Hololec: Augmented Reality in Teaching

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Abstract

The use of Augmented Reality as a teaching tool is ever growing, and holds the potential to provide a greater impact on students learning abilities around specific subjects. My project focuses on the use of Augmented Reality in Chemistry to further the understanding that students have of chemical molecules and structures alike. I worked closely with Dr Christian Klinke to develop software that would be used on the Microsoft HoloLens, to grant a better visualisation of structures in a 3D format, to students studying Chemistry. Using this tool, I was able to incorporate his visions for Chemistry as a subject into a working piece of reality. Augmented Reality working in this way to further students knowledge on a specific subject is unique, with the potential to grow into an everyday teaching tool if enough time and effort is put into developing new teaching methods.

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Declaration

This work has not previously been accepted in substance for any degree and is not being currently submitted for any degree.

May 12, 2019

Signed: Benjamin Lewis Sampson

Statement 1

This dissertation is being submitted in partial fulfilment of the requirements for the degree of a MEng in Computing.

May 12, 2019

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Contents

1 Introduction

My project makes use of the Microsoft HoloLens, which is a Virtual Reality headset with transparent lenses for an Augmented Reality(AR) experience [4]. This piece of Augmented Reality technology is cutting edge and has many uses around the world, ranging from remote instruction, gaming to holographic attractions and entertainment [6]. Each different use has their own software builds behind the HoloLens which make it capable of producing such feats.

I chose Augmented Reality over Virtual Reality due to the specific aspects that the software can provide over its counterpart. The different uses that Augmented Reality has, along with its superior set-up time, only requiring minimal effort, made it the prime choice for a development platform over Virtual Reality. Augmented Reality software can be developed specifically for educational usage and generally has a greater impact on learning ability over Virtual Reality.

Not only does the HoloLens have a good standpoint when it comes to usage around the world for a wide range of applications, it also has great educational use and is being further developed to become more of an effective tool. AR can be used to help further students experiences regarding specific subjects along with opening them up to not only different learning methods, but also provides them room to explore on their own.

Thanks to recent developments in technology, not only with the Microsoft HoloLens, but with other AR related products, the different learning methods that can be applied in schools are expanding. Augmented Reality software is being developed to not only encompass general use but also spread into education. It helps students grasp a better understanding of subjects along with providing the ability for students to become more engaged. However, I feel that more could be done in this sector to further the teaching and learning abilities of not only students, but also teachers.

The software I have designed focuses primarily on furthering the instructional tools that teachers have, in regards to chemistry. I worked closely with Dr Christian Klinke, a chemistry Professor at Swansea University, to develop and build software that would allow students to better visualise chemical structures and molecules, to provide them with a better learning environment.

I chose this project as I believe that education can be taught many different ways, and that using cutting edge technology to help achieve this can be beneficial to not only students, but also teachers. With the use of a HoloLens, I can help engage students more in subjects such as chemistry as the software I have developed helps provide a more hands-on experience for students. Using the guidance of Dr Christian Klinke, I was able to achieve this to a high standard where his visions have been met alongside my own.

1.1 Motivations

AR is a particular part of technology that is further developing across the world; it is being used in many different areas of expertise and is something that I felt I had to jump onto. Being able to develop a piece of usable software for the HoloLens, has given me a good step on the path to further my knowledge of Augmented Reality as a whole. Augmented Reality is a very unique piece of technology, as it differs from most things we know, furthermore, it is a great tool that can be used in furthering the educational learning of students, from young to old. The ability to better visualise something in front of you, providing the ability to move around and even interact with the object, is outstanding and ground breaking on a technological level. Using this level of interaction, it provides an ideal environment to develop teaching tools, giving students and teachers the ability to have hands on experiences in specific subjects, and also providing a more enjoyable learning environment.

With Microsoft developing the HoloLens, and placing good emphasis on educational usage of the hardware, this makes it an ideal platform for further development of educational software; this also gives me the ability to develop on a piece of expanding hardware. The HoloLens is being used around the world for not only education, but other helpful and fun purposes, some of which are new ideas, others are copies from original works but adapted to suit the needs of Augmented Reality. Schools and Universities are slowly incorporating the use of Augmented Reality technology to help students benefit from its educational properties.

With the addition of the HoloLens 2 and its new features and abilities, it is being more tailored towards educational usage alongside usage in companies for meetings and pitching of ideas. This also helps provide a good platform for these sorts of things, along with the use of interactive classroom experiences with people who are either next door, or miles away teaching or presenting, or even in the use of conferences. This is achieved by using their new software called Spatial. The Spatial software turns the space around the user into a shared augmented reality workplace, which can be used to interact with others as if they were in the same room [3].

Having the opportunity to use the HoloLens and further develop educational software for the product, gave me the ability to use something that normally I wouldn't dream of ever using. On top of this, it gave me the ability to contribute and design something towards an expending field that is education. My work has the potential to be further developed and used by the University as a small educational tool. Alongside this, it gave me a good insight into the world of Augmented Reality and has allowed me to obtain knowledge that can be used for future endeavours.

This project is something that I have been extremely happy to progress and

further develop both my knowledge and skills with. It is something that I am very interested in and is also part of a side of technology that is making breakthroughs. Furthermore, it allows me to focus on a specific field of study, work and develop towards something that can be used as an educational tool by all students. This gives me a good motivation to produce something that others can constantly use, and further develop their own knowledge and expertise about the chosen area of design, chemistry. Alongside this, AR for the use of chemistry can be very unique because of the different things that can be produced and has many different applications for the hardware.

1.2 Aims

AR is a new and interesting area of development, not only for educational usage but also a general one too. There are many challenges that come with Augmented Reality development, especially for an educational setting. I needed to develop something that would ensure students can have fun learning, and better help visualise chemical structures which can in turn help them understand. My project focuses mainly on chemistry, which in it self brings many challenges to the table during the development of my product.

I had to work closely with the chemistry department and Dr Christian Klinke, to ensure I could obtain and further develop and carry through their goals for this project, along with meeting my goals that I set myself along the way. I had to expand and develop on the ideas that were brought in front of me, to ensure that what I was developing, was a useful educational tool that could subsequently be used to help further students' knowledge, views and overall education in the subject of chemistry.

The main aim I fully considered when I was starting development of the product, was to create and develop a piece of prototype software that would teach students of chemistry in a specific way and in a specific scenario. To do this, I ensured that I knew the direction of the project that I was working towards, all the while ensuring that I was in contact with Dr Christian Klinke, who helped me to further develop a prototype to meet this aim. Not only was this my aim, but also his, as he had intentions of using the software to teach his students in a more detailed manner.

From the aims I initially set myself at the start of my project, I feel as though I met the main bulk of these aims. I was able to develop and create a piece of software that I feel was able to benefit the chemistry department at University. This is because the software helps visualise structures in a way that is more interactive to previous measures. Alongside this, I received good feedback from the students indicating that not only would some of them use it again, but that some enjoyed their experiences.

