that could not be seen without a specialised device” (Fotaris et al., 2017, p. 189). This makes Science education in classrooms the perfect fit for the use of currently available marker-based augmented reality applications. As for Social Sciences, the use of location-based augmented reality can make lessons more engaging. (Fotaris et al., 2017, p. 189-190). Most schools these days already have access to relatively decent computers in form of a computer lab for IT-related courses. Additionally, it is mentioned by Devane et al. that the majority of students already own mobile devices, more precisely smartphones, that are usually brought with them to school and that this enables new possibilities for the usage of technology in the modern-day classroom. (Devane et al., 2007, p. 266). This makes mobile devices, such as smartphones, and computers the go-to platform for augmented reality-based learning games in the field of school education.

One issue that augmented reality-based learning games are facing. when used in school education, is that it can be difficult to manage time and cost required for this kind of educational technology, as with all scenarios that use a learn-by-doing approach. (Antonioli et al., 2014, p. 98). While some students, who are avid gamers, might finish a certain level of an educational game within minutes, some students might struggle to even comprehend how to use the basic controls and features of an augmented reality game. Obviously, this depends on what kind of augmented reality game is used, how old the students are, which subject is being taught and how the instructions are given, but it is an important aspect to look out for nonetheless.

4.3 MEDICAL USES

In the field of school education, augmented reality-based learning games are mainly used to improve the student’s learning and knowledge gains. While this can also be a goal in the field of medicine, augmented reality has arguably more potential to enhance training methods and procedures in the medical field. It is not uncommon for students and trainees in the medical field to practice medical procedures on either real-life 3D models, donated corpses or even live patients. This has obviously always invoked fear for patient safety and allows errors being made, purely because of the stress that the person undertaking the medical procedure can be experiencing, as they are under constant pressure to not make any mistakes and might have had no prior hands-on experience. Because of this issue, Barsom et al. say that “Since training in this real-life context is not always possible for reasons of safety, costs, or didactics, alternative ways are needed to achieve clinical excellence” (Barsom et al., 2014, p. 300).

Augmented reality is well suited to fill this need. This is confirmed through Barsom et al. stating that "Educational technology and more specifically augmented reality (AR) has the potential to offer a highly realistic situated learning experience supportive of complex medical learning and transfer" (Barsom et al., 2014, p. 300). It has also been said, by Barsom et al. (2016), that augmented reality "is thought to increases trainees' subjective attractiveness, enhancing learning retention and performance" (Barsom et al., 2016, p. 4180), while other advantages range from "training better surgeons to making fewer errors in the operating room, ultimately leading to improvement of patient safety" (Barsom et al., 2016, p. 4181).

5 EVALUATION

In total, the number of studies, conference papers and so on that have been looked at for this seminar paper is 37. Out of those, 18 have been focused specifically on an augmented reality learning game. Marker-based augmented reality has been used in roughly 89% (16) of these games, while location-based and marker-less have only been used in roughly 5% (1) each. The fields for which these learning games are designed are language learning (22%, 4), school (44%, 8), preschool (11%, 2), medicine (11%, 2) and other fields (11%, 2). The majority of devices used are handheld displays (72%, 13), more specifically the number of smartphones/tablets used is 6, while PDAs were used 3 times and 4 games did only specify that mobile devices are used. The most popular tools used in the creation are Unity, OpenGL, ARToolKit, NyARToolKit and AURASMA.

The reviewed sources came to several conclusions regarding augmented reality-based learning games. Barsom et al. state that "Learning supported with AR technology enables ubiquitous, collaborative and situated learning" (Barsom et al., 2014, p. 309). It was also found that these games can be advantageous when it comes to social interactions, especially for the interactions between students. (Feijs et al., 2017, p. 624). In another paper, Feijs et al. found that "the most reported effects for AR learning games were the enhancement of learning performance and the learning experience in terms of fun, interest, and enjoyment" (Feijs et al., 2017, p. 612). Similar benefits are listed by Fotaris et al.: "The main advantages of AR game-based learning experiences are knowledge gain, increased motivation, augmented interaction, and enhanced collaboration" (Fotaris et al., 2017, p. 190). The conclusion that augmented reality-based learning games can improve learning performance, partly through increased motivation, a rise in social interaction and overall better learning attitudes, and therefore lead to a boost in learning achievement, is further reinforced by several studies. (Taşkıran, 2018, p. 894, Fotaris et al., 2017, p. 190, Feijs et al., 2017, p. 624).

Feijs et al. conducted a literature review on augmented reality-based learning games. In it, they tried to answer the following questions:

- "What Learner Groups, Subjects, and Environments Are Commonly Focused on for AR Learning Games According to the Reviewed Studies?" (Feijs et al., 2017, p. 615)
- "What Are the Effects of AR Learning Games on Students in Terms of Learning Achievement and Motivation and What Are the Measurements According to the Reviewed Studies?" (Feijs et al., 2017, p. 617)
- "What Are the Effects of Social Interaction in AR Learning Games on Students According to the Reviewed Studies?" (Feijs et al., 2017, p. 619)
- "What Kinds of Elements or Features Are Commonly Used in AR Learning Games According to the Reviewed Studies?" (Feijs et al., 2017, p. 620)
- "What Are the Suggestions for the Design of AR Learning Games According to the Reviewed Studies?" (Feijs et al., 2017, p. 622)

In their literature review, they found that the biggest focus was on primary and middle school students. (Feijs et al., 2017, p. 615). When it comes to subjects, most games were centred around science and biology. (Feijs et al., 2017, p. 615). Feijs et al. explain this by saying: "This might be because the AR technology can provide advantages in reflecting the concept of knowledge in the real world environment, allowing students to observe the objects in real-time." (Feijs et al., 2017, p. 615). The lion's share of games in their reviewed studies were supposed to be played outdoors or in the classroom. (Feijs et al., 2017, p. 617). While they reviewed a few studies that found augmented reality-based learning games to be ineffective when it comes to improving learning achievement (Feijs et al., 2017, p. 618), approximately half of their investigated studies found them to be effective (Feijs et al., 2017, p. 617), with similar conclusions as were found here. In addition to greater engagement and joy, they found positive effects regarding cognitive skills like problem-solving and multitasking. (Feijs et al., 2017, p. 617-618).

6 WHAT IS A MEANINGFUL APPLICATION?

The following section of this seminar paper tries to find multiple criteria that justify an augmented reality-based learning game to be called "meaningful" and answer the question "What is a "meaningful" application of augmented reality-based learning games?". Additionally, these aspects are then applied to the examples for augmented reality learning games given in section 2.

