TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

FARIDA YEASMIN
METODI NETZEV
TAMILSELVI JAYAVELU

INMOOV AS A SOCIAL ROBOTICS TEACHING TOOL THROUGH AN AR APPLICATION

TIE-41506 – User Experience in Robotics Group Report

Course staff: Dr. Aino Ahtinen, Dr. Kirsikka Kaipainen, Aparajita Chowdhury
Deadline: 13th of May 2019

CONTENTS

LIST OF FIGURES

1. INTRODUCTION

The topic of this project is the investigation of an AR robot implementation for its suitability to teach social robot assembly to middle-schoolers. Because robots are defined as" machine capable of carrying out a complex series of movements, esp. one which is programmable" (Oxford University Press, 2019), virtual representations of robots are not excluded from relevance to the topic. In fact, using virtual representations of robots in industry is common. Digital environments such as Gazebo offer the possibility to simulate robots before implementing the movements in real life. (Open Source Robotics Foundation, 2019) By contrast, the current alpha stage InMoov AR robot implementation is geared towards introducing the concept rather than accurate simulation. The customer company is interested in both "Building a Robot" and in "Robots and Programming". Because, robots require vast expertise ranging from design, manufacturing, programming and user experience, the focus of this work is design and manufacturing in the context of user experience.

Target context is design and manufacturing in the context of user experience because robots require vast expertise ranging from design, manufacturing, electronics, programming and user experience. The knowledge required to do a full investigation is currently not available and the topic would become too broad as electronics change as well. With robotics becoming ubiquitous, universities and industries have started focusing on developing the systems that underpin robots holistically. (Aalto University, 2019), (Tampere Universities, 2019) As such, introducing the topic from an earlier age may give an advantage in work life by understanding the assemblies, sub-systems and the goals they need to achieve through example.

Target user groups include university students, high schools and other secondary educational institutions. The first part of the audience had been defined in the initial project brief and the second part is defined in the Futurice studying materials. Each audience is mentioned without reference to the other, which may create conflict as both groups are distinctive. In the end, the main user study group was first year university students. Despite some of them already being experienced they are representative of the technicians likely to take care of a robot fleet.

2. LITERATURE REVIEWS

2.1 Farida Yeasmin

We reviewed the article (Green et el., 2008) to get insight about human-robot collaboration. From this paper, we learned several characteristics of human-robot collaborations, and tools used in AR for this collaboration. For example, we have learned that meaningful interaction and exchange of dialogue is important for human-robot collaboration. Based on this requirement, we designed an audio feedback system in our application to improve interaction between the AR robot and students.

Again, we reviewed the paper (Kesim et el.,2012) and (Kaufmann 2003) to learn about the basics of augmented reality, benefits of using augmented reality compared to the virtual reality as a learning tool,and use cases of augmented reality. Kaufmann et al. uses AR as a learning tool for Mathematics and geometry by superimposing virtual model over reality. They conclude AR approach is better than earlier pen and paper-based learning method. Using the similar concept, we use AR as a learning tool to reduce physical teaching workload by minimizing tools required and increasing interactiveness.

From the paper (Roesner et al., 2014), we found out that we need to concern about security issues for our application so that users of our application feel secure while using the application. AR technologies always require many inputs in real time. For example, in our application, we used audio feedback to response to the users. In our application, when the AR robot gives feedback to the user, if at that time some other application (attacker) gives a false feedback, then the user will have no choice other than believing on that false feedback. So, privacy is required in our application to prevent such scenarios.

Finally, we reviewed the paper (Cooperstock 2001) to learn about how a presentation can be done more effectively without concerning about the modern technologies (e.g.swap slides, adjust classroom lights etc.)of presenting a lecture in the classroom. Cooperstock 2001, evaluated that automated system of presentation can improve learning system. Following this concept, we use AR to improve the effectiveness of creating course materials and uploading data in the student devices.

Human-Robot Collaboration: A Literature Review and Augmented Reality Approach in Design

To reduce human working load, many companies are interested in human-robot interaction (HRI2006 2006). This paper analyzes on human-robot interaction focusing on communication, collaboration, and enhancing human-robot collaboration with the help of augmented reality (AR) technology through spatial dialogue. For human-robot collaboration, the paper first reviews how human to human collaboration happens in various situations such as non-verbal, verbal, and with real objects. The knowledge can be used for better understanding of human-robot collaboration.

The paper presented several considerations about human-robot collaborations. These are:

- The robot needs to learn quickly
- The robot needs to understand different aspects of human psychological needs such as, beliefs, goals, intentions, and emotions.
- With meaningful interaction and exchange of dialogue between human and robot, effective human-robot collaborations can be achieved.

Special qualities of AR make it an idle platform for human-robot collaboration. AR supports face-to-face collaboration which helps users to interact freely using AR spatial cues. Different types of AR collaboration applications are presented in this paper such as Magicbook and shared space collaboration through mobile AR. The shared space application allows user to interact freely in the space with spatial cues, and transition from the physical world to the augmented or virtual world is provided by the Magicbook(Billinghurst, Kato et al. 2001). Mobile AR also help users to collaborate with robot by superimposing the virtual world over the real world. Additionally, as it works in outdoor settings, mobile AR requires proper data management and correct registrations of the outdoor augmented objects. The paper reviewed that human-robot collaboration will be more effective if robot can communicate with human with different gestures used by humans. Features like audio channel, environmental channel, and visual channel need to be considered for effective collaborations. Audio channel handle automated speech recognition which is require for human-robot collaboration. Again, environmental channel refers to understanding of human gestures. With AR all these features can be handled while collaborating with robot.

Finally, AR robot can help both human and robot to communicate and collaborate with each other through various modal. AR technology also allows multimodal technology through which human can understand robot activities and the intention of the robot. AR technology brings better understanding of human-robot collaboration design.

Augmented reality in education: current technologies and the potential for education

The paper (Kesim et el.,2012) presents augmented reality (AR) as a medium for education, its uniqueness and affordability in the learning process. The paper describes AR technology followed by use cases in education. AR offers a way to manipulate the world without replacing the real world. It composes computer generated virtual scene on top of real world. This augmentation can happen on top of real place, thing and spaces. According to Azuma, an augmented reality has three characteristics. First, it combines real world with the virtual world, secondly it provides real time interactions, and finally it provides real time experience rather than the static view. The most common devices used for AR are displays, computers and tracking devices. For example, a head mounted display on top eyes can superimpose computer generated images on top of real world. Another example is a handheld display with video-see-through capability allows viewing superimposed virtual object on top of reality. A third example could be a pinch-gloves which can be used to grab or touch a virtual object.

A person world view is three dimensional, however most of our educational content is two dimensional. Creating two-dimensional content is easy and affordable. However, this lacks the inter-activeness and effectiveness in learning process. One alternative to bring realism is via virtual reality in which students immerse into the virtual world. However, this approach diverges from the reality. The paper positions augmented reality offers several benefits compared to other media in education. First, AR offers seamless interaction between virtual and real world. Secondly, the learners interact with the 3D world in a tangible manner and finally, AR offers smooth transition between virtual and real world. These enables a learner to work on a real-world task in an engaging manner. Take for example, hard copy books which are still popular compared to the soft books. However, hard copy books limit the information in print. By using augmented reality addition information such as images, videos and animation can be superimposed on top of hard book. This reduces the barrier to interact with technology and allows learners to aid in the learning process. Additionally, AR can be used for collaborative task such enhanced face-to-face and remote collaboration work in the learning process. Tools such as AR supported displays and pinch gloves can assist in remote learning process. The paper concludes that AR has potential as a learning tool. This requires further research. On the down side, the paper fails to measure the effectiveness of AR in education. The paper could be improved by providing real world learning scenario analysis and comparison with other media.