I met my functionality aim of the project, where you can zoom, resize, move and

rotate the specific structures, which gives students a more hands on approach when it came to interacting with my software over other similar pieces of visualisation tools. Following this, thanks to the software being used not only by the lecturer, but also a number of varying students in and outside of a dedicated chemistry lab session, I believe that what I developed is and will be used for educational purposes. During the development process, I also ensured to create several prototype builds and versions of my software. This allowed me to test each new feature and also present the chemistry department with a prototype each meeting, to further develop and obtain ideas of where to head next.

I considered a wide range of aims at the start of my project which I worked closely too so I can make sure that I met as many of these aims as I could. Following this, I feel like I met a substantial amount of aims, including the important aim of ensuring that what I was developing would be used in an educational setting and environment. Furthermore, the feedback results that I subsequently received from the lab session test, shows that these aims were met in regards to the feedback obtained by the students actually testing my product. However, not all my aims were met as clearly and concisely as I would have hoped, as some students had differing opinions about the Augmented Reality project, when it came to visualisation of different molecules.

Overall, I feel like the main aims I set myself for my project were achieved, and that overall my project was a success when it came to developing a teaching tool that would be used to help further the understanding of chemical structures towards students at a University level.

2 Background Research

Augmented Reality is not new technology by any means, rather an emerging form of experience in which the Real World is enhanced by computer-generated content [22]. Following from this, it is finding uses in a wide range of areas, one of which is education. The ability to create Augmented Reality popup books in which still or animated 3D images hover over the pages [22], can further students learning abilities.

Following from this, researchers believe that Augmented Reality has vast potential implications and numerous benefits for teaching and learning enviroment's [22]. Augmented Reality has the beneficial usage that can engage, stimulate and motivate students to explore class materials from different angles and perspectives [22].

Augmented reality has the ability to enhance a users perception of and interaction with the real world. Giving the user the ability to move around three-dimensional virtual images and view them from any specific point [10]. This plays a big part in the usage and potential that Augmented Reality has

in education and I feel that this is one of its biggest strong points, as it allows the development of innovative computer interfaces that merge virtual and real worlds to enhance collaborations [10].

Not only does the use of Augmented Reality headsets play a part in education, but mobile devices also play just as an equal part. Studies have shown that mobile devices play a major role in education [15]. In 2006, an educational game was developed called Virtuoso. The aim of this game is to sort a collection of artworks according to their creation date along a timeline following 3 different conditions: a paper, PC and PDA. Although there were 3 different testing conditions, the results showed that there were no significant differences in educational outcomes [15].

CONNECT is a project that uses MAR (Mobile Augmented Reality) that was developed to support students learning science [15]. What is most interesting however, is that this study was conducted with learners with physical disabilities and able bodied students. From the test results, it showed that the disabled students had almost the same results, which provides support that MAR technologies has potential to improve the landscape of education for disability students [15].

Not only does Augmented Reality have the prospects of being used in an educational setting for schools, but it can be adapted for use of medical education. The use of Augmented Reality technology could offer additional teaching methods for anatomy education. This is because you can have better visualization capabilities, including the 3D rendering of anatomical imagery [9].

Several Augmented Reality systems have already been developed specifically for anatomy education. Trainees can stand in front of a TV screen that has a camera attached. The image from the camera is flipped horizontally and shown on TV screens, mimicking a mirror function which is part of a CT dataset, which is augmented to the user's body [9].

The educational prospects that follow schools can be quite large. Not only can Augmented Reality be used in the upper levels of education, but also it can be highly impactful to the lower levels. Educational Magic Toys (EMT) have been developed with Augmented Reality technology, these toys display virtual objects such as story animations [20]. The overall aim for these types is to determine children between 5-6 years of age, and their behavioral patterns whilst playing with EMT's, to determine whether EMT activities were a viable step in education for young children [20].

For students within the educational sector to learn more and excel, education has to be both experimental and interactive, where more hands-on experiences are valued and provide a better learning platform. The use of Augmented Reality can help provide this. Augmented Reality provides the ability to transition

between reality and a virtual world. Furthermore AR can be used for online education with MARIE(Multimedia Augmented Reality Interface for E-Learning) where AR is used to present 3D information to students [16].

Not only has Augmented Reality been used in various forms of educational subjects, it has also been used in chemistry. Software has been developed to visualise different chemical reactions between molecules. As the user controls two different molecules in both hands using markers [14], they gain the ability to see how these different molecules react to each other. This helps grant students a better visualisation of chemical reactions and their counterparts. [20]

All these works have played a big part in directing the scope and overall direction my project will take. It has provided me with good incite into what Augmented Reality technology can achieve and using previous works surrounding Augmented Reality in chemistry. I am able to deduce what steps I need to take for my project to become something unique along with an effective teaching tool because of this prior research into already existing software.

3 Proposed Solution

My project is all about developing an effective teaching tool that helps chemistry students get a better understanding of chemical structures, through the use of AR. In order to further develop a solution to my project, making it not only meaningful but also an effective teaching tool, was to ensure I knew other pieces of software exists, that does what I want to be able to achieve. This meant that I had to understand the functionality of JMOL for use of chemical structures, before planning the functionality of my own project.

Following this, I was able to draw up an outline on what I wanted to achieve, how I would achieve it and what my project would eventually be able to do, at the end of development. I worked with the chemistry department to ensure that I was heading in the right direction, ensuring that the functionality I am adding along with the direction of the project would be able to produce something that meets the goals of not only me, but also the chemistry department. Subsequently, what I proposed was used, developed upon and eventually I produced a product that helped further visualise chemical structures, using a wide range of functionality features.

4 Project Management

My chosen methodology for this project was Agile, this was because that due to the nature of my project, working closely with the chemistry department of the university and more specifically Dr Christian Klinke, I had to ensure I produced a piece of software that not only met the goals and specifications of

my project, but also met the goals and specifications of Christian. Agile allowed me to achieve this by giving me a stepping stone to constantly obtain feedback during different developments and builds of my project. This in-turn gave me the opportunity to edit the software as I went along, leaving ample time to do this without it impacting the overall speed of development.

The reason why I chose Agile methodology for this project is because it offers the use of sprints. Sprints are a set period of time that is allocated for particular phases of a project [17], when the sprint time ends; it is assumed that the phase is completed. Another reason for me choosing to use Agile for my project is because it offers me a [17] continuous development cycle alongside this, it gives me the ability to constantly work with the client to improve, change or evaluate the software during production.

Going into this project, I had to take into the account specifications set out by Christian. These included ideas on how he wanted the product to interact, look, usability and overall functionality. Following this, I had to make sure that my own goals and specifications were met. Due to my product being a chemistry related product, I had to ensure I could implement all the important functions revolving around chemical structures and molecules, to not only ensure that I could meet my specific goals, but also meet Christian's expectations of how he wanted the product to be used.