6.1 CRITERIA OF A MEANINGFUL APPLICATION

The task of making an augmented reality-based learning game "meaningful" can be a difficult one, all the while it is incredibly easy to make a game with many issues. One key aspect of learning games is usability. When an augmented reality learning game has problems with usability, negative effects can appear in regard to motivation and learning benefits. (Ferrer et al., 2013, p. 2). According to Fotaris et al., being able to intuitively traverse the user interface and the overall ease of use are extremely important for an augmented reality experience that feels rewarding to the user. (Fotaris et al., 2017, p. 189). Fotaris et al. go on to say that "it is imperative that UI specially tailored for young audiences are developed" (Fotaris et al., 2017, p.189). Naturally, this does not only count for young audiences. The user interface is a big part of usability in games, therefore it should always be carefully designed to sit well with whatever target audience the game will have. Fotaris et al. also warn that, apart from applications that do not track or display data properly, another source of possible negative feeling towards an augmented reality game are problems with either markers or the device being used. (Fotaris et al., 2017, p.189). Therefore, it is of vital importance to choose the device, and whatever kind of augmented reality is used, wisely. For example, it is a good choice to use handheld displays in use cases in which the target audience consists of a younger generation, as handheld display, namely smartphones, are easy to transport and already commonly used among young people. (Buckley et al., 2016, p. 395). In addition to that, younger generations are already knowledgeable when it comes to these mobile devices, which consequentially means a higher usability by default. From this we can conclude that one integral facet of a meaningful gaming experience for augmented reality-based learning games is, that elements, like the user interface, game controls, game design (and anything else that can be related to the usability) has to be well thought-through and carefully customized to fit the game's target demographic.

Similar to this, the gameplay has to be fitting for users targeted by the game. As Godwin-Jones says, not every user will be familiar with games. (Godwin-Jones, 2016, p. 14). Another interesting point related to this has been made by Devane et al. in 2007:

> "Game systems are in a very real sense co-constructed by their players; they are less linear content and more constructed as a world for players to enter, to perform in, to inhabit. As a result, players' experiences of them differ wildly, according to their backgrounds, personal interests, and critically, the paths they choose to traverse within them. [….] whereas some players enjoy the narrative-based missions of Grand Theft Auto: San Andreas, others use the game primarily as a vehicle for constructing chase scenes, customizing automobiles, or constructing their own narratives." (Devane et al., 2007, p. 266-267)

This only confirms further that augmented reality-based learning games have to be custom tailored to a specific audience in order for them to be of value.

A further essential requirement, that a meaningful augmented reality-learning game should fulfil, is that it should evoke feelings of motivation, fun and interest in the game's content and the gameplay itself. Fotaris et al. go even as far as to say that the two pillars of augmented reality-based learning games are motivation and enrichment of the learning experience. (Fotaris et al., 2017, p. 181). This is reinforced by Godwin-Jones by saying that "if the game does not reach a minimal threshold of player interest, there will be no learning, as the student will have stopped playing" (Godwin-Jones, 2016, p. 14). Sparking interest in a learning game can be more difficult dependent on which field it will find use in. A good example of this is a school environment and an explanation for this is given by Godwin-Jones as he says that "Students are already likely to be skeptical of anything labeled as an educational game" (Godwin-Jones, 2016, p. 14). A good way to evoke motivation for learning, according to Devane et al., is to emphasize and expand on the game-like aspects of whatever environment the game is used in. (Devane et al., 2007, p. 277). A well-balanced gaming experience is also mandatory for motivation and fun, just like in any game. Poor balancing has deep-rooted effects on gameplay and can easily demotivate players and even scare them off, especially in the early parts of a game.

Barsom et al. state that an application must be able to deliver information to the user in order for it to be valuable. (Barsom et al., 2016, p. 4174). In the case of learning games this means that knowledge and information have to be conveyed to the player through the game. Based on Fotaris et al., "the learning material should be clear, understandable, comprehensive, and relevant to the course learning objectives" (Fotaris et al., 2017, p. 189). This means that the game has to facilitate realistic content through real life concepts and being grounded in reality while also being accessible to its users.

Last but not least, augmented reality should not only be used as some sort of gimmick in a learning game. If augmented reality is not used properly it can easily have a negative impact on several aspects of the user's gaming experience and therefore ruin effort put into the establishment of high usability and other factors. Consequently, it is only natural to think twice about using augmented reality in the game and if this technology really adds something noteworthy to the users' experience.

In summary, in the best-case scenario a "meaningful" application of augmented reality-based learning games should fulfil the following criteria:

It should…

1. … have good usability
2. … have proper balancing
3. … be able to evoke motivation, fun and interest
4. … be developed to fit the target audience
5. … have the ability to transfer knowledge and information
6. … not use augmented reality only as a gimmick

In some cases, it might be difficult to apply these criteria to an augmented reality-based learning game and for a small amount of games it might be even harder to measure or assess the required data for these aspects accurately. Furthermore, if a game should not be able to fully satisfy these criteria it does not necessarily mean that the game is bad, as these are just supposed to be guidelines.

6.2 WHEN AND WHY USE AR TO BEGIN WITH?

Seeing how it can be quite the undertaking to create a meaningful augmented reality-based learning game and an abundance of problems for the game can occur, particularly during development, it is of great importance for the quality of the end product to think about if augmented reality is a suitable addition to the learning game to begin with. As Wetzel et al. explain:

> "A common misconception about augmented reality is that everything is improved by augmented reality. Sometimes developers and marketing people are very enthusiastic about this new technology (new in the sense that is has not yet been widely used in game development) and do not question their decision to use augmented reality technology in the first place. This is a very dangerous attitude as although players might be astonished the first couple of times they play such a augmented reality game, the novelty factor will war off sooner or later." (Furht, 2011, p.526)

This evidently raises the question: When should you use augmented reality in a learning game? Based on Cai et al., augmented reality finds its best use when applied in situations where something cannot be simulated in reality, or experiments have obvious downsides in real life. (Cai et al., 2014, p. 31). A suitable example for this would be a use case in which a 3D model of some sorts has to be dissected to explore its inner-workings, as this cannot be done easily with real-life objects. Another fitting example are experiments conducted in a school's chemistry course that require the students to handle fire sources and potentially dangerous chemicals. This example also highlights a further situation in which augmented reality should be used. This is similar to what Barsom et al. say about training in some fields not being plausible to occur in a real-life context. (Barsom et al., 2014, p. 300). Additionally, Martinez et al. say: "An important advantage of Augmented Reality is that the environment does not need to be disturbed at all. Instead of that, it can be somehow improved, giving the final user useful feedback information." (Martinez et al., 2013, p. 376). This statement emphasizes one more case in which it is a good idea to make use of augmented reality. Whenever the surroundings are to be kept in a specific state, augmented reality has the ability to keep it that way, while also allowing the user to learn in an uncompromised way. To further explain this, a useful example is the use of augmented reality inside the department for product design in a company that produces mechanical parts. Product designers can easily make use of augmented reality to get a better look at and impression of the 3D appearance of the parts without having to get their hands or their workplace dirty.

In today's digital age it is exceptionally easy to effortlessly find information on virtually anything online within a matter of minutes. Devane et al. asks a good question related to this: "What is the use in asking a student to memorize and "spit back" information when the answer can be looked up in a matter of seconds?" (Devane et al., 2007, p. 266). Game-based pedagogies take a different approach to this issue, according to Devane et al., as learning games try to guide their

players towards understanding the topic and its content, rather than purely learning it inside-out. (Devane et al., 2007, p. 266). Devane et al. further state:

> "As educational game designers, we produce roles within these systems for players to inhabit so that through performance within the system, they develop understandings of academic content. These systems of rules, roles, and representations stand in stark contrast to most academic subject areas that are organized around content (e.g. history, biology) or exams." (Devane et al., 2007, p. 266).