Collaborative Augmented Reality in Education

The article (Kaufmann 2003) reviewed use of Augmented reality (AR) in educational purposes and considerations of application design for this purpose. Though Virtual Reality (VR) is using for learning experiences, the potential of VR learning is challenging for the real world as VR cannot be use in real world scenario. However, AR technology is able to see the real world without replacing it. There have not any existing technology available that can fulfill all the requirements for a proper learning environment. To design applications for education system, it is necessary to have correlations between previous and new learning system so that student can relate AR/VR technology with previous (pen and paper) learning system. For example, flexible learning should be provided while using AR technologies in education system. This paper presents a three-dimensional tool for mathematics and geometric education called Construct3D. The purpose of the tool is to visualize three-dimensional objects with the help of AR technology. This is an advantage for student to see the three-dimensional objects in real-world scenario as previously students need to calculate and draw the dimensions, which is become easier now. The Construct3D model allows multiple people to share a virtual space. The construct3D model feature provide improvement in learning process such as, a speaker-independent speech interface which controls all interface via speech commands which improve the speed and efficiency of working.

The paper showed real life example of users using the construct3D model which helps to evaluate the model with real world scenario. Evaluation aspects such as technical, relationship of user with virtual environment, users liking or disliking in the virtual environment, and how effective teaching can be provided has been included to measure the model. However, the paper did not provide the fina result of the model as they are working on the result with real students and teachers.

In future, the author plans to validate the tool against real world data. This will improve the model as a learning tool of mathematics and geometry.

Security and Privacy for Augmented Reality Systems

Augmented reality is a challenging system in terms of other system. Though the technologies which supports augmented reality will bring many benefits to the users still AR technologies have concerned with security and privacy issues. In this paper, the author (Roesner et al., 2014) analyzed privacy and security issues of using technologies with augmented reality and provided challenges in security and privacy of different types of AR applications (single/multiple application)

As, AR technologies require sensing input all the time, the technology requires more security and privacy compare to other technologies. For example, the possible challenges in a single application can be: an unknown application can convert a correct road speed limit to an incorrect speed limit which can make users to trust on that false speed limit output. These type of unknown attack on an application is more serious in AR applications than they are in today's other technologies. The challenge in a multiple application is, it is important to know which content is generated by which application as in multiple application, there are multiple things going on at the same time. For example, inside a car, an AR application is used to listen music while viewing a road map at the same time. To provide both features (viewing map and listen to music) a secure output, AR applications need to be more concerned with privacy and security to fulfill users intended output.

The author provided different scenarios about privacy and security related to AR technologies. However, this paper doesn't provided how users will react with these types of security or does the users really think about the privacy at all while they will use AR technologies.

The Classroom of the Future: Enhancing Education through Augmented Reality

The complexity of modern presentation technology in the classroom and different approaches to overcome the complexity with the help of augmented reality (AR) have been suggested in the literature. Modern technologies Improved the learning systems which is undeniable however, the effectiveness is yet need to improve. Cooperstock (2001) suggested an automated control presentation system for the classroom environment. The author focused on the improvement of the presentation system with several automated sensors and computer processing system. For example, the author suggested a simply log in to the classroom computer which will automatically adjust the lights, screens and other sensors for a presentable lecture environment so that the teacher can concentrate on the lecture rather than focusing on adjusting the classroom environment.

Instead of suggesting an automated system for the classroom lectures, the author showed the importance of manual control over the technologies (e.g. lights, speaker volume). Interviewees of the automated controlled classroom project wanted to manually control some specific technologies as they felt these technologies should have both automated and manual options. To solve this problem, the author made changes in some part of the control systems. Cooperstock (2001) suggested that, augmented reality approach in the classroom have more potential in remote participation option e.g. videoconferencing.

Though, the author suggested several approaches of making the classroom automated, the paper fails to show the acceptancy of the automated control system in the classroom with the help of augmented reality. Again, the paper also did not research on user notion of using manual modern technologies. Designing such automated system might be challenging and users might not like the system if they are not aware of using the system.

2.2 Metodi Netzev

2.2.1 Introduction

The literature selected is centred around AR for training purposes. The reason being, “AR Robot – Learning Robotics Using Augmented Reality” project requirements and because the underpinning technologies are aimed towards this goal. The demo provided from Futurice includes an open-source robot, located in an augmented reality environment. Interaction with the 3D model is done through a GUI, visual and an accelerometer-based modality. Through the full combination of both control types, the robot can be exploded demonstrating viscera and animations of its gesticulation. This technology is designed to support the learning process of assembling social robots for students by making the process comprehensive through easy and natural examination of the model. It is a guide to diminish the ambiguities related to assembly instructions associated with large and varied assemblies. (Saaski, et al., 2008)

2.2.2 Augmented Reality: Designing Immersive Experiences that Maximise Consumer Engagement (Scholz & Smith, 2016)

The main purpose of teaching robot assembly using AR is increased engagement and ease of understanding the structure order. Despite not dealing with social robotics directly, the paper “CAD model based virtual assembly simulation, planning and training” shares a similar goal of improving the success of assembling. Issues from the likes of part identification are hence identified as common to both projects. (Leu, et al., 2013) Despite AR systems being used for more traditional assembly line work, the main goal is to increase task performance. As such an article by Gomes de Sa and Zachmann (1999) is suggested, making use of storyboards which is likely to improve memory of commands used in AR/VR assembly manipulation. Monitoring and tracking these features can then be important for a supervisor. In the process, guiding how the user engagement is managed. As the customer project is selling the knowledge of working with social robots to students, marketing is directly relevant to enhancing viewer or user engagement. The goal is not the AR experience itself but another service or product. The similarity between teaching and marketing is the inclusion of a narrative. This technique is used to express brand or project meaning through seeing oneself in relation to the products they sell or provide context for learning skills.

Selling knowledge can be enhanced through the proposed ENTANGLE framework. The literature reviews previous AR campaigns to summarise their techniques. They are presented in a practically applicable checklist format, related to the AR Robot project scope. A more detailed description on how they can be implemented into the InMoov AR instance is described through sub-points.

- Experiences – AR experiences should be focused on achieving a unique, stimulating and valuable consumer response rather than on ensuring the use of the newest technologies. Using new and untested technologies binds resources to a project with an unknown end AR product. In the case the end result is unsatisfactory, these are sunk costs.
    - In a student AR project with a short duration, it translates to working with technologies we are experienced with such as paper or Powerpoint prototypes.
- Nourishing engagement – Usage is determined as more valuable than the type of implementation. The goal is giving customers a reason to return to the experience. Implementing a scoreboard or being able to leave a mark in the augmented or virtual model is seen as more engaging than simply using a high definition AR model.
    - Experiences based on InMoov should be easy to work with, without having to read lots of paperwork, for example using a physical version of its hand to draw attention to and compare similarities.
- Target audiences – In essence, campaigns or study enhancements taking into account the interactive social dynamics of the students. Giving a reason the materials to be talked over. Provocative events are one such recommended technique.
    - Using references to pop culture, for example if more actions for InMoov to do are introduced, they can include the “floss” dance from “Fortnite”. Care should be taken, however, since online culture moves at a much faster pace, rendering fads obsolete in a week.
- Aligning AR with the marketing program – Using a multi-modal approach to selling or teaching. An example is releasing material on how a “Walking Dead” AR commercial on a bus stop achieved 400,000 facebook shares. Similarly, the multiple modalities the robot can be used in can make an integral and inseparable part of the teaching material.
    - Students can be given multiple methods to solving problems, through AR, physically or on a computer. Switching between these is currently absolutely necessary to complete a built instance of the robot at the current time.
- Neutralising threats – Considering threats to marketing campaigns or teaching materials. Mostly centred around reducing vandalism. Specifically, ensuring the AR environment has the required space to operate efficiently as in the case of a crowded lego store where the contents of boxes are projected above them.
    - The 3D model AR experience should be shared so students can perform tasks inside classrooms other. The current experience requires a tabled, camera and display, however, which introduces additional technological complexity of having screen delay.