To help with the overall management of the product, I developed a detailed Gantt chart to not only help me in time management, along the course of development, but to also it gave me a graphical backbone that I could present to Dr Christian Klinke. This allowed me to express where I was in development, present to him feedback periods and also add or edit it accordingly, depending in which direction the project was heading during the time of meeting.

Following this time plan I developed, I tried to stick to it as best as I can. I detailed a list of sprint sections, with what I would do during that development sprint and the overall goal at the end of the sprint. However due to some issues with not only software, but also hardware, I couldn't manage to stick closely to the plan, however this didn't hinder overall development with my project.

These risk factors that hindered my projects progression were accounted for and analysed as potential risks before the project started. However following this, I did not take the proper steps to avoid these risks which meant that when I encountered them, I had to work and develop a solution around them in order to keep my project on track. One of the main risks that I encountered was the lack of Operating System software that could run the programs I required in order to develop my project. This meant that I had to use dedicated University computers in order to progress on with development.

5 Implementation

In order to develop my product I had to use different pieces of software to help me achieve the overall aim of my project. In order to obtain the chemical structures required, I had to use JMOL, which is an open-source stand-alone Java viewer for chemical structures in 3D with features for molecules, crystals, materials and biomolecules [2]. I had to subsequently export these structures into a 3D object file. Figure 1 shows the method that I used to export JMOL files into a usable X3D file.

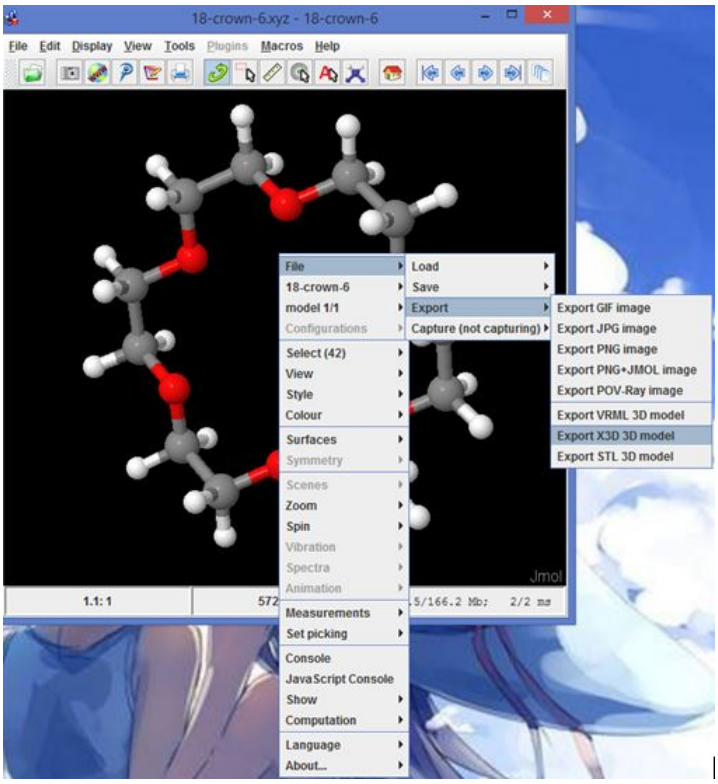

Figure 1: JMOL Exporting

After the exportation of the structures into usable 3D files, I proceeded to use Blender, which is a free and open source 3D creation Suite [7]. Inside blender, the 3D structures would be broken into many individual objects, and for ease of use, I had to manually re-join all these objects which allowed me to create a usable object. Following this, I had to then save the blender file as a .blend, as exporting the blender file into a 3D object that Unity would use as an as-

set, meant that the different colours on the molecules would not transfer over. Figure 2 shows how I went about exporting the X3D files into Blender, so I can use in Unity.

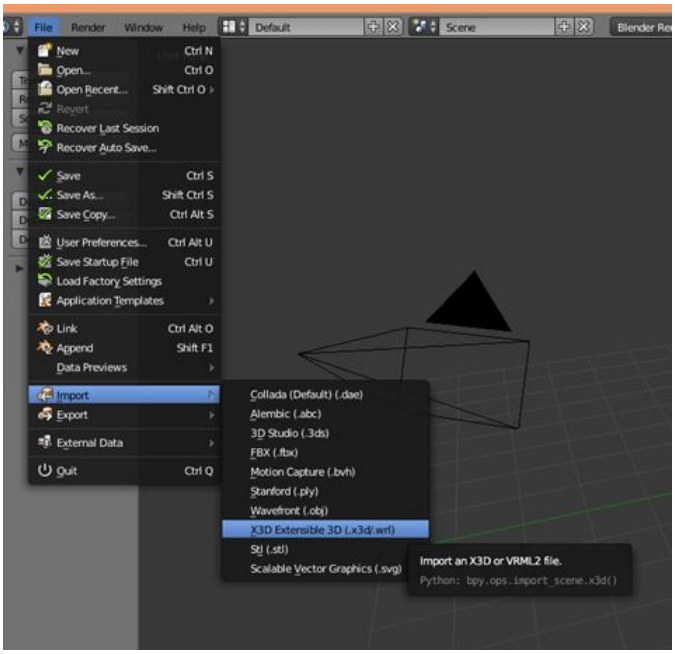

Figure 2: Blender Importing

The main piece of software that I used was Unity, which is a game development platform which is used to build high-quality 3D games that can be deployed across mobile, desktop, VR and Augmented Reality [18]. Inside Unity, I had to set up a correct Unity scene that would allow for Augmented Reality development. I then had to import the .blend files (usable 3D models) as assets, which I can drag and drop onto my Unity scene. Following this, I used scripts from various sources to help add functionality and slowly build my project. Figure 3 shows the exporting/saving of the Blender files as .blend. This allowed for easy asset importation into Unity.