Augmented reality can be easily tied into this mindset of understanding the content over just knowing information, as according to Devane et al., augmented reality games have the ability to transform learning from only giving information to learning that gives its users an experience. (Devane et al., 2007, p. 268). Users can become immersed in this experience through roles in the game and tasks that correlate with their existing knowledge.

6.3 DO THE EXAMPLE GAMES MEET THE CRITERIA?

The following is an analysis and discussion of the examples from section 2 in this seminar paper. This section is supposed to show if the games in these examples meet the criteria for a meaningful application of an augmented reality-based learning game as defined here earlier.

First off is the game "Pathomon" presented by Bucher et al. (2018). As the game runs on modern smartphones that are using the common operating systems IOS and Android, it is safe to assume that players are already knowledgeable of these mobile devices and therefore will not have an issue with the controls and navigation. From the pictures of the game seen in figure 9, the user interface looks relatively straight forward and thus, the player should be easily able to traverse it. The use of marker-based augmented reality makes it both simple and reliable in terms of usage. Bucher et al. mention in their paper, that the android version was running with unstable performance in comparison to its iOS counterpart. (Bucher et al., 2018, p. 3). Even though performance is a big part of usability, it was only affecting one operating system and can be fixed in time, therefore it can be concluded from the aspects mentioned above, that the game's usability meets the required level. While in the user study that has been conducted, no in-depth focus was directed on game-balancing, Bucher et al. have said that a few participants complained about the issue that the progression was too challenging, especially in the early parts of the game. (Bucher et al., 2018, p. 3). Since users only spent a small amount of time with the game during the user study, this could just be due to the players being too inexperienced with the gameplay, but the developers should look into this concern nonetheless. Motivation, fun and interest in the game's learning material have a chance to be brought forth, as Bucher et al. said after evaluating their questionnaire, that "the game seems to evoke feelings of immersion and positive affects while not being tensioning or bringing out negative emotions" (Bucher et al., 2018, p. 4). It has not been mentioned if "Pathomon" has been designed with a specific user demographic in mind, but the overall topic and design of the game suggests that it is gathered towards teenagers and above. The user interface and displayed content are lacking any form of stylization, as often seen in games addressed to younger audiences. Statements on the possible learning and knowledge gains cannot be made yet, as Bucher et al. have said that the user study conducted by them has not included an evaluation of the game's learning effectiveness. (Bucher et al., 2018, p. 4). Considering that augmented reality is used through-out the gameplay and can be used to view and learn about the viruses' shape and appearance, it can be said with confidence that in the case of the game "Pathomon", augmented reality is not just used as a gimmick.

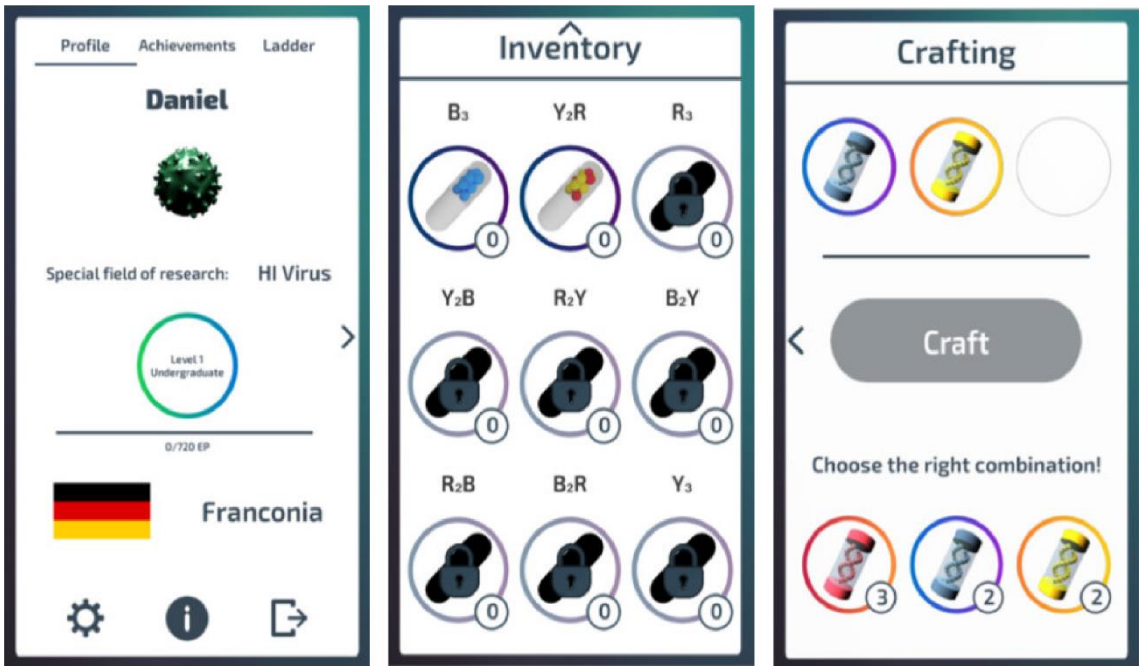

FIGURE 9 DIFFERENT PARTS OF THE USER INTERFACE IN "PATHOMON"

Up next is the game "Table Mystery" developed by Costas Boletsis and Simon McCallum. This game runs on an iPad mini, which makes it similarly easy to use compared to a game that is running on common smartphones, since the controls and navigational experience are basically the same. The fact that it runs on a tablet gives it the additional advantage of having a bigger screen, which could have the effect of positively affecting the game's usability. It is hard to judge, if the user interface is intuitive enough to not get in the way of the user experience, as the pictures provided in the paper by Boletsis and McCallum do not show much of it, though it does seem minimalistic. In their paper it is also said, that no technical issues were found during one of the initial test sessions. (Boletsis & McCallum, 2013, p. 91). As this game was still in the design phase when the paper was published (Boletsis & McCallum, 2013, p. 92), no extensive studies on its learning benefits have been conducted, but Boletsis and McCallum have claimed that the game "does not aim to provide significant knowlege transfer, but instead to create a psychological association between educational content and enjoyable experience, utilising a new medium with the flexibility to accomodate a variety of learning styles" (Boletsis & McCallum, 2013, p. 93). In reference to a target audience, it is obvious that this game is targeted towards school students and that the game should be used during chemistry class. Game-balance is not much of a problem for this kind of game, as it mainly consists of riddles that can easily be adjusted to the user's needs, however, Boletsis and McCallum have mentioned that the experts took issue with the difficulty of one of the riddles during testing, though this has been taken care of afterwards. (Boletsis & McCallum, 2013, p. 92). While the aforementioned information lets one conclude that the first five criteria for a meaningful augmented reality-based learning game are met, the sixth criteria is not. The way that augmented reality is used in this game does not add much to the overall experience, as it can easily be removed from the game without affecting much. For example, in the game the appearance of an object that is associated with the scanned element could simply be replaced with a 2D picture and still have the desired effect.