- Goals – The incorporation of features should support the marketing goals of the campaign. Creating social features should be used only when the goal is engaging a brand community.
    - Timing is the simplest that can be introduced to InMoov, this does not seem enough to convey the usefulness of the robot. More complex challenges could include designing actions to
- Leveraging brand meanings – Alignment of the appeal of the product with the appeal of the marketing campaign and delivering an eye-opening meaning regarding the product.
    - Freedom and opensource is the main argument for InMoov. As such, the users can be encouraged to hack their robot to their heart's content. For example, designing fingertips shaped like bones to create a true abomination. This can fulfil the student need for creativity.
- Enticing customers – Providing reasons for consumers to activate the AR layers such as reducing the physical demo piece count inside a store. The amount of clutter would be reduced, making shopping an easier experience.
    - Comparing Pepper and InMoov, the major selling point of InMoov is the cheap price. For example, assembly and disassembly of Pepper by students who can break the robot is not recommended.

Placing the AR Robot project in the context of marketing reveals cross-applicability of techniques to engage students. With small variations in interpretation, they can be used to guide the development of teaching materials. For example, "leveraging brand meanings" can lead them to discover new robot features that can be directly relevant future their future goals. To better align marketing to teaching, the ENTANGLE framework should be presented in the philosophical context of teaching. The end goal of education and the end goal of the students, giving them an aim, which this paper is not geared to provide. Resulting background work in the context of AR for education is therefore a necessary investment.

2.2.3 Current Status, Opportunities and Challenges of Augmented Reality in Education (Wu, Lee, Chang, & Liang, 2013)

2.2.3.1 Summary

The background requirements of education are partially discussed in the context of Augmented Reality. (Hsin-Kai, Silvia Wen-Yu, Hsin-Yi, & Liang, 2013) Teaching new material requires combining instructional approaches to foster notions of the taught material for students. AR offers additional opportunities to understand the material through an interaction, not possible with traditional education technology. In particular, the ability to visualise content in 3D and in the situational context of the classroom or in whatever context is needed. At the same time, use of new technology needs to be implemented only in situations where it is safe and beneficial. Despite this being a concern in any AR deployment, losing track of where the environment starts and ends can cause physical harm in schools. Another issue is the breath of information to be learned, where each new technology requires knowledge of multiple control gestures.

The main peer review outcome can be summarised as a checklist to be implemented on the side of the learners and teachers. Additionally, the 3 curricular targets for the engagement of students, roles, locations and tasks can be aligned to curricular characteristics. Thus, making the implementation of the technology into teaching material straightforward. The relationships are described as:

Instructional Approaches	**Affordances**	**Notions**
Emphasizing “Roles”	Learner sense of presence, immediacy, and immersion	Engagement
Emphasizing “Locations”	Ubiquitous, collaborative and situated learning	Contextualisation
	Bridging formal and informal learning	
Emphasizing “Tasks”	Learning content in 3D perspectives	Authenticity
	Visualizing the invisible	

2.2.3.2 Commentary

The project customer problem specifications of “How do the students explore the AR robot?” and “Usability and usefulness of the AR robot in learning situations.” can hence be answered. Emphasis of locations and tasks is most relevant towards fulfilling the usefulness of the AR Robot project. Where with the current state of the app, robot product can be visualised in the assembly space. Students are hence able to understand the context of their assembly locations and their suitability for the task. Formal and informal learning would be bridged if it the app was able to scale to the dimensions of the room automatically within a set tolerance. As of currently, contextualisation is available in the case an instructor can scale the model to the right dimensions. Once the scale is set, the students can explore the model themselves, without the need for an instructor. Thus, currently it uses formal and informal teaching techniques.

Task based learning can be supported in the near future through assignment of goals based around assembly. The result is a gamified real-world task. Although it is difficult to integrate the entire detail of assembling the robot, learning the layout of that robot will speed up actual performance. The only thing left is acquiring a physical feel for how the task is performed i.e. how much force to apply when press or screwing together parts.

In terms of making this useful for an InMoov AR implementation, space usage is the biggest concern due to the robot height being 1.52m. (Grattard & Matt, 2016) With an arm-span of a similar width, a viewing zone is required. Similar to an operating theatre, an operating bed like arrangement is possible. With adjustability, the furniture can be used for writing and AR teaching. The robot is expected to take classroom space which may be an issue in locations with facilities geared towards traditional teaching instead of group work. Additionally, tables for collaborative work can be wider and taller than

2.2.4 Augmented Reality for Collaborative Product Design and Development (Shen, Ong, & Nee, 2010)

Inevitably, the point of education and acquaintance with the task and robot is the capability to contribute to a chosen professional field. Product design and development are

the skills in which the project customer is interested in through the field of robotics "The AR app helps the student to understand what they are building". Physical product design programs have previously attempted to implement such AR features and the paper illustrates efforts made in 2009. Despite being increasingly focused on design of simple part features and not assemblies, the relevance and observations hold true in terms of visualising the problem.
Enabling collaborative design is one of the major driving forces for reducing time-to-market. As large projects require multiple engineers to be completed in a timely manner, concurrent development is the only solution to shortening design duration. The paper proposes increased accessibility for concurrency through a discretised AR environment. Two major contributions being: users utilising snapping grids to administer changes to a model in collaboration with visual tasks and a decision-making model to administer them. In the AR Robot case, this would increase the accuracy and control over manipulating the model by being accurately able to move the chest plate, a formalised cooperation and thus a better utilisation of space during viewing.

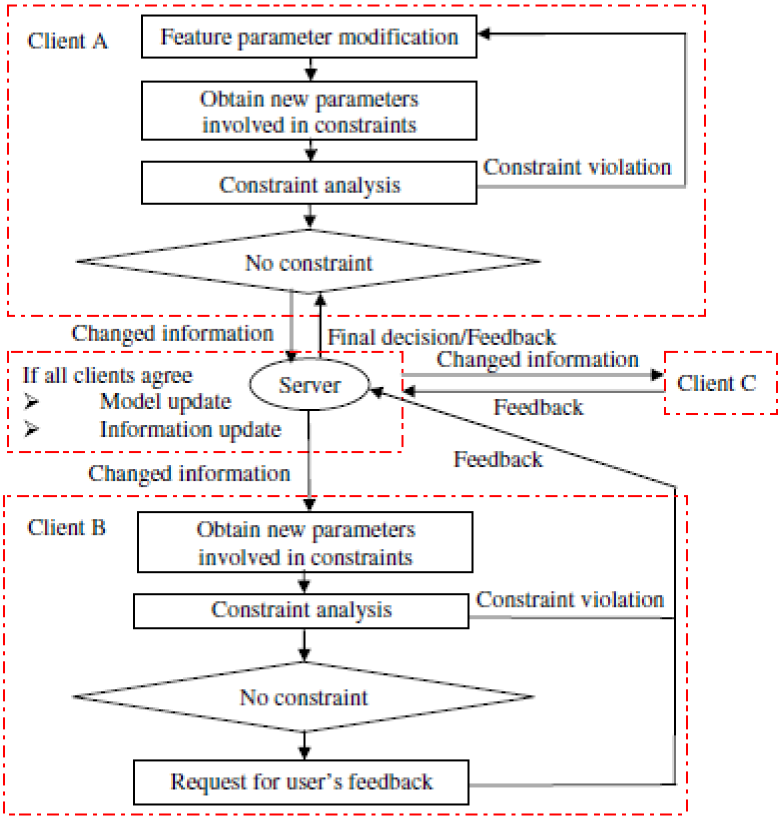

Figure 1. Collaborative workflow for at least 2 users.

Users report completing the tasks involves a "smooth bi-direction communication between the AR-Based System and the CAD kernel". Meaning the system managed administering changes effectively. The user study is limited in that it utilises only 14 mechanical engineering student participants. This demographic is already familiar with 3D design software , however, they are able to compare the efficiency of AR for model manipulation to previous experiences and give a professional opinion on its usefulness. Interestingly, experienced users commended the implementation for its intuitiveness in viewing the model.
Limitations of the technology were the physicality and implementation of the system. Parts of the menu had been moved and users spent time trying to find them. Despite

merely signalling market readiness and polish, in lab conditions the jitteriness was reported by the users as a hindrance. This is also likely to affect the perception of ease of use and the identification of some features as it distracted them from completion of their assigned tasks. Since 2009 the capabilities of CAD, AR and VR has improved with an increasing number of features, modules and the accuracy of sensors. This problem is also likely to decrease.