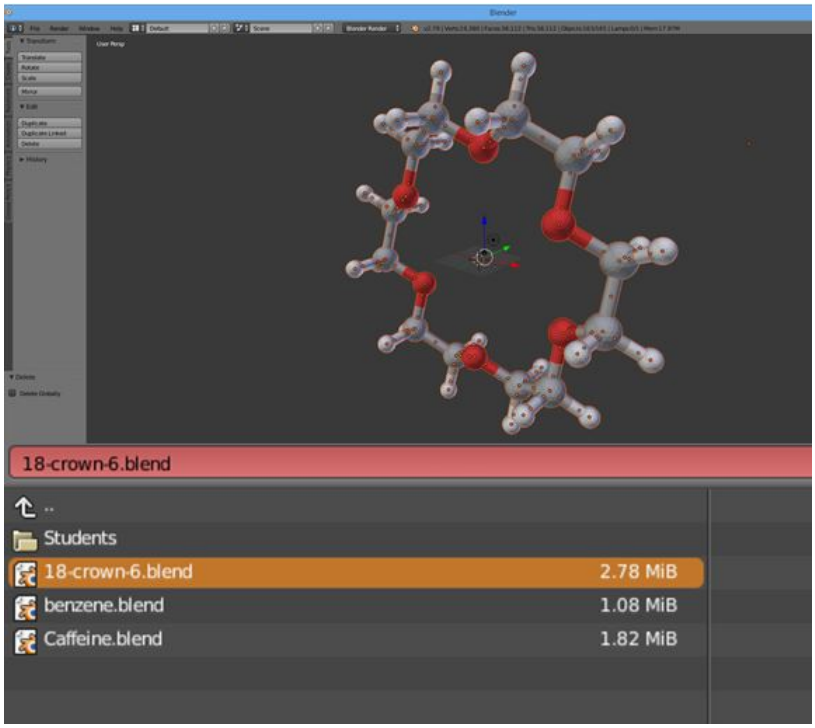

Figure 3: Blender Importing

Following from this, after functionality was slowly being added, I made sure to deploy the unity scene to ensure that what I was adding would work smoothly and as intended. Furthermore, I created several builds as time progressed on, each build having new features. These builds allowed me to test the current progression of the software on the HoloLens itself. This also allowed me to show the product to Dr Christian Klinke, the chemistry Professor I was working closely with, so I could exchange ideas and also obtain feedback in regards to the progression of the product.

6 Evaluation

Overall the development of the product went quite well; there were a few setbacks and areas of difficulty when developing the product. The product was designed to help ensure better visualisation of chemical molecules and structures, and through a showcase of testing, this was proved to be accomplished.

There were several aspects of the project that went well and some that didn't. The overall design and implementation of the product worked well in terms of it being easy to provide functionality to the overall product. Following guides

provided by Microsoft helped to ensure I could set up the correct Unity scene to work in and further develop my product using scripts.

Development was slow to start, finding all resources required alongside understanding how different packages worked and how the functionally could be supplied. Finding specific resources to help provide functionality proved to be hard but I managed to find and subsequently adapt them to work with my project. Understanding the code of scripts was a challenge I was easily able to overcome. Due to my previous coding knowledge, reading the scripts in C# was manageable; however, figuring out what was required within the script proved to be a challenge. Once the underlying basis of scripts were found and implemented onto a tester object. I was able to build and subsequently start the first round of testing, to ensure that I was heading in the right direction with my project and also ensure that I could make any changes necessary.

Due to my project life cycle being Agile, I ensured that I did regular meetings with Dr Christian Klinke, to discuss the next steps in development and to let him know how the project was developing. Using these meetings, I was able to ensure that I stuck to the overall project goal, and also was able to ensure that I recieved feedback on possible new features to be implemented alongside possible changes that could be made. These sessions were very informative and also allowed me to fully stick to my chosen methodology.

In order to test my project, I was required to produce several build versions of the project. Each version tested new features or changes that had been made prior to the previous build. This was a way to track my overall progress of the project, and also gave me the ability to load a previous version if something went wrong or didn't work as intended. This also allowed me to bring different versions to the meetings so I could obtain feedback on the direction of the project, and also allowed me to quickly implement any new changes without worrying about breaking the file.

During these build phases, I was able to test my product using the hardware it was intended to be used on. This gave me a proper feel of how my product would be used and what the functionality and interaction would be like to the user. This also allowed me to make fine tune tests to the functionality system, making it easier to do certain things over others. Furthermore, I was able to get an overall grasp of how my project was developing, watching it progress from a basic build to a complex one over time.

There were a few technical issues that I encountered when initially working on my project; one of the main issues was the fact of Windows 10 compatibility. Augmented Reality software only works on Windows 10 PC's, which meant all of my development had to be done on campus. This made working at home difficult as I could only find resources without implementing or testing them, however this proved to also be a strong point as it ensured I was able to

comfortably work on my project with limited distractions.

6.1 Description

The product is designed to help visualise chemical structures in a better way than previous pieces of software and over the actual chemical equations/formulas associated to each structure. The user will be able to interact with their own chemical structures alongside others, in an immersive and interactive way, allowing them to rotate, resize and move objects. Furthermore, the user can move through or around objects projected in front of them, to help provide a visual aid to visualise and envisage and understand different structures. This product is designed for chemistry students, or people interested in Augmented Reality/chemistry.

6.2 User Study

I was invited by Dr Christian Klinke, to bring my software and a Microsoft HoloLens to a chemistry lab session. In this lab, I introduced my software to the chemistry students present who would, in future, use the software to help further their education, when it comes to visualising chemical structures. The aim of the day was to not only present my software to students, but also ensure that they had time and resources necessary to explore the software by themselves. This helped to build their knowledge of the system, chemical structures and furthermore provide them with enough information to fill out a short survey at the end. This survey helped me to evaluate the overall success of the product I designed.

6.3 Hypothesis of Study

I proved that my overall product would work by using numerous tests, prototypes and sticking to the Agile methodology, which ensured I presented working software to obtain feedback for further development. Furthermore, the lab session I was invited too, to assist me in directly testing my product with chemistry students, who are familiar with similar software. As my product is also intended for use by these students, this gave me a good standing point to say that my product worked as planned, and subsequently will be used as I intended from development.

6.4 Participants

On Thursday 4th April, I took a prototype of my project to a chemistry lab session. This session held 14 participants who were all second year chemistry students, with the aim to test my project and compare it to other visualisation techniques, the main competitor being JMOL. They each took turns testing my project, using 5 pre-loaded molecules that they could pick from. They explored

the different functionality of moving, resizing and rotating of the molecules. Following this, they were asked to answer a short questionnaire of their experience which helped provide me with feedback to develop the project further, using knowledge from testers whom the project is intended.

JMOL is an open source piece of software that allows people to search and view different chemical structures. They can load up a wide range of structures and even create their own - they can then develop further electron density clouds around their molecules and view them from different angles and positions. My project is an Augmented Reality approach to JMOL, allowing for the same visualisation techniques alongside providing a more in-depth learning experience to chemistry students. However, as shown from the feedback obtained during this session, some of the students who tested the project preferred JMOL and chemical formula/equations to visualise molecules over an Augmented Reality approach.

6.5 Procedure

A lab was held for chemistry students, allowing them to view and use Augmented Reality technology to visualise chemical structures. After the participants had used the software, interacting with it and using all the features available to them, they were presented with a question sheet which gave them several questions regarding the overall software and all different aspects of the software. This included functionality, ease of use and if they preferred AR over other methods of visualisation. Using the results obtained, I was able to formulate statistics and obtain knowledge on how to further improve the software to meet user requirements.