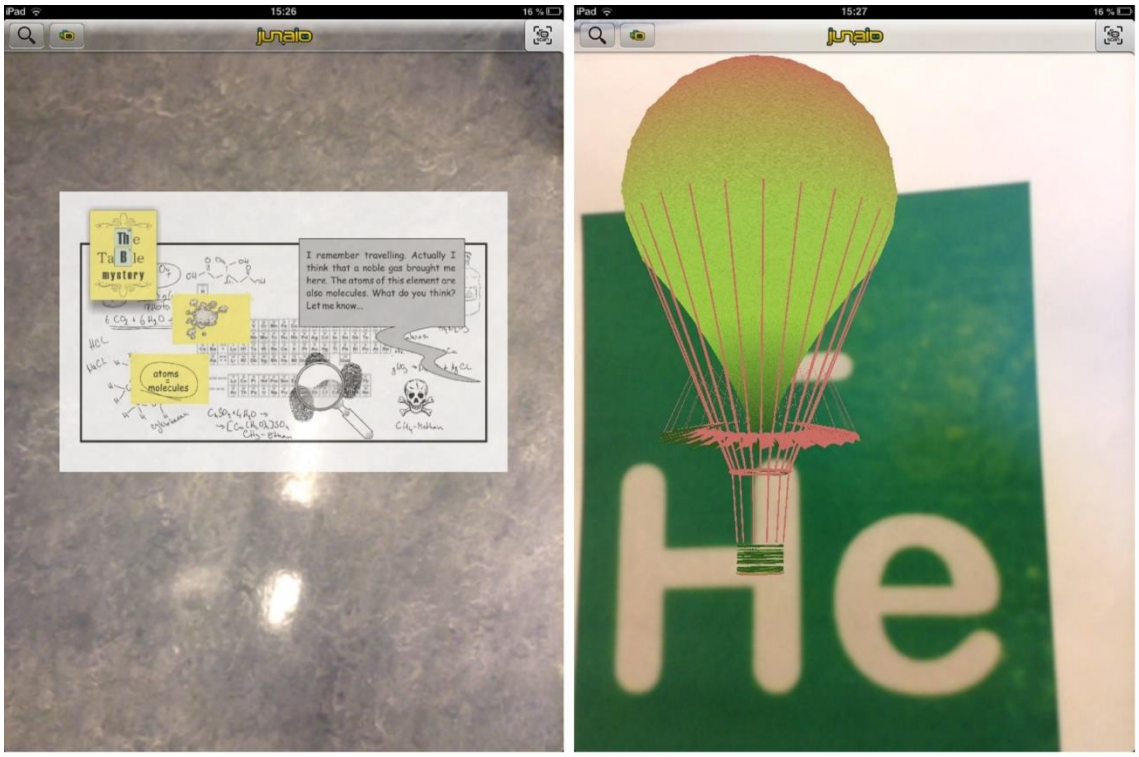

FIGURE 10 SCENES FROM THE GAME "TABLE MYSTERY"

Next, the dental surgery training simulator, presented in "Augmented Reality Haptics System for Dental Surgical Skills Training" by Dailey et al., is discussed. Since this is an augmented reality-based learning game designed for training in a real working environment, balancing is not an issue in the slightest as changing specific training exercises to make them easier or harder would keep the game from reflecting its real-life counterpart. The usage of a head-mounted-display could have a negative impact on usability if the user does not have prior experience with such an augmented reality device. Although adapting to this can be easy for most people, some users might find it difficult. From the paper, not much is known about the user interface of the game. Naturally, this game is to be used in the medical-field of dental care, which means that it probably has been developed with the target demographic of students and trainees in this field in mind. Considering that only a preliminary evaluation of this learning game has been conducted, it is hard to say if an increase of knowledge transfer can be achieved. The haptic function included in the game helps the user to get more accurate feedback of what he is doing and therefore the player might achieve higher expertise through the usage of this game. Augmented reality is used as an integral part of the game and cannot just be removed without breaking it, hence it makes sense to say that augmented reality is not just used as a gimmick.

Lastly, the game "HELLO", presented in "2D Barcode and Augmented Reality Supported English Learning System" by Tan-Hsu et al., is taken a look at. The game is developed for a specific target audience, as it was developed for students to develop their English ability. The criteria of proper balancing and usability seem to be satisfied, as all students found the game to be easy to use (Tan-Hsu et al., 2007, p. 9), though one usability-issue has been identified, which is the fact that the PDA did not have a keyboard and therefore had negative effects on the writing experience. (Tan-Hsu et al., 2007, p. 9). Since it is indicated that the game led to a higher motivation for learning and students liked to use it after class and would like to use it in other courses as well (Tan-Hsu et al., 2007, p. 9), it is safe to assume that it also evokes fun and interest in the learning material. Tan-Hsu et al. also found that it is seems to improve the

listening, speaking and reading abilities of the students (Tan-Hsu et al., 2007, p. 9), therefore it also fulfils this aspect of a meaningful augmented reality-based learning game. It could be argued that augmented reality is used as a gimmick in this game, but the virtual learning partner was found to be helpful and able to deliver an improved learning experience. (Tan-Hsu et al., 2007, p. 9). It is hard to say if a non-augmented reality version of the virtual learning partner would have the same benefits.