2.3. Tamilselvi Jayavelu

2.3.1. Social Robots for Education: A Review (Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. ,2018)

This research paper was chosen to review why the social robots can be used in education and to learn know the advantages of physically embodied robots that could be partially adopted for AR robot as a learning platform. The author defines and classifies the social robot and addresses the applications the social robots are used. According to author the physically embodied robots have advantages over virtual agents such as (i) they can be used for curricula or populations that require engagement with the physical world,(ii)when engaging with social robots, more social behaviours are shown by the users that are beneficial for learning, (iii) increased learning gains were shown by the users. From the research it is proved that a social robot has the potential to deliver a learning experience, that supports and challenges students in ways unavailable in current resource-limited educational environments. The author summarises that the robots can free up precious time for human teachers, allowing the teacher to focus on providing comprehensive, empathic and rewarding educational experience.

2.3.2. Learning with Augmented Reality Martins, Sónia & Fernandes, Elsa. (2015)

Augmented Reality has shown significant growth and contributions in various fields. This paper provided concrete examples of free mobile based AR applications which had many educational proposals through which users can interact with virtual elements. The AR applications reviewed in paper are Aurasma, Daqri, Mirage. **“Mirage”** is a set of applications for mobile devices intended to be used in the classroom. These applications are related with different curriculum contents and are supported by lesson plans to be used by teachers. With the same paper markers, users can observe and interact with virtual objects (geometric solids, molecules, planets, satellites, etc.) from all angles. This provides a concrete base to highlight that the interaction is occurred between the user and virtual objects that are produced from AR applications.

2.3.3. Mixed reality educational environment for robotics

This paper was chosen to address how mixed reality environment solves the difficulties and provides an improvement in usability.
Teaching practical courses of highly affect as resources in time and equipment are fre-

quently more limited. The researchers present an environment for the realization of experiments based on mixed reality approach. From their research ,it provides an easy and simple way for carrying out experiments,modifying behaviours and paremeters of virtual simulation environment and it helps students to learn about robotics , to get them interested in performing experiments different parameters of the physical robots and allows for a better understanding of the complexities of real sensors and control algorithms using real hardware.

2.3.4.A Design-Centred Framework for Social Human-Robot Interaction (DiSalvo, C., Gemperle, F., Forlizzi, J., & Montgomery, E.(2003).

This paper was chosen to gain complete guidelines for the design of social robot. The author presents a framework to classify the properties which are
(i) The social robot should mimic human-human dialogue in human-robot dialogue and be able to manage communication failures.
()The robot should mimic human social norms and be able to provide a consistent set of behaviors. Designers use form to balance the needs of people, the capabilities of technology, and the context of use into a single product. Design approaches form as the total expression of the product - not just how something appears, but the whole experience of the interacting with the product. Form includes a product’s physical manifestation, materials, and behavioral qualities (DiSalvo, Gemperle, Forlizzi, & Montgomery,2003). Designers use form to balance the needs of people, the capabilities of technology, and the context of use into a single product.

2.3.5. User Experience in Social Human-Robot Interaction (Alenljung, B., Lindblom, J., Andreasson, R., & Ziemke, T. , 2017)

This paper is chosen to know how the user experience could be carried out in Social human robot interaction. A positive UX does not appear by itself but has to be designed for and evaluated systematically. Briefly stated, user experience is about people’s feelings, as caused and shaped by the use of technology in a particular context (Hartson & Pyla, 2012; Hassenzahl, 2013), and UX is therefore essential for user acceptance of social robots (de Graaf & Allouch, 2013).
The author justifies that to design for a high quality interaction as the basis of positive UX, the design process should include the whole cycle of central activities; these are analysis, design, implementation, and evaluation (Anderson, et al., 2010; Hartson & Pyla, 2012). A current trend in HRI research concerning UX of socially interactive robots is to focus on UX evaluation and examination of UX. Evaluation is a crucial activity in the UXD process, and research-based guidance for robot developers of socially interactive robotic products can be valuable. Likewise, similar guidance regarding the other UXD activities should be beneficial. These will be reviewed again in the evaluation section.

3. PROJECT SUMMARY – WHAT, WHY AND HOW

3.1 What? – Investigating the Use of InMoov as an AR Robot for Teaching Social Robotics

InMoov is an open source robot, designed by sculptor Gael Langevin with contributions from the community. The design is downloadable from his website, in a STL file format. It is accepted by slicing software and turned into G-Code for 3D printing. The robot is anatomically split into sub-assemblies for download and subsequent assembly.
The entire project should be manufacturable on a 12x12x12cm printer, hence the forearm, an anatomically large limb is split into 4 parts. The overall design takes advantage of the limited manufacturing volume to place actuators and sensors. There are clear cut-off points in the robot body according to which, stand-alone components can work independently of each other. For example, in the case of the arm, the finger actuators are located into the forearm and without them they would be unable to move. This shows the robot does not have the same actuation capabilities as a human and although expressiveness is possible, user experience professionals need to design gestures around these limitations.
An AR version of the robot from Futurice features the full complexity of the head and legs in a recent design. It is assumed this is done to showcase the end-goal of the learning material which includes gesture integration. The robot can perform 2 actions, one is turning its head and the other moving its arms and looking at them. An exploded view provides an insight towards into the torso assembly. With some of the electric motors having been labelled, The demo shows the intent to make all parts recognizable.
The user study conducted had the intent to identify the next improvement. Technological shortcomings have been ignored from the feedback. For example, the non-inclusion of image stabilisation during viewership. Despite being pointed out by multiple users, it should be an easy to implement feature in later versions through for example Camera2 API for Android. The questions asked were then prioritised according to recommendations from Futurice and the lecturer. The main goal of the questions was therefore based on acquiring the first impressions and the preferences of the students regarding use of AR as a learning tool.

3.2 Why? – Why is This Method Chosen to Teach Social Robots to Children, a Hand Prototyped and the

Despite the obvious limitations in terms of expressiveness the robot is chosen for learning for its safety in design. Due to the absence of high-voltage circuits and its home replaceable nature, it is suitable for the failures associated with it. For example, replacing the ring finger would cost 0.24 Euro. The biggest bottleneck to getting the robot to function again are the assembly and printing times. Again, the printing time alone would take 1h and 54 minutes. In industry, these are often the biggest bottlenecks and cost pools. In this sense, students can learn the practical implications of breaking and fixing the robot by doing. It is also possible to acquire a physical feel of how the parts should interface.