6.6 Results

Over the course of the project showcase, students were asked to fill in a questionnaire with 10 specifically designed questions to help draw feedback and results from the entirety of their time using the product. Using this feedback I am able to develop my product to become a better education tool towards schools and other students. Furthermore, it has given me a wide range results to reflect on and also gives me a different view on how the product may be used by those whom it is designed for.

Out of the 9 participants that interacted with my product, all of them said that it had good functionality; this functionality was based on the different range of interaction techniques that could be used, alongside the menu relating to the overall molecules alongside their own personal menus.

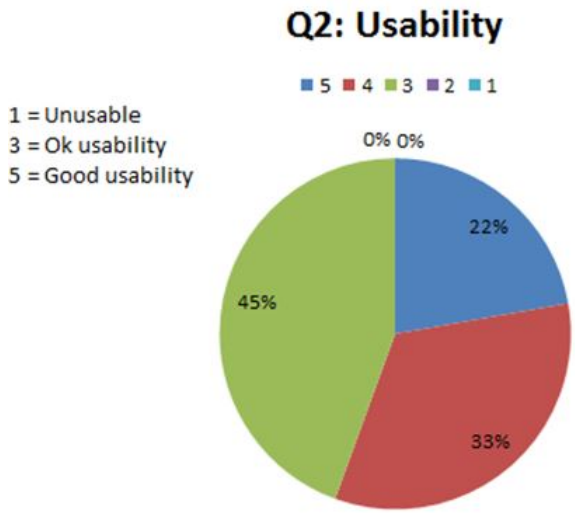

Figure 4: Usability

However despite the product having good functionality, the overall usability could have been improved. This was because of how the user interaction was surrounding molecules alongside other aspects. From the 9 responses, 4 said it was okay, 3 said it was good, 2 said it was very good. People found being able to view the molecule in 3D, a useful way to learn and develop their knowledge, with the program overall being somewhat easy to use and operate. However, some people found that overall sensitivity of the functionality behind the molecules when moving, rotating or resizing could be improved, as this was a semi-difficult thing for people to use and actually get used too. Furthermore, as the students had never used the HoloLens before, they found it difficult to grasp and understand the interaction techniques of 'clicking' or 'tapping' to select molecules. As you can see in Figure 4, the majority of people said the usability was 'OK'.

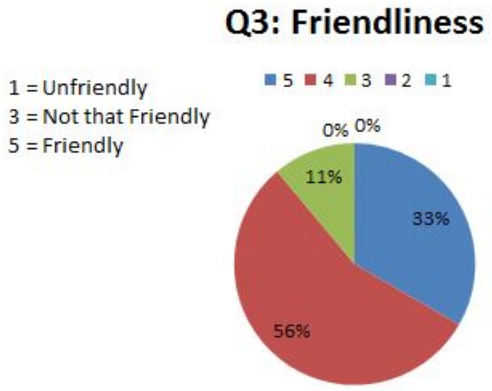

Figure 5: Friendliness

Due to the overall wide use of age ranges my product could be used for. Ensuring the program was user friendly was a key aspect to focus on. From the 9 participants, 3 said it had very good user friendliness, 5 said it was good and 1 person said it was ok in aspects of friendliness. Some people found the overall product fun and easy, alongside with it being uncomplicated in terms of interaction, with everything clear and self-explanatory. This was not the case for all participants; some struggled to get used to the functionality and needed further explaining on what specific parts do and how to use them. Others found the tracking 'somewhat random' when moving, resizing or rotating the molecule. This could be in part to how people used the software or how the hardware was used in operation. In Figure 5, you can see that the majority of people said that the product was friendly in terms of use, but still has some progress to be made.

Due to this product being hopefully used to better teach students chemical structures, I asked the 9 participants to mention if they see themselves using this product in the future, 1 said yes, 3 said perhaps, 2 said maybe and 3 said not really. Some people thought that, visualising molecules in this way with different aspects of functionality would be a massive help when it comes to actually understanding and visualising complex molecules. Some thought it was a good tool to help them get interested in chemistry more while others thought it was very helpful. Another view was that there were already different tools and software available for students to access. As shown in Figure 6, the ability of future applications by the students was very spread across a different mix of answers

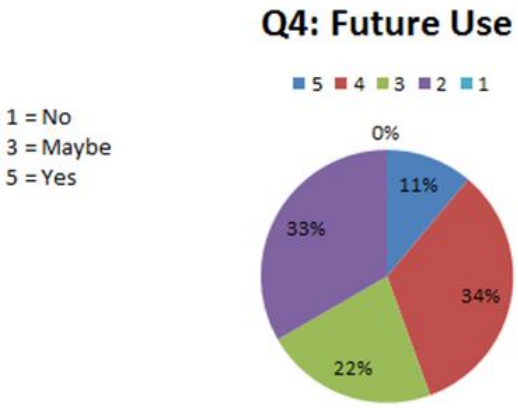

Figure 6: Future Use

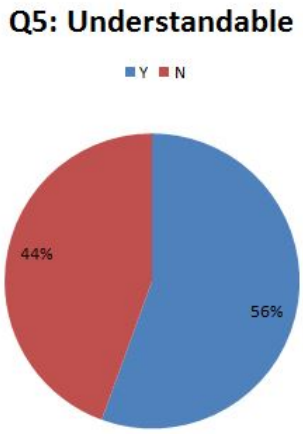

Figure 7: Understandable

The overall aim for this project was to be able to create a piece of software that could be used on the HoloLens, and could help people better understand molecules. When presenting this question to the participants, 5 people said that it was a good way to understand molecules, and 4 said it was not. This was eye opening as it allowed me to gain knowledge into the positives and negatives of my product. This also means that I can develop further on my product in the future to make it a better program to understand molecules. Being able to view

and interact with the molecules in a new way, was useful for people, alongside it being easier to view and experience each element of different structures. Furthermore, being able to see them up close and personal on a 3D environment with functionality and different interaction tools made it easier for students to grasp different molecules. Some students preferred alternative methods to view molecules due to the potential difficulties in setting it up for different molecules and the fact that programs like JMOL already exist. Figure 7 shows the split between users on how understandable the program was in terms of learning the molecules.

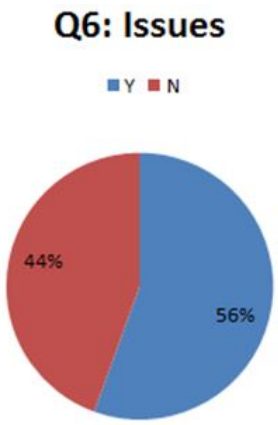

Figure 8: Issues

When it came to issues surrounding the software, there were always the same few issue that popped up. From all participants that took part, they all came across some sort of issue when interacting with molecules. Some students had issues when it came to resizing and rotating the molecules, due to the difficulty of accuracy required. Others had issues when it came to wearing the headset, this was due to adjustments or the fact that they have glasses which impeded how the headset rested. There were some software issues, when you tried to walk through or got too close to molecules, it would violently shake, making it making it uneasy to look at. Some people also had difficulties when it came to moving or actually clicking with the object, as it wasn't picked up or they themselves had difficulties using the hardware. Similar to Figure 7, Figure 8 the split between uses who had issues with the software and those who didn't, is very similar.