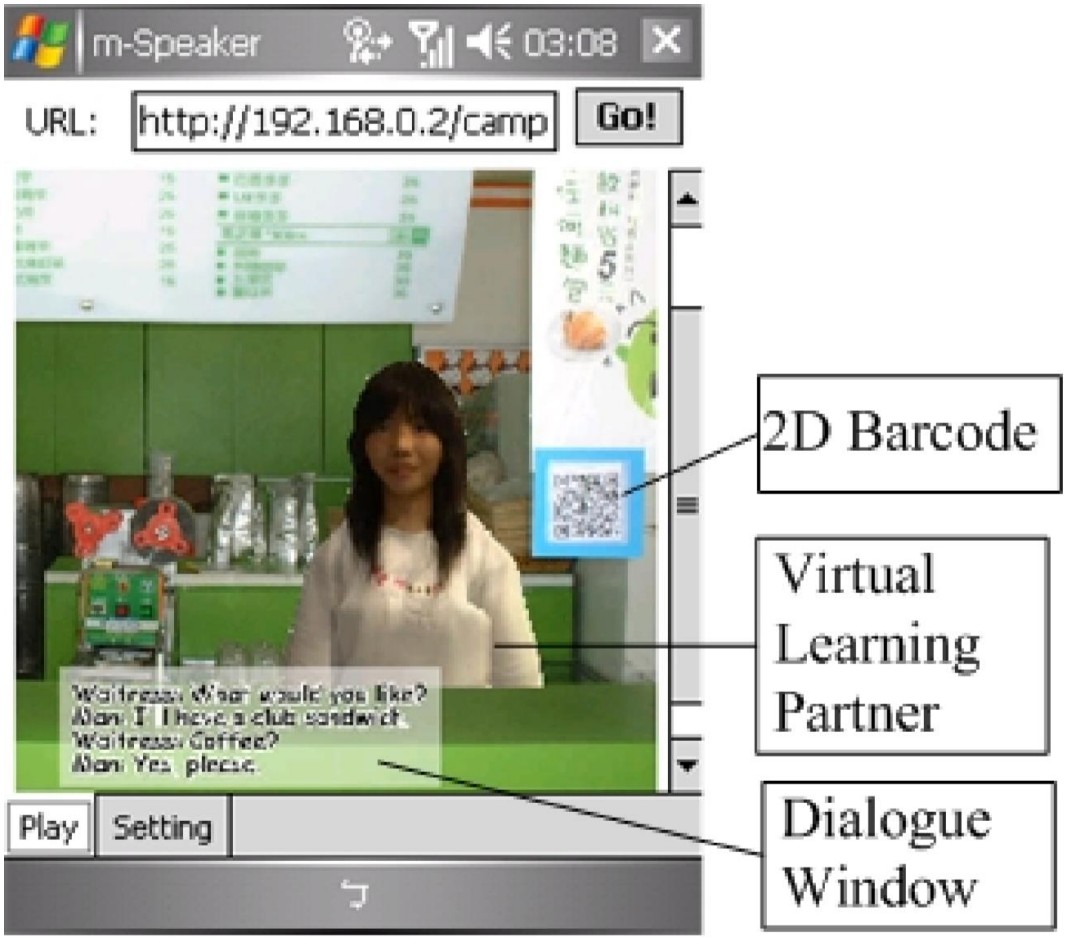

FIGURE 11 A SCENE WITH THE VIRTUAL LEARNING PARTNER IN THE GAME "HELLO"

Even though not all these games meet the entirety of the established criteria for an augmented reality-based learning games that are "meaningful", their creators developed all of them with a specific goal in mind. As said earlier, it does not mean that a game is bad just because it does not fulfil all of the aforementioned aspects, but to maximise the effectiveness of an augmented reality-based learning games, these criteria can be used as a sort of guideline.

7 DEVELOPMENT OF A MEANINGFUL APPLICATION

This section is supposed to highlight a few aspects of augmented reality learning games that should be taken into account during the design and development augmented reality learning games. An overview is given on the aspects of game design principles and game design patters, hardware and software, as well as on possible problems that might arise during development. Additionally, in this section the questions "What has to be paid attention to during the

development of a “meaningful” augmented reality-based learning game?” and “What problems should the developer be aware of during development?” are being answered.

7.1 GAME DESIGN PRINCIPLES, PATTERNS AND SUGGESTIONS FOR DEVELOPMENT

The development of a game can be quite tricky at times. This is particularly true when it comes to games that are supposed to be used for learning and education, as these not only have to be fun and enjoyable, but also deliver a certain amount of specific knowledge and information to the player. While game design principles and patterns are already helpful in normal game development, they can provide the game developer with even more immense help in the development of augmented reality-based learning games.

Several design principles for augmented reality learning games have been suggested in the reviewed literature. Baldiris et al. suggests that the game’s focus should be on the player and that it should not be focused on the content (Baldiris et al., 2015, p. 42), which means that the game should be aware of who the player is and why they play the game. Baldiris et al. goes on to list augmentation of things from the real-world environment, avoiding game elements that can cause frustration, promotion of self-learning, rewarding players for acquiring knowledge and skills during gameplay, and, of course, the game’s fun-factor as design principles. (Baldiris et al., 2015, p. 42-43). In addition to these design principles for augmented reality-based learning games, Devane et al. deliver further ones, including “Identifying contested spaces”, “Interactive Storytelling” and “Transforming Game Research Roles into Game Play Roles”. (Devane et al., 2007, p. 276-278).

“Identifying contested spaces” means that, as Devane et al. say: “it is useful to identify places where there are conflicts over space and place” (Devane et al., 2007, p. 276). An example for such a conflict over space can be seen in the game “Pathomon” discussed earlier. The viruses in the game are occupying different locations that have to be cleared by the player in order to win. Since other players have the ability to accidently spread a virus to these places again, the conflict over this space is ongoing. Devane et al. add to this by saying that “Other games might be more place agnostic, in that they are using space as an organizing metaphor for content” (Devane et al., 2007, p. 276).

“interactive Storytelling” will be familiar to most people, as it is used in most video games nowadays. In most cases, the players are supposed to piece together information by themselves and therefore think for themselves. Devane et al. say that “This model of game play seems particularly well suited to fields that depend heavily on argumentation, such as history and certain forms of science” (Devane et al., 2007, p. 276) and that “Narrative can both scaffold players thinking by attaching information to narrative events, as well as forming the basis of game play as players seek to construct narratives of events“ (Devane et al., 2007, p. 276). Storytelling as a whole can be used in learning games to better immerse players in the experience of the game, though the need for a background story or narrative is dependent on the kind of game. While a game dedicated to younger audiences like children and students can greatly benefit of a good game story, a narrative in augmented reality-based learning games that are more focused on an adult audience or job-training, like the dental surgery training simulator talked about earlier, can be unnecessary and potentially get in the way of the learning experience.

The augmented reality game design principle “Transforming Game Research Roles into Game Play Roles” is built on the suggestions of Devane et al., that game designers who are in search of roles that can be used in the game, might find an advantage in transforming the roles that they

inhabited during research for the game into game roles. (Devane et al., 2007, p. 277-278).

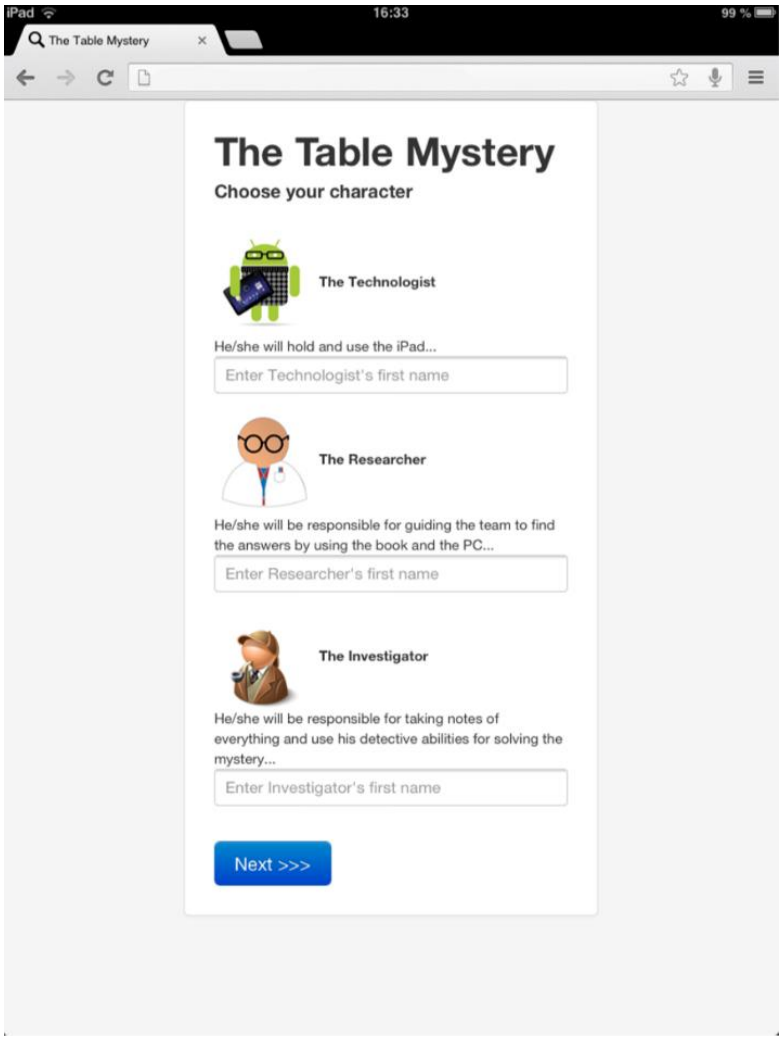

FIGURE 12 ROLES IN THE GAME "TABLE MYSTERY"