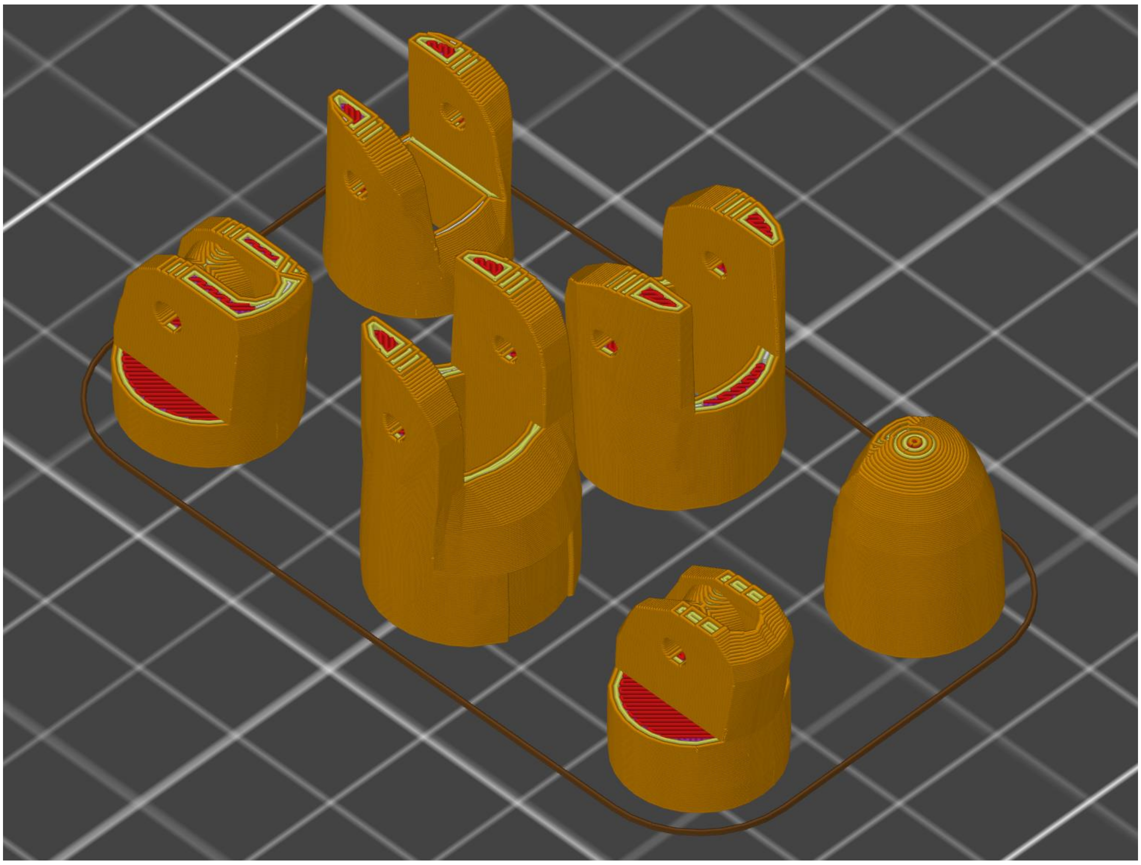

Figure 2. InMoov ring finger, sliced, showing assembly parts.

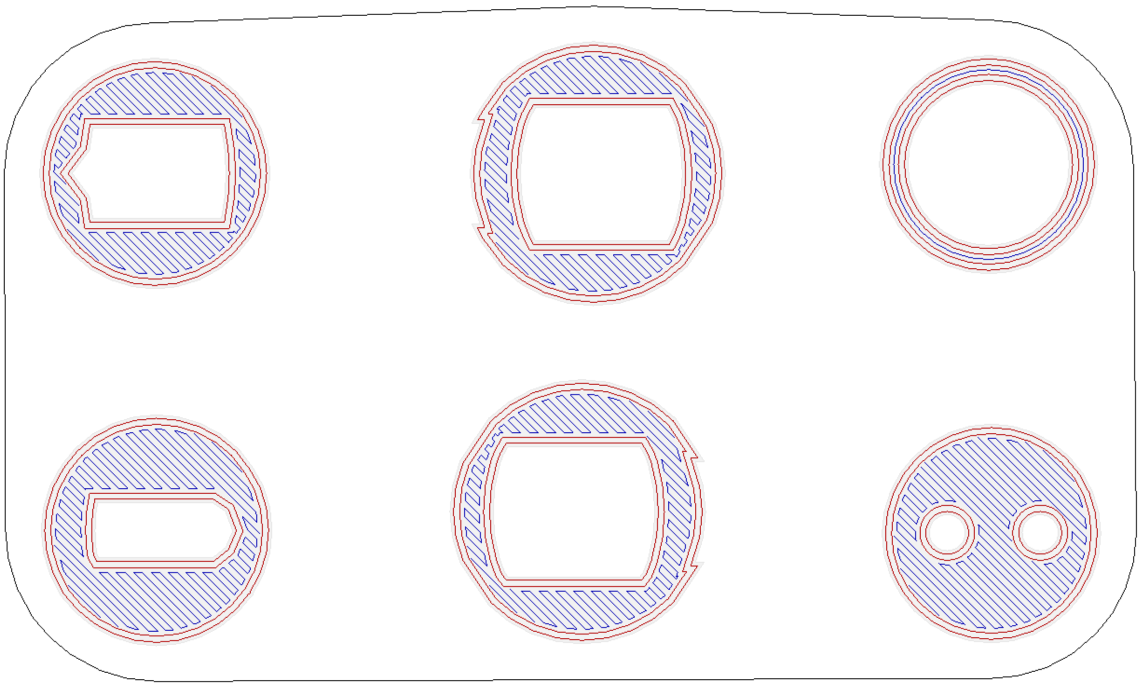

Figure 3. InMoov ring finger, sliced, showing paths.

The structure allows progressively learning the mechatronic devices. Due to the breadth of the project and its goal, only the palm of the robot was built. The idea being, there is no better way of discovering hidden challenges before the students attempt to make and assemble the robot themselves. Additionally, it allows a direct comparison between the digital model and the physical one. This can reveal small details in the hands that would otherwise be unnoticed. For example, finger joint assembly is not detailed in the view. Additionally, the accessibility through

3.3 How? – Should the User Study be Carried Out

Due to the conflict between the recommended target audience, the task is carried out on both the university students and 3 lower secondary students. The content presented, reflects the goals described in the Futurice materials. Primarily that students should learn how to assemble the robot, without touching on the philosophical aspects. As such, a brief introduction was given to them regarding the AR demo "the goal is learning how to assemble a social robot". This was also introduced on the meeting room door. Before the experiment is carried out, the students received a lecture on interaction modalities. As such the session should have served as a learning opportunity for them as well.

A project partner suggestion from Saila Ovaska, was that the most important part of the AR demo experience are the first impressions. It was hence recommended to record how users perceived the demo within the first moments of opening the application. Due to the difficulty associated with recording video while taking notes, only notes and dual channel audio recordings remain. The amount of data acquired is overwhelmingly abundant from the questionnaire. It was possible to analyse and obtain valuable insights through frameworks from Karoliina Leisti. This was done using an affinity board shared online. This method proved effective whereby allowing us to find trends such as; a lack of clarity of task goals. Which are then used to develop the first concept prototype in conjunction with experimentation from the physical model.

Since the project is based around AR, the reality itself is part of the study. Ideally, it should have been possible to record and quantify spaces in the location. Photos could also suffice to extrapolate the space students had to work in, however, this remains a possible improvement for future studies. Unfortunately, due to its location in the middle of the Pinni B building, the room was also dimly lit. Video recordings of the participants are made, however, the videos are lost. To acquire a permission for doing so, every participant filled a consent form giving their permission to be recorded.

Data organisation from the user study is primarily done using an affinity chart. After summarising the feedback in a word file, the information is copy pasted in a digital and online charting software Miro RealtimeBoard. It allows realtime collaboration from distance as well as colour coding feedback according to importance or themes after being written. It also allows connecting topics using connectors which can be moved around. As such it is generally more efficient than doing a paper copy.

Figure 4. Online affinity diagram snippet.

Choosing implementable features is done using frameworks developed by Minja Axelsson (2019). Despite having to use the entire series of guidelines, the group was unable to finalise the solution space. Despite this, we got far enough to the point it was possible to categorise the suggestions, use them to create solutions and categorise the solutions according to their feasibility in accordance with the time and skill budget available.