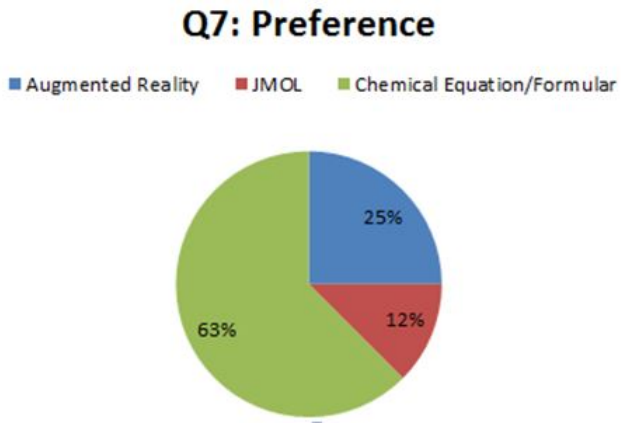

Figure 9: Preference

Due to AR being a different way to view 3D molecules compared to JMOL, some students made comparisons between the two. Some students preferred JMOL due to the wide range of functionality that it offers, alongside it being a piece of software that they have used often. This is because JMOL feels more stable to use and visualize molecules over the use of AR to do this task. JMOL is easier to use as it is less complex; however both can achieve the same results with time and practice when using the Augmented Reality software. Some people found Augmented Reality to be a more fun and enjoyable way of visualising molecules, which was a goal during this project. I feel like they found this way of interacting was a good way to learn and further enjoy chemistry more.

Due to the different ways to visualise molecules, AR being a new way to do so, I asked the question: Which do you prefer when visualising molecules? This question generated some interesting results; 2 preferred Augmented Reality, 1 preferred JMOL and 6 preferred the use of chemical equations and formula. This came as a somewhat interesting surprise to me as I thought Augmented Reality would be a new and intuitive way to view these molecules; however students preferred to view them on paper using their equations and formula. To some extent, this makes sense when revising and studying, as it gives them the ability to actually learn the molecules. This can be solved however by showing the chemical equations/formula on top of the different 3D being shown by students. This can help put a visual representation next to the equation/formula view. Figure 9 shows this comparison, and proves that the students preferred older methods of visualisation over new.

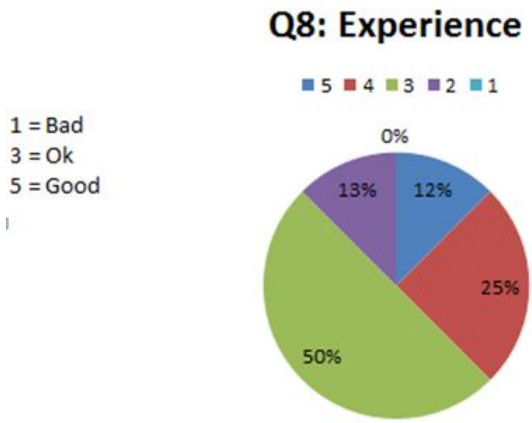

Figure 10: Experience

At the end of the study, participants were asked to rate their overall experience with using Augmented Reality, and were asked to rate it over other methods to do the same task. 1 person had a very good experience, 2 were good, 4 were okay and only 1 was unsure. These sets of results tied into peoples first time experiences with Augmented Reality or not. Those who had a good or satisfactory experience, were not new to AR and had in fact had used either similar software or used other AR applications that worked in a very different way. Those whose first time it was using some sort of Augmented Reality, had an overall good experience with the software and enjoyed what it had to offer, in terms of visualising molecules. Figure 10 puts this into a good retrospect and shows that, despite students impression on the Augmented Reality software and its implications, half agree that their overall experience with the program was ok.

7 Discussion

Thanks to the lab session where I presented my work, I was able to obtain lots of feedback regarding the project from students who might use it in the future. Following these results, it gave a wide range of feedback, some of which I was not expecting. The fact that, for the majority of the students, this was their first time using Augmented Reality; it changed my perception on how my project would be perceived by those who might end up using it. This meant that I had to formulate a way that would interest students into trying the AR experience and make it more enjoyable for them in terms of usage. Thanks to the results obtained, it allowed me to produce a set of demographics which can help me improve the product. These results tie in well to the improvement of the project, as it gives me something to work towards and change for my future works. Furthermore, it has given me a detailed insight into what is

fundamentally wrong with the software and also a way how to change and improve to overcome these issues. The range of students that took part, some being new to AR, also gave me a good look into what students may want when using the software.

7.1 Literature

Augmented Reality has several different uses around different sectors of industry, not only education. One of these uses is the ability to apply Augmented Reality technology to building construction, maintenance and renovation. Augmented Reality systems are being developed that use a head-worn display that overlays graphics on a person's naturally occurring sight. This then tracks user's objects that can provide the user with visual information that is tied to a physical environment [19].

Not only can Augmented Reality be used in construction, but it can also be used in military operations in urban terrain. One of the previous methods used were the application of head-mounted displays that combined maps and rolling compasses, but these follow with many limitations that obscure the user. One of the ways around this however is by applying mobile Augmented Reality systems to these issues [12]. The system consists of computer tracking, that detects a person's position and orientation which in-turn superimposes graphics and annotations that align with real objects in the users view [12]. This becomes a feasible system that can be implemented to sort any implications that the head-mounted displays currently have.

Augmented Reality is also a great tool that can be implemented in the world of tourism. Innovation in tourism not only represents an important source of economic growth, but also satisfies a demand for a unique tourism experience [21]. Augmented Reality in tourism can help provide a great source of revenue for attractions across the globe. Furthermore, it provides tourists with a unique experience that will be shared and captured to other locations. Augmented Reality can also be applied in museums, to further develop the overall visitor experience. Augmented Reality can be used to display detailed and interactive animation displays, alongside more more information about specific exhibits around the museum. The use of AR in this setting can help display digital signage and content without compromising the original architecture or landscape. Following this use, it is revealed that the availability of enjoyable and engaging Augmented Reality applications can further the tourism learning experience [8].

Mobile Augmented Reality technology can also be applied to tourism, further enhancing the overall experience. Software like Tuscany+, which is the first Augmented Reality application developed specifically for Tuscany, operates like a digital tourist guide [11]. This brings more of an immersive tourist experience to the city alongside making tourists enjoy and take in the sights more than they usually would. This method of AR applications have benefits for tourists

as it enhances their overall experience, offers a wide range of interactivity and entertainment. AR applications used in this way, can allow users to explore the world by adding new layers to their reality, which can in turn add more of a dynamic experience [11].