In addition to this design principle, the overall correct implementation of game roles can greatly benefit the players' whole game experience and learning outcome. In relation to the usage of roles in the augmented reality learning game "Mad City Mystery", the following has been said by Mingfong & Squire in 2007:

> "The game roles encouraged collaboration and served as a scaffolding for reading. Specifically, they encouraged students to share information, synthesize what they read, communicate orally with their group, ask questions, and debate meanings. Because no one player had enough information to develop a coherent narrative of events, the group was forced to read, synthesize, and discuss findings." (Mingfong & Squire, 2007, p. 24)

This hints at a possible positive effect on the learning experience in augmented reality learning games through the use of complimentary player roles.

Design Patterns are commonly used in game development to comprehensibly show how different design approaches can achieve specific outcomes. Oftentimes game design patterns

are already implemented in game engines and sometimes even in augmented reality devices, as mentioned by Emmerich et al. (Emmerich et al., 2017, p. 167). Emmerich et al. have found and analysed multiple basic game design patterns used in augmented reality games, through research of literature and characteristics of existing augmented reality games. (Emmerich et al., 2017, p. 166). Afterwards, they have proposed the augmented reality learning game design patterns seen in Table 1 below, which are a combination of the basic game design patterns that have been analysed and identified by them before. (Emmerich et al., 2017, p. 166).

Pattern	Forces/Problem	Feature/Solution	Effects/ Consequences
Extended Room	The gameplay may require additional virtual rooms, spaces, and structures.	*Obscured Information Visualization*, *Environment Requirements*, and *Environment Adaptation* enable virtual objects to overlay physical structures (e.g. showing non-existing rooms). "Magic Doors" allow to virtually enter a different room.	Useful e.g. for historic learning (what did a scene look like previously) or for change planning (what might it look in future). Also useful for virtual travels.
Exploration and Search	Virtual Objects should be hideable behind/under physical objects to force the player to search them within the physical environment.	Based on *Obscured Information Visualization*, *Information Filtering*, *Environment Requirements*, *Environment Adaptation* from this collection and *Exploration*, *Clues*. Optional hints can be used for guidance.	Explorative learning tasks to foster orientation, exploration strategy
Asymmetric Multiplayer	Two players require different information, e.g. according to individual roles, locations, or progress.	Based on *Information Filtering*, *Shared Pointer* from this collection and *Asymmetric Information* information can be individualized.	Asymmetric information can be bound to teacher/ learner roles or to reflect individual learning needs
Augmented Ghost Track	A player can see and follow the track of another player in the physical environment	*Shared Pointer*, *Information Filtering*, *Directed Gaze*, *Directed Movement* can be combined to create ghost tracks.	A learner can follow guided steps or work on continuous improvement of own ghost track data.
X-Ray Vision	Visualizing internal processes or mechanisms not visible	*Obscured Information Visualization*, *Environment Adaptation* and *Gaze POI* are the basis for showing hidden	Explain hidden features of complex setups, can be extended to allow for

TABLE 1 DESIGN PATTERNS FOR AR LEARNING GAMES

There are also further suggestions on a variety of elements that play a role in the design of an augmented reality learning game. For one, it has been suggested by Feijs et al. that designing an augmented reality game for use at home instead of classrooms or outdoors can be more effective as it might lead to a more spontaneous and more enjoyable learning experience. (Feijs et al., 2017, p. 624). Non-Player-Characters (NPCs) can be used to increase the positive effects of such games. Mingfong and Squire say that, in the game “Mad City Mystery” briefly mentioned earlier, NPCs are designed to “propel action, build engagement, promote interaction, and scaffold thinking” (Mingfong & Squire, 2007, p. 14). Naturally, designing the game’s difficulty curve to be steadily increasing in order to provide the player with a constant challenge can also have benefits for the player’s engagement in the game, while building the challenges around knowledge and skills that the player has already learned through the game might make them see the gameplay as more rewarding.

A literature review by Feijs et al. has identified the four most proposed design aspects for an augmented reality learning game in their reviewed literature:

- The involvement of learners should be considered, as is has been found by Feijs et al., that different kinds of learners can be influenced differently during a play session with an augmented reality-based learning game. (Feijs et al., 2017, p. 622). Feijs et al. go on to conclude from this that the design process should always include the preferences and feedback of the games target group, in order to take their different levels of knowledge and skills into account. (Feijs et al., 2017, p. 622). This is coinciding with one of the criteria for a "meaningful" application of an augmented reality-based learning game in this seminar paper, i.e. that it should be developed to fit its target audience.
- Learning objectives should be specific and clear, as it can be difficult to achieve all effects that are desirable for developers of learning games in one game. (Feijs et al., 2017, p. 622). Feijs et al. go further to says that "Only when the educational objectives are clear, the proper game elements and AR features can be selected, and effective AR learning games can be designed"(Feijs et al., 2017, p. 622).
- During the design process, Developers should be highly aware of the varying outcomes and effects that can be achieved with the augmented reality features and overall game mechanics used in the game. (Feijs et al., 2017, p. 622-623).
- Lastly, social interactions should be encouraged, as augmented reality already has a social advantage by default according to Feijs et al. (Feijs et al., 2017, p. 622).

7.2 HARDWARE

Augmented reality based-learning games can be played on a variety of devices. Most commonly used are handheld-displays and head-mounted-displays (HMDs), though a normal computer with a webcam attached can also be used. Choosing the right kind of device to output your augmented reality game can be of great importance for various reasons. Gameplay is by far the most affected factor when it comes to the different devices, not only can choosing a certain type of device enable various kinds of gameplay and game styles, but also make interactions more intuitive from the user's perspective.