4. IMPLICATIONS – SOCIAL ROBOT ASSEMBLY TEACHING WITH AR AND OTHER CONCERNS

Guidelines for teaching the physical manufacturing and assembly should be based on the value the AR application delivers to students and therefore teachers. Despite quantitative data not being available, it is possible to tell AR robot assembly viewing can improve the physical time needed to assemble the robot based on the experiences of students. Challenges such as being unsure of the exact point to focus on and learn remain. A selected participant points out "G8R - I'm not sure I learned anything this time but it has potential"

- To have a measurable effect on learning, assembling the robot must be completed from start to finish. Because the entire robot is too time consuming a useful sub-assembly is enough as it features the same principles e.g. actuation, pressure-sensitive resistivity readings, 3D printing, wiring, assembly.
- Doing so should be done by linking the materials prepared by Gael Langevin and the AR tablet. Currently, the in-model app does not include details to locate unmarked parts which his online resources can be used to extrapolate.
- Defining the experience is more important than teaching model itself. The assembly is likely to change, so an overview might remain more accurate than detals.
- The robot should be split into sub-assemblies. Tasks given to students will include group work and InMoov is particularly suitable for this with its clearly defined break-off points.
- Task metrics related to sub-assemblies must be defined. Achievements can start with smaller goals such as assembling a single finger and then a palm to grasp. This being the natural progression of learning robotics is shown by the designer.
- Context within the entire assembly. Already shown by the Futurice app. Each group and sub-assembly should work with the rest of the groups.
- The experience should be designed around a group of people viewing the model at the same time. Safety should be part of the considerations so users do not collide into each other while viewing the same model.
- Representation should include scale. Using the real scale of the robot in relation to the location it is viewed in, gives a real perception of how big the parts are, hence long they would take to print.

Futurice has reiterated the application is still in alpha phase, however, these shortcomings can take more than a year to implement alongside with adding the electronic aspect. Assumptions are not tested on the target student audience as difficulties are universal. For example, all wires for the sensors and fingers must be available before assembly begins. Similarly, all finger parts should be available and assembled concurrently to maximise time utilisation. Wiring within the palm printable have changed within the past 2 years.

5. IMPORTANCE OF USER EXPERIENCE AND A HUMAN CENTRED APPROACH IN ROBOTICS

Benefits of user experience in robotics should be viewed in the context of the AR version of InMoov. The easiest way to represent them is through the value they create for the company employing these measures. In this case it was the time saved in teaching but can be additional knowledge transferred. Most importantly, decision making should be supported through a presentation of value in the context of a balance sheet. On the other hand because balance sheets can be vague, more details are required to influence internal decisions. Hence the importance or benefit should be expressed as following: Activity Based Costing should be used to define what employing the AR application requires and what it detracts from. The process required to set this procedure can roughly described in 3 stages;

1. Cost pools are generated based on factors such as direct and indirect labour.
    a. Direct tablet costs, time to set-up the tablets, the time to keep them updated and the time to teach staff how to use them.
2. Define the activity drivers through trial and error or estimation frameworks as described in operations management.
    a. For example, the amount of printing filament used and the time technicians and teachers spend for some of the activities.
3. Allocate costs to cost objects through the costs for a unit of activity determined
    a. Activities should be billed according to for example, days or hours.

6. CONCEPT PROTOTYPE

Based on the user study results and the goal of achieving how AR robot be used in efficient way for learning robotics, a concept prototype was created.

The AR robot as a learning tool to program AR robot and to build 3D print AR robot. The admin served data or customizable data of robotics course materials are feed to the cloud document which is then transferred to AR robots. To increase the interaction between user and the AR robot the multimodal interactions are designed to AR robot. There are two tasks designed when the AR Robot launches on the screen.
First, learn to program AR Robot.
Second, learn to build 3D print AR robot

When the first interaction is initiated with learn to program AR robot, The student will be provided tasks for programming AR robot. Once the right program is given and run the AR robot would perform the program output. For example, if AR robot is written a program with say ‘Hi’ the AR robot would perform it. That the real time robot actions can be tested using the AR robot itself. Secondly, Learn to build 3D print AR robot provides voice command of the part touched by the user and highlighted the part explaining the complete 3D print method of that part. Thus the AR robot could be used to test the real time robot which is not possible to provide real robots to each student to test and see the tasks.

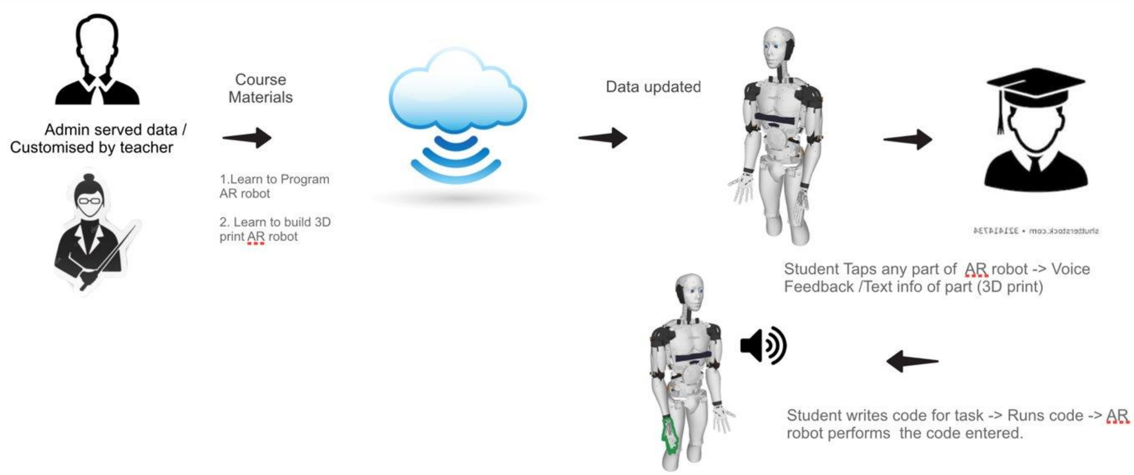

Fig.4 Concept prototype

7. CONCEPT EVALUATION

The concept evaluation is done by showing the video prototype and tested with random two secondary school participants in the shopping mall. The participants felt the application is 'cool' and could be customized for learning robotics and receive hands on practise through AR robot.

The goal of our user study was validate our idea to improve the existing InMoov AR robot for secondary schools, concentrating especially to the educational AR robot. For this, we selected an user group consisting of bachelor students and secondary school students. To validate our idea, we conducted overall three interviews. We collected interview data for bachelor students from the UTA (University of Tampere) campus and for secondary school students from shopping mall. During the interviews we noticed that users felt positive about the idea and they also wanted to be part of such learning system.

The improvement process of the InMoov AR robot includes multiple phases. For this, In the beginning we used qualitative context study methods (Interviews) to develop a set of questionnaires and took interviews to understand what is the users perception regarding existing InMoov AR robot. Based on the users ideation, clients meeting, and literature background study we developed a prototype for mobile devices. Later, we took interviews again with improved prototype. Using the collected data we evaluated our prototype.

8. CONCLUSION

In this paper, we have researched and evaluated to examine the purpose of AR robot as learning assistance. We have discussed about the AR applications useage in The demo shows the intent to make all parts recognizable.
The user study conducted had the intent to identify the next improvement. Technological shortcomings have been ignored from the feedback. For example, the non-inclusion of image stabilisation during viewership. The questions asked were then prioritised according to recommendations from Futurice and the lecturer. The main goal of the questions was therefore based on acquiring the first impressions and the preferences of the students regarding use of AR as a learning tool. The AR robot would be a great learning tool to the robotic learners as the 3D printing of real robot is time and space consuming, this AR robot can be used as a tool in learning 3D printing . Due to time limitations iterative evaluation was not possible to test and redesign to reach final goal. However, with collaboration of HRI HCI and UXD the AR robot can be developed.

Reflection of work

For this group work, we had to interview three times. We have submitted one video, prepared one presentation for the class presentation. We had meetings with our respected clients three times. In all the phases of work, our three group members worked equally.