Outside of the tourist sector, Augmented Reality can be applied to shopping scenarios. Augmented Reality assisted shopping applications running on terminals, may be able to find virtual objects to further display in local environments. A simple front end display can be implemented to help shoppers find a wide variety of shopping choices, typically from multiple vendors [5]. This can further deepen an uninteresting shopping experience and provide the potential to make shopping more of an enjoyable and unique occasion.

Augmented Reality can help overcome limitations provided by e-commerce, because it cannot provide enough direct information about products. AR can be used to enhance e-commerce systems, where tools have been developed that can be used on hand-held devices to help achieve this. These devices can help place a marker on specific areas that can then be used as interaction points for a virtual environment within the system [13].

Gaming is a big area that Augmented Reality has the potential to cover; not only is it a growing industry but it also holds many possibilities for development. Games using marker technology can often include a flat board which becomes a 3D setting when viewed with a mobile device or webcam [23]. A popular example of this is the application of Pokemon GO. Gaming using Augmented Reality can also allow educators to utilize a new, highly visual form of learning. SimSnails is a piece of software that utilizes a set of printed symbols, to help create an immersive 3D world [23].

8 Conclusion

8.1 Outcomes

I felt that during the entirety of the project, I came across some issues I didn't expect but also managed to avoid those that I had recognised beforehand. Using this, I think the project went well and I was able to achieve both my own goals and that of Dr Christian Klinke. The project turned out as I expected and how I planned for it to be developed. There were some additions in functionality and features as the development process progressed, and this was thanks to the constant feedback meetings along with the questionnaire I provided.

The lab session where I showed and tested the software with chemistry students went well and I was able to obtain enough information to have a good, structured plan on where to take my project further. Having a fresh insight into the possible functionality and features that could be added into the project, ob-

tained from students, allowed me to open up to all different areas of chemical structures. Each student came up with something new in regards to a feature, some of which I would have never thought to implement.

8.2 Limitations

When designing my product, I had to take into account a list of factors that could hinder my progress in a number of ways. There were several risks that I had to be wary of as the severity they held would have stopped me from progressing with my project until they were solved. Alongside this, I also encountered new issues that slowed my progress.

Software updates on the software I was using, didn't post that much of an overall risk when it came to progression with my project. The HoloLens environment on Unity would only work with a set of patches, and were compatible with subsequent patches after. This meant that as long as I stuck to one patch or a set of patches, I could further progress and develop the project. Updates to JMOL were very limited and did not affect the overall progress of my project due to only needing JMOL for the exporting of structures, this followed closely with Blender. Software updates for these two pieces of software were minimal and due to how much they were used, didn't impact progress. Unity and the HoloLens it's self were my two biggest concerns for software updates, thankfully Unity didn't experience any updates during the development process, and this meant that the software stayed the same build throughout. Furthermore, there were no updates with the HoloLens that hindered development.

During development, one thing that I had to be careful was with hardware or software failures, these being related to Unity or the HoloLens. There were minor issues when it came to Unity that didn't fully equate to a software failure, but was in regards to my own machine not having the software to subsequently run an Augmented Reality development environment. I was able to overcome this issue by ensuring that I used a machine that had the correct software installed, this allowed me to progress with development without hitting any further issues. Another small issue that occurred was in regards to the HoloLens. At a few stages throughout the project, the HoloLens refused to be accessed/read from the computer when plugging in the device, furthermore, running a test build of my current project on the device proved to be troublesome at first, but over time as I fully understood the steps and procedure required, was overcome. Visual studio also had a minor issue with software, where the built-in emulator wouldn't run my project, requiring me to use a HoloLens for testing each build I produced.

One of the main issues that I experienced, that subsequently caused big issues in testing my builds was the fact that my project became too computationally expensive to run first try. The reason for this was because of how the objects were formulated and imported into a Unity scene, having each individual bond

and molecule display as a separate object and then grouped together. This however, was the only way to go about importing the structures into Unity in the format I desired. This however posed a small issue as the project became too large to run. A bypass around this was to subsequently hide and un-hide structures as required using a user interface. Furthermore, the lag on running the project could be overcome if the project was closed and further re-opened. This seemed to sort all lag issues for the rest of the session.

8.3 Future Work

Thanks to the initial lab session that I was able to attend, I gathered lots of feedback about not only the current state of the project, but I also acquired feedback on possible new features or additions that could be done, to further develop my product as a tool of learning. This particular set of feedback results, I found useful as it allowed me to not only further develop my product and add small suggested features in, but also gave me a good starting point to further develop the product.

One of the popular responses regarding future work that the students would like to see is the ability to create new molecules from scratch and also have the ability to edit new and existing molecules. This would add a lot of diversity to my project as it gives students many different viewpoints to work with, from creating their own, individual and unique molecules, to editing others and seeing how it impacts the structure of the molecule.

I feel that this is a good addition to my project; it adds a deeper, unique way of learning chemistry as it gives students the ability to explore molecules more in-depth and also allows them to learn what bonds go together. Furthermore, it also gives the students some intensive to use what they have learnt, and put it into a practical setting - allowing them to create their own molecules helps to accomplish this.

Another addition that was suggested was a way to properly visualise different chemical reactions, alongside their electron density clouds. Currently, the project doesn't have any means of doing this, however I do feel like it is a good feature to work towards. Electron density clouds are an important feature of chemical structures, as it allows students to properly visualise the structure in greater depth and detail. This is because each molecule provides a number that tells us the relative probability of finding electrons at particular points in space [1].

I feel like this is another great addition that could be implemented. This is because it allows students to study a molecule in greater depth and also sees the electron density surrounding the molecule. Following this, it would also possibly improve the experience of students, as JMOL already does this. Having the ability to view it in an Augmented Reality format would mean that stu-

dents can have a better understanding of it. Furthermore, the ability to view different chemical reactions taking place between two molecules could further the enjoyment and overall experience of the software. This would be especially good when it came to teaching in schools, tailored towards people just starting out learning chemistry.

A data file, or option, was suggested by a number of students. Inside this option, it would contain advanced chemical property data in relation to specific structures. This would be the inclusion of the molar mass, density, melting point and other properties that the student may find interesting. I personally think that this would be a good addition to the program, not only because in its current state, you only grasp a visualisation of molecules and don't learn much more.

Because I felt that this was a minor but also important detail that could be added into the project, it is one of the future features suggested to me that I actually added, after the initial design and feedback session. I felt that because it holds a strong value in giving students a better ability to learn about molecules, it was an important aspect that should be included inside the software. Furthermore I also feel like it helps provide a better knowledge base to students who are interested in bigger aspects of specific molecules.