A Handheld display can be any small mobile device that is portable. This can range from modern smartphones and tablets all the way to old PDAs. Naturally, whatever mobile device is being used, be it modern or outdated, must fulfil certain criteria. For one, if marker-based or marker-less augmented reality that requires visual feedback is being used, the device needs to be equipped with a functioning camera. Depending on what kind of augmented reality is being used it might also be required to have functions like a GPS, an accelerometer or a magnetometer available. (Johnson et al., 2011, 122). The main benefits of using handheld displays over head-mounted displays or stationary computers are the guaranteed high portability of mobile devices, like smartphones, and the fact, that they can be found in abundance everywhere. Nowadays, a lot of students already own smartphones that are able to display augmented reality content. (Ferrer et al., 2013, p. 1). Mobile devices have also been found to foster a higher willingness of students to learn as Fotaris et al. say that they can "rapidly increase students' learning participation through practical hands-on experiments" (Fotaris et al., 2017, p. 190). Of course, they also bring some drawbacks with them. The most obvious drawback can already be seen it the name "handheld" devices, as users usually have to use at least one hand to hold the mobile device in place. If marker-based augmented reality is being used, it can also important to firmly hold the mobile device without much shaking, as the tracking of the markers might be difficult for the device otherwise. It has also been said by Ferrer et al. that usability could be impacted by other aspects such as the phone's screen size

and the methods used for interaction, which can have an unfavourable influence on the effectiveness of learning and the user's motivation. (Ferrer et al., 2013, p. 1).

Head mounted displays are augmented reality devices that the user wears on their head like a pair of glasses. With the help of a camera, the augmented reality picture is rendered onto the display in front of the wearer's eyes. This display can be either see-through or not. Head mounted displays are not only used in augmented reality, but since they are in fact so well suited for the use with augmented reality, it is said by Emmerich et al. that the whole field of augmented reality is predicted to go through a significant evolution because of the widespread availability of state-of-the-art head-mounted-displays and augmented reality devices lately. (Emmerich et al., 2017, p. 161). Microsoft's Hololens is probably the most popular AR-head mounted display currently on the market. It is equipped with a depth camera and is able to track movement with its sensors. Other aspects that make it so popular consist of its marker-less tracking technology called spatial mapping, the fact that it is not tethered and that it does not require an additional computer for its use. It is mentioned by Emmerich et al. that when the HoloLens is used with current game engines like Unity, several game design patterns are already implemented, this includes: Directed Gaze, Directed Movement, Gaze Cursor, Gesture-based interaction and Voice Commands. (Emmerich et al., 2017, p. 167).

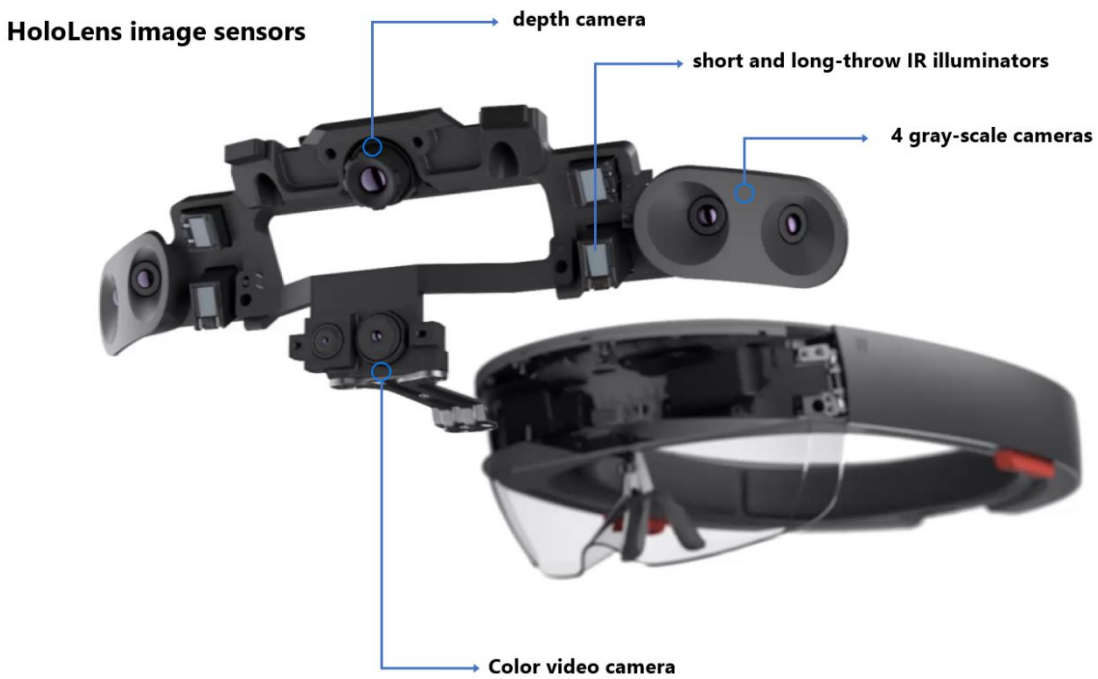

FIGURE 13 MICROSOFT'S HOLOLENS HMD WITH ALL ITS CAMERAS AND SENSORS

While other head mounted displays might not be as advanced as the HoloLens, even much simpler devices come with several benefits like having your hands free, being able to move around in space naturally and potentially feeling more immersed in the experience. Dependent on the device used, multiple issues can arise. These downsides can include the device being too heavy for prolonged use and a lack of depth perception when only a monocular camera is used. (Dailey et al., 2010, p. 98). Similar to virtual reality headsets, AR-head mounted displays can also cause motion sickness and nausea, though much less likely.

The biggest advantage when using a normal computer with a webcam attached is that it provides excessive processing power compared to most mobile solutions. This setup is often used for testing games during development, as it does not require the developer to port the game build to another device.

7.3 SOFTWARE

Choosing the right kind of software for the particular needs of the developer is an integral part of the game development process. Not only can this make the solving of issues related to the development much easier, but it can also stop certain problems from showing up in the first place.

There are different kinds of software development tools for augmented reality, for example, Johnson et al. explained that "Some tools, such as Daqri, MixAR, and ZooBrust, are quite simple and require no programming knowledge or skill. Others tools include SDK kits such as ARToolKit, Unifeye Mobile SDK, and Wikitude, which have been developed for serious AR developers" (Johnson et al., 2011, 130). This indicates that developers must choose between two types of augmented reality development tools:

- A more basic, and presumably more limited, software tool that can be used without much knowledge of game development and programming, thus being better suited for people that want to develop augmented reality-based learning games but do not have the expertise to do so.
- A software tool that is more complex in its nature and offers more opportunities but requires the developer to possibly have extensive knowledge of programming and game development.

Learning games in particular can suffer from this dilemma. As stated by Antonioli et al.: "Many teachers do not have the skills to program their own AR learning experience and therefore must rely on the ability to create this AR environment through pre-made creation tools" (Antonioli et al., 2014, p. 100). This severity of this dilemma gets elevated, as Antonioli et al. go on the say that "AR tools are becoming more user-friendly and require less programming skills making them more attractive to the common educator" (Antonioli et al., 2014, p. 100). This trend can be seen especially well when it comes to game engines like "Unreal Engine 4" and "Unity". Both of these game engines offer developers integrated support for several tools that are used in the creation of augmented reality-based learning games. This support ranges from the native support for augmented reality tools like "Vuforia" in Unity, all the way to the easy integration of Microsoft's HoloLens in Unreal Engine 4. Moreover, features like the ability to "code" through using nodes and simple drag & drop mechanics in Unreal Engine 4 make programming knowledge almost non-mandatory, while still retaining the opportunity to make full use of its advantages in game development. Apart from a well-structured documentation, a widespread and healthy community is another benefit both game engines can enjoy. Developers have access to a myriad of different forum posts, tutorials and lessons that can help resolve any issues during the development process.