REFERENCES

Aalto University. (2019, May 8). *Major: Space Robotics and Automation 2018-2019 & 2019-2020*. Retrieved from Into Aalto: https://into.aalto.fi/pages/viewpage.action?pageId=4853384

Alenljung, B., Lindblom, J., Andreasson, R., & Ziemke, T. (2017). User experience in social human-robot interaction. International Journal of Ambient Computing and Intelligence, 8(2), 12-31. doi:10.4018/IJACI.2017040102

A. P. García, G. V. Fernández, B. M. P. Torres, & F. López-Peña. (2011). Mixed reality educational environment for robotics. Paper presented at the 2011 IEEE International Conference on Virtual Environments, Human-Computer Interfaces and Measurement Systems Proceedings, 1-6. doi:10.1109/VECIMS.2011.6053845

Axelsson, M. (2019, May 10). *social_robot_co-design_canvases*. Retrieved from github: social_robot_co-design_canvases

Bartneck, C., & Forlizzi, J. (2004, September). A design-centered framework for social human–robot interaction. *Proceedings of the 2004 IEEE International Workshop on Robot and Human Interactive Communication* (pp. 591–594). https://doi-org.libproxy.tuni.fi/10.1109/roman.2004.1374827

Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., & Tanaka, F. (2018). Social robots for education: A review. *Science Robotics*, *3*(21), eaat5954. doi:10.1126/scirobotics. aat5954

Cooperstock, J. R. (2001). The classroom of the future: enhancing education through augmented reality. *Usability evaluation and interface design: cognitive engineering, intelligent agents and virtual reality*, 688-692.

de Graaf, M.M.A., & Allouch, S.B. (2013). Exploring influencing variables for the acceptance of social robots. *Robotics and Autonomous Systems*, *61*(12), 1476-1486.

Grattard, A., & Matt. (2016, April 16). *InMoov FreeCAD Assembly*. Retrieved from Google Groups: https://groups.google.com/forum/#!topic/inmoov/be_16H8Jq6o

Green, S. A., Billinghurst, M., Chen, X., & Chase, J. G. (2008). Human-Robot Collaboration: A Literature Review and Augmented Reality Approach in Design. *International Journal of Advanced Robotic Systems*. https://doi.org/10.5772/5664

Hartson, R., & Pyla, P.S. (2012). *The UX Book: Process and guidelines for ensuring a quality user experience*. Morgan Kaufmann, Amsterdam.

Hassenzahl, M. (2013). User Experience and Experience Design. In: M. Soegaard & R.F. Dam (Eds.). *The Encyclopedia of Human-Computer Interaction*, 2nd Ed. Aarhus, Denmark: The Interaction Design Foundation. Retrieved September 15, 2013, from http://www.interaction- design.org/encyclopedia/user_experi-ence_and_experience_design.html

Hsin-Kai, W., Silvia Wen-Yu, L., Hsin-Yi, C., & Liang, J.-C. (2013). Current Status, Opportunities and Challenges of Augmented Reality in Education. *Computers and Education*, 41-49.

Kaufmann, H. (2003). Collaborative augmented reality in education. *Institute of Software Technology and Interactive Systems, Vienna University of Technology*.

Kesim, M., & Ozarslan, Y. (2012). Augmented reality in education: current technologies and the potential for education. *Procedia-Social and Behavioral Sciences*, *47*, 297-302.

Martins, Sónia & Fernandes, Elsa. (2015). Learning With Augmented Reality.

Leu, M., Hoda, A., ElMaraghy, H., Nee, A., Ong, S., Lanzetta, M., . . . Bernard, B. (2013). CAD Model Mased Virtual Assembly Simulation, Planning and Training. *CIRP Annals - Manufacturing Technology*, 799-822.

Open Source Robotics Foundation. (2019, May 08). *Gazebo: Main page*. Retrieved from Gazebo Simulator: http://gazebosim.org/

Oxford University Press. (2019, 05 08). *Robot: Definition*. Retrieved from OED: http://www.oed.com/view/Entry/166641?result=2&rskey=EFwn8B&

Roesner, F., Kohno, T., & Molnar, D. (2014). Security and privacy for augmented real-ity systems. Commun. ACM, 57(4), 88-96.

Saaski, J., Salonen, T., Hakkarainen, M., Siltanen, S., Woodward, C., & Lempiainen, J. (2008). Integration of Design and Assembly Using Augmented Reality. *International Precision Assembly Seminar* (pp. 395-404). Chamonix: IFIP International Federation for Information Processing.

Scholz, J., & Smith, A. (2016). Augmented reality: Designing immersive experiences that maximize consumer engagement. *Business Horizons*, 149-161.

Shen, Y., Ong, S., & Nee, A. (2010). Augmented reality for collaborative product design and development. *Design Studies*, 118-145.

Tampere Universities. (2019, May 8). *Information Technology, Robotics and Artificial Intelligence* . Retrieved from Tampere Univesities: https://www.tuni.fi/en/study-with-us/information-technology-robotics-and-artificial-intelligence#show-field-degree-study-objectives

Wu, H.-K., Lee, S. W.-Y., Chang, H.-Y., & Liang, J.-C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, 41-49.

APPENDIX:

[1] Concept video is produced during presentation could be found in the moodle and the link to video prototype can be found below https://tuni-my.sharepoint.com/:v:/r/personal/metodi_netzev_tuni_fi/Documents/1.%20Doctoral%20Degree%20-%2001.03.2019/TIE-41506%20-%20User%20Experience%20in%20Robotics/Final%20Presentation%20and%20Video/Video/The%20Final%20Video.mp4?csf=1&e=N14ZxY

[2] User study interview questions and data transcriptions:

User Study Questionnaire(Tamilselvi Jayavelu):

1. What do you like most about the app?
2. What do you like least about the app?
3. How easy is the app to use?
4. Is there anything missing from the app?
5. What was your first impression when you looked at the app?
6. What different things you would like to learn with an AR robot? How?
7. How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?

8. Does the demo provide better ways of interaction?

9. What other modalities do you think could be introduced to improve the interaction and make learning fun?

10. Was it useful to learn about robotics through an AR application?

11. What challenges did you face while using the app and how can it be improved?

12. How likely would you recommend the app to a friend or colleague?

13. On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?

Data Transcription (7 participants)

Questions	Answers of 7 participants
1.What do you like most about the app?	(1) I like the AR -element(R) (2) The design of the robot (R) (3) The robot was nice (Left) (4) You can exploor robot (R) (5) That the robot appears on the QR-code (Left) (6) The ability to see everything in 3d helps a lot in understanding the robot (Left) (7) How it interacts with the user (M)
2.What do you like least about the app?	(1) It is a little difficult to use (2) Lack of features (3) Going away from the info screen was unclear (4) – (5) The interection of the robot was clunky and weird (6) The controls were a bit unresponsive at times

	(7) Hard to use. Couldn't figure out what could be done with it
3.How easy is the app to use?	(1) It takes a while to learn the different gestures (2) Fairly easy (3) Some gestures were clear, some not (4) – (5) It was okay (6) very easy (7) It was easy to get the robot to appeal, but hard to make it do something
4.Is there anything missing from the app?	(1) I would like to be able to move the robot more freely (2) I think it needs more dhimantions (3) Possibility to go away from the info screen anytime (4) – (5) – (6) – (7) Tuitorial of something that introduces an user to the all
5.What was your first expression when you looked at the app	(1) I thought it looked neat but I had no idea what to do. (2) Meh (3) What can I do with this? (4) Cool (5) Neutral, I don't know (6) The AR robot was very well modelled (7) Wasn't that impressed at first glanced, but my opinion changed when I found out that I could interact with it
6.What different things you would like to learn with an AR robot? How?	(1) I am not sure (2) Internals of robots (3) For example medical field things

	(4) – (5) I don't know (6) Different models(ships,glases etc) (7) Dancing, exercise… just make the robot a model
7.How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?	(1) It could do a little victory dance or somehow congratulate the user (2) Maybe help kids get interested in robots (3) Maybe some game-time features (4) – *(5) don't know* *(6) The 3d representations already is very motivating* *(7) Make it look different depending on the individual using it. It could look like a celebrity for instance*
8.Does the demo provide better ways of interection?	(1) Compare to what? I am not sure (2) Not (3) – (4) – (5) I wish it would (6) yes (7) --
9.What other modalities do you think could be introduced to improve the interectaion and make learning fun?	(1) Maybe audio and tablet movement (2) Other phsical objects in AR (3) – (4) – (5) I don't Know (6) Perhaps more interectivity with the robot? (7) --
10.Was it useful to learn about robotics through an AR application?	(1) Somewhat. It would require more time with the application (2) I don't Know (3) For me the goal (what I,m learning) was a bit unclear (4) yes

	(5) I am not sure if the AR -aspect made any impact (6) yes (7) I don't think I learned anything
11.What challenges do you face while using the app and how it can be improved?	(1) The instruction didn't close it I taped on the side. Moving the robot was a little difficult (2) Maybe adding more features (3) More intutive gestures or a tutorial (4) – (5) I didn't know what to do. (6) Handling the tablet device was quite clamsy (7) Making a tutorial would make the app easier to understand
12.How likely would you recommend the app to a friend or colleague?	(1) As this point not very likely (2) No (3) when the learning goal is more specific, I could recomend (4) – (5) Not likely at all (6) Very likely if it had fuctionality That I would think useful to a friend (7) Not very likely, but I am not aware of all the things one could achieve with the app
13.On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?	(1) 7 (2) 4 (3) 6 (4) 7 (5) 3 (6) 7 (7) 4, was really laggy and didn't quite grasp how to use it, but the AR things were interesting and the app has a lot of potential

Data Transcription (6 participants)

Group 10 User L Study Transcript

What do you like most about the app?