The last feature that was suggested to me from the feedback I received was the inclusion of specific atomic selections in relation to the molecules. This would provide the ability to keep track of specific atoms inside a larger molecule structure, effectively allowing the user to see how that atom connects and binds to others.

Due to the difficulty in adding this, and my level of chemistry knowledge, I feel that this feature is something that isn't as important at the projects current stage of development, mainly because the users of the program range from new persons being introduced into chemistry to students at university level chemistry, where I feel that this feature would benefit most.

Overall the feedback I was able to obtain from the practical lab session was very informative and eye opening, not only as it provided new branches that allowed me to further develop my project, but also included things that I might have not thought would ever be considered. It also allowed me to further deepen my understanding of what is achievable within the HoloLens and the educational field of chemistry, as I have had to further research and see what is achievable in regards to my skill set.

8.4 Concluding Remarks

Overall I felt that my project was a success, it had ups and downs but these were factors that I considered when I initially started creating the software for

the HoloLens. I am happy with the development cycle and process that I chose to use throughout the project and feel that I chose the correct methodology, to not only get the most out of the product, but also develop a better interaction with my software and the Chemistry department. The use of regular feedback sessions helped me to develop a tool that not only met my own goals, but also the goals set by Dr Christian Klinke, who helped me invision this project.

Despite the overall success the project had during its feedback and prototype sessions, there is a number of aspects that I would change about my project and also develop differently. One of these factors that I would change would be how I initially approached the design and development stages. I would allow more time to further reflect on the feedback obtained from Dr Christian Klinke, and hope to encompass his visions into this project more. However, due to not only time constraints, but also my lack of ability to use the software, we mutually agreed that some features would be left out, due to different scales of complexity. Although these features didn't make it into the finial build of the project, both I and Dr Christian Klinke, are happy with how the project finalised. We are also happy with how students perceived the software presented to them, the feedback of which they provided, being very detailed and informative.

With the recent development changes that Microsoft are introducing Augmented Reality, I would be interested in building further on top of my project to suit the functionality of the HoloLens 2. I feel that with my current standing with the project as an essential backbone, developing and essentially upgrading the software to fit the HoloLens 2, I could achieve a lot more in the same given time frame. Furthermore, the ability to make use of the new features that the HoloLens 2 presents, would enable the software to develop into a platform that can be used to teach a wide range of students, from not only one classroom, but broadcast to several across the world. Allowing everyone to use and interact with the software simultaneously would not only further the learning environment for students, but also have the potential to deepen their understanding of specific subjects including chemistry.

References

[1] Density clouds relating to chemical structures.

[2] An open-source browser-based html5 viewer and stand-alone java viewer for chemical structures in 3d.

[3] Spatial software regarding the hololens.

[4] What is microsoft hololens? - definition from whatis.com.

[5] Juha Arrasvuori. Augmented reality assisted shopping, March 20 2008. US Patent App. 11/523,162.

[6] Rick Delgado. 8 real-world uses for microsoft hololens, Feb 2015.

[7] Blender Foundation. Home of the blender project - free and open 3d creation software.

[8] Timothy Jung, M Claudia tom Dieck, Hyunae Lee, and Namho Chung. Effects of virtual reality and augmented reality on visitor experiences in museum. In *Information and communication technologies in tourism 2016*, pages 621–635. Springer, 2016.

[9] Carolien Kamphuis, Esther Barsom, Marlies Schijven, and Noor Christoph. Augmented reality in medical education? *Perspectives on Medical Education*, 3(4):300–311, Sep 2014.

[10] Mehmet Kesim and Yasin Ozarslan. Augmented reality in education: Current technologies and the potential for education. *Procedia - Social and Behavioral Sciences*, 47:297 – 302, 2012. Cyprus International Conference on Educational Research (CY-ICER-2012)North Cyprus, US08-10 February, 2012.

[11] Chris D Kounavis, Anna E Kasimati, and Efpraxia D Zamani. Enhancing the tourism experience through mobile augmented reality: Challenges and prospects. *International Journal of Engineering Business Management*, 4:10, 2012.

[12] Mark A Livingston, Lawrence J Rosenblum, Simon J Julier, Dennis Brown, Yohan Baillot, II Swan, Joseph L Gabbard, Deborah Hix, et al. An augmented reality system for military operations in urban terrain. Technical report, NAVAL RESEARCH LAB WASHINGTON DC ADVANCED INFORMATION TECHNOLOGY BRANCH, 2002.

[13] Yuzhu Lu and Shana Smith. Augmented reality e-commerce assistant system: Trying while shopping. In Julie A. Jacko, editor, *Human-Computer Interaction. Interaction Platforms and Techniques*, pages 643–652, Berlin, Heidelberg, 2007. Springer Berlin Heidelberg.

[14] Patrick Maier and Gudrun Klinker. Augmented chemical reactions: 3d interaction methods for chemistry. *International Journal of Online and Biomedical Engineering (iJOE)*, 9(S8):80–82, 2013.

[15] Danakorn Nincarean, Mohamad Bilal Alia, Noor Dayana Abdul Halim, and Mohd Hishamuddin Abdul Rahman. Mobile augmented reality: The potential for education. *Procedia - Social and Behavioral Sciences*, 103:657 – 664, 2013. 13th International Educational Technology Conference.

[16] Manuela Núñez, Ricardo Quirós, Inma Núñez, Juan B Carda, Emilio Camahort, and JL Mauri. Collaborative augmented reality for inorganic chemistry education. In *WSEAS International Conference. Proceedings. Mathematics and Computers in Science and Engineering*, volume 5, pages 271–277. WSEAS, 2008.

[17] Linchpin SEO Team. A beginners guide to the agile method and scrums, May 2019.

[18] Unity Technologies. Unity.

[19] Anthony Webster, Steven Feiner, Blair MacIntyre, William Massie, and Theodore Krueger. Augmented reality in architectural construction, inspection and renovation. In *Proc. ASCE Third Congress on Computing in Civil Engineering*, volume 1, page 996, 1996.

[20] Rabia M. Yilmaz. Educational magic toys developed with augmented reality technology for early childhood education. *Computers in Human Behavior*, 54:240 – 248, 2016.

[21] Zornitza Yovcheva, Dimitrios Buhalis, and Christos Gatzidis. Engineering augmented tourism experiences. In Lorenzo Cantoni and Zheng (Phil) Xiang, editors, *Information and Communication Technologies in Tourism 2013*, pages 24–35, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

[22] Steve Chi-Yin Yuen, Gallayanee Yaoyuneyong, and Erik Johnson. Augmented reality: An overview and five directions for ar in education.

[23] Steve Chi-Yin Yuen, Gallayanee Yaoyuneyong, and Erik Johnson. Augmented reality: An overview and five directions for ar in education. *Journal of Educational Technology Development and Exchange (JETDE)*, 4(1):11, 2011.