FIGURE 14 MARKER-BASED AUGMENTED REALITY WITH THE SOFTWARE "VUFORIA" IN THE GAME ENGINE UNITY

7.4 PROBLEMS

During development of an augmented reality-based learning game a multitude of diverse problems can be encountered. As mentioned earlier, one of these problems is the fact that most teachers and educators usually are not game developers. They normally do not have the required skills to program augmented reality learning games and might find it difficult to produce 3D models due to the absence of technical knowledge. (Johnson et al., 2011, p. 133, Antonioli et al., 2014, p. 100). Additionally, dependent on the processing power of the kind of device that is used for augmented reality, it might be mandatory to simplify used assets, 3D objects and effects. Overcoming these limitations can bring multiple perks and handicaps with it, as Godwin-Jones says:

> "For those researcher-practitioners who do jump into creating an AR project themselves, there are a number of advantages. Typically for such projects, there will be a lot of trial and error, even if a detailed road map or storyboard has been created. As a consequence, such projects tend to go through many iterations, with multiple testing cohorts; each time resulting in minor or major adjustments. Waiting for programmers to make adjustments to the program can be problematic (and possibly expensive). Of course, the simpler the game and easier to use the authoring tool, the quicker adjustments can be made. [….] On the other hand, there is the possibility that, compared to commercial games, educator-developed games will have bugs or less than optimal game flow. The quality of the game experience is central to student acceptance." (Godwin-Jones, 2016, p. 14)

Apart from these problems, several aspects that are relevant after the release of the game have to be taken into account during the development as well. As it might be difficult to implement a curriculum into a game about learning, it is a good idea to integrate learners in the development process. (Moldoveanu et al., 2013, p. 110). In order to avoid backlash from

educators that are focused on a more traditional approach to learning, it is important to keep in mind that the game should promote realism in terms of content and concepts.

8 OUTLOOK & FUTURE RESEARCH

As it has been already established, the development of video games, especially learning games that make use of augmented reality, has become easier and easier over last couple of years. This will eventually lead to more opportunities and the higher accessibility of augmented reality-based learning games in all fields of education. In accordance to Fotaris et al., further theoretical frameworks and methods for evaluation of augmented reality learning games must be researched to construct the pedagogic nature of these games. (Fotaris et al., 2017, p. 190). Furthermore, Feijs et al. warned in their research about AR learning games that "there is a lack of systematic research on how different AR features and game elements influenced or supported the effects specifically" (Feijs et al., 2017, p. 624).

This leads to the conclusion that further research needs to be done on the effects of different game design choices as well as other integral elements. Feijs et al. have also advised that the effects of augmented reality in learning games on both the short-term and long-term should be explored further. (Feijs et al., 2017, p. 618). Bucher et al. have suggested that a possible advancement for their learning game in the future might be the move towards an adaptable scaffolding that can be easily altered to accommodate a variety of content. (Bucher et al., 2018, p. 4). This approach could be adapted to augmented reality-based learning games as a whole.

9 SUMMARY

Augmented reality gets more and more popular in today's world and video games get easier and easier to develop through game engines like Unreal Engine 4 and Unity. Seeing how this development has led to many people trying to create their own video games without proper experience and knowledge in game design and game development, thus flooding the game market with a widespread variety of games that do not deliver a good and useful experience to its players, it is not unnatural to assume that a similar development could also occur in the market of augmented reality-based learning games.

This seminar paper wants to answer several questions related to this issue, while also giving a brief overview over related aspects. The questions that it wants to be answered are:

- What is a "meaningful" application of augmented reality-based learning games?
- What has to be paid attention to during the development of a "meaningful" augmented reality-based learning game?
- What problems should the developer be aware of during development?

There are plenty of examples for augmented reality-based learning games, focused on all kinds of fields, that have been developed. A couple of good examples for these are:

- "Pathomon", an augmented reality learning game by Bucher et al., that is based on the popular mobile game "Pokémon GO" and tries to teach its players about the different attributes of viruses.
- "Table Mystery", a game developed by Costas Boletsis and Simon McCallum, which wants to educate its users about the elements on a periodic table through the use of riddles and a narrative experience.

- The dental surgical training simulator by Dailey et al., which helps trainees in the dental-field through the virtual and accurate simulation of dental surgery procedures with haptic feedback.
- The game “HELLO” by Tan-Hsu et al., developed to help students improve their knowledge on the English language and increase their skill in speaking it.

Augmented reality can be achieved through the use of different tracking technologies, that each have their own benefits and downsides when used in augmented reality learning games. In this seminar paper, a brief overview is given over marker-based tracking, marker-less tracking and location-based tracking technologies for augmented reality. Marker-based tracking technology seems to be the most commonly used one in the educational field, according to the example games researched for this seminar paper and similar findings by Fotaris et al. further indicate this. (Fotaris et al., 2017, p. 188). Furthermore, it looks like marker-based tracking finds its best use in the educational field, as most students already own a mobile device that is capable of marker-based augmented reality. (Ferrer et al., 2013, p. 1). As location-based tracking can be defined as a subcategory of marker-less tracking, they both have the advantage of not requiring print-outs of markers or similar. While location-based augmented reality can cause safety concerns (Johnson et al., 2011, 128), marker-less tracking, through the use of depth-cameras and sensors like in Microsoft’s HoloLens, has the great benefit of being able to be used anywhere without much prior preparation.

Augmented reality-based learning games find uses in a multitude of different fields. The fields of language learning, school education and medicine have been selected as examples for these in this seminar paper. Each one of those three fields has its own reasons to use learning games that make use of augmented reality technology and benefits that can be achieved by doing so.

The papers on games that have been researched for this seminar paper have been evaluated and the question “What is a “meaningful” application of augmented reality-based learning games?” has been answered through the criteria/guidelines that have been formed in section 6.1. According to these criteria, a game should…

1. … have good usability.
2. … have proper balancing.
3. … be able to evoke motivation, fun and interest.
4. … be developed to fit the target audience.
5. … have the ability to transfer knowledge and information.
6. … not use augmented reality only as a gimmick.

Moreover, it has been highlighted what should be paid attention to during the development of a “meaningful” augmented reality learning game. This includes multiple aspects such as game design principles and game design patterns. Additionally, a few other suggestions on the design of game elements have been given. The strong points and drawbacks of different kinds of hardware & software solutions that can be used for augmented reality gaming have been given an overview on and numerous problems that can affect the development of an augmented reality learning game have been discussed.

It has been concluded, that in future research more focus needs to be put on the different effects that particular game mechanics and augmented reality features can have on the players of augmented reality-based learning games, only through this, their full potential can be explored.

10 ABBILDUNGSVERZEICHNIS

11 LITERATURVERZEICHNIS

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