G10L - The way you can easily rotate the model.

What do you like least about the app?

G10L - The QR code was making the robot appear annormaly sometimes

How easy is the app to use?

G10L - Quite easy

Is there anything missing from the app?

G10L - More details into the actual disassembly of the model

What was your first impression when you looked at the app?

G10L - Impressed

What different things you would like to learn with an AR robot? How?

-

How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?

G10L - Feels more like a game than reading a book

Does the demo provide better ways of interaction?

G10L - Yes

What other modalities do you think could be introduced to improve the interaction and make learning fun?

G10L - Making other scenes e.g. making the robot walk while disassembling

Was it useful to learn about robotics through an AR application?

G10L - Yes

What challenges did you face while using the app and how can it be improved?

G10L - QR Code positioning

How likely would you recommend the app to a friend or colleague?

G10L - Not likely yet because I think the app needs at least one detailed model

On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?

G10L - 7

Group **10 User R Study Transcript**

What do you like most about the app?

G10R - That you can view objects that aren't really there.

What do you like least about the app?

G10R - The robot moves around a lot if you don't have steady hands

How easy is the app to use?

G10R - I found it rather easy

Is there anything missing from the app?

G10R - Higher detail

What was your first impression when you looked at the app?

G10R - I liked it. My first reaction was "cool"

What different things you would like to learn with an AR robot? How?

G10R - Muscles, parts, organs etc.

How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?

G10R - For studying purposes, maybe some sort of task list?

Does the demo provide better ways of interaction?

-

What other modalities do you think could be introduced to improve the interaction and make learning fun?

-

Was it useful to learn about robotics through an AR application?

G10R - Yes

What challenges did you face while using the app and how can it be improved?

G10R - Biggest challenge was mentioned in Q2

How likely would you recommend the app to a friend or colleague?

G10R - I found it very interesting, would definitely recommend it

On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?

G10R - For alpha I'd say 7 but it has a lot of potential

Group 9 User R Study Transcript

What do you like most about the app?

G9R - I liked how you can look around by just moving the tablet

What do you like least about the app?

G9R - For longer viewing tablet might be too heavy

How easy is the app to use?

G9R - I think pretty easy

Is there anything missing from the app?

G9R - Specification for the pants.

What was your first impression when you looked at the app?

G9R - First I was a little bit scared but when I got to use it, it felt quite natural.

What different things you would like to learn with an AR robot? How?

How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?

G9R - What specific pants do-Animating the pants

Does the demo provide better ways of interaction?

G9R - I think the interaction feels quite natural

What other modalities do you think could be introduced to improve the interaction and make learning fun?

Was it useful to learn about robotics through an AR application?

What challenges did you face while using the app and how can it be improved?

G9R - Changing the vertical angle with a button was a bit weird

How likely would you recommend the app to a friend or colleague?

On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?

G9R - 8

Group 9 User L Study Transcript

What do you like most about the app?

G9L - Easy to use

What do you like least about the app?

How easy is the app to use?

G9L - Very

Is there anything missing from the app?

What was your first impression when you looked at the app?

What different things you would like to learn with an AR robot? How?

How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?

G9L - Possibly speach feedback

Does the demo provide better ways of interaction?

G9L - Yes

What other modalities do you think could be introduced to improve the interaction and make learning fun?

G9L - Speech

Was it useful to learn about robotics through an AR application?

G9L - It was interesting, different way to look at things

What challenges did you face while using the app and how can it be improved?

How likely would you recommend the app to a friend or colleague?

G9L - Neutral

On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?

G9L - 8

Group 8 User L Study Transcript

What do you like most about the app?

G8L - It looked professional and interesting

What do you like least about the app?

G8L - You expect it to do move

How easy is the app to use?

G8L - For me I was hard remember the functions i.e. what you can do to the robot

Is there anything missing from the app?

G8L - Walkthrough animation, how to use.

What was your first impression when you looked at the app?

G8L - Didn't know what to do

What different things you would like to learn with an AR robot? How?

G8L - Maybe assemble the whole robot bit by bit, then organize parts to know what differents parts do

How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?

G8L - Sounds of assembling, animation

Does the demo provide better ways of interaction?

G8L - (Compared to a manual) Depends on what kind the manual is, but probably

What other modalities do you think could be introduced to improve the interaction and make learning fun?

G8L - Sounds, animations

Was it useful to learn about robotics through an AR application?

G8L - Yes

What challenges did you face while using the app and how can it be improved?

G8L - More instruction I guess

How likely would you recommend the app to a friend or colleague?

G8L - 7

On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?

G8L - 8

Group 8 User R Study Transcript

What do you like most about the app?

G8R - You can move the QR code and the robot changes place. It's cool that the perspective changes when the camera moves, looks real.

What do you like least about the app?

G8R - I couldn't get all the gestures to work all the time

How easy is the app to use?

G8R - Quite intuitive

Is there anything missing from the app?

G8R - It is a demo still but it would be interesting to see more details inside the robot.

What was your first impression when you looked at the app?

G8R - I haven't used many AR applications before so it was nice to see the robot appear "in the room"

What different things you would like to learn with an AR robot? How?

G8R - It would be good for testing and learning to use the robot

How could the AR robot motivate learning? What kind of motivational and rewarding features could it include?

G8R - Human gestures would bring character and feel more rewarding (like a smile, applause)

Does the demo provide better ways of interaction?

G8R - Sure it's more informative to look at an animation vs text, It's also fast to use when it's interactive

What other modalities do you think could be introduced to improve the interaction and make learning fun?

G8R - Voice commands would be fun

Was it useful to learn about robotics through an AR application?

G8R - I'm not sure I learned anything this time but it has potential

What challenges did you face while using the app and how can it be improved?

G8R - The swiping didn't work every time, maybe instructions about the type of swipe needed (sharp, long)

How likely would you recommend the app to a friend or colleague?

G8R - If it helps build Ikea furniture very likely 😊

On a scale from 1 to 10 (1 being the lowest and 10 highest) how would you rate our app?

G8R - Good job with the animation of the robot, it looks great! Still needs some more functionalities to keep it interesting.

Data transcription (9 participants) by Tamilselvi Jayavelu:

Group 1 G 1

USER 1 (U1)

1.It was simple . First time using it wasn't too daunting.

2.The controls are a bit too sensitive? Small movements and adjustments were challenging to make.

3.Fairly easy once you get started

4.I might not be part of the " target audience",so I can't say with much confidence. But not that I can think of anything

5. Oh that's cool, very helpful, I know

6.how about a robot is built?

8.touching a part of the robot could " isolate" it , take it apart /away from the rest of the robot for closer inspection.

10.Again ,I'm not the best person for this. But it certainly was interesting.

12.If I knew they might benefit from something like this? Very likely.

13.7

User 2:

1.The robot is movable so that you can turn it, zoom it and so on .

2.it is not so easy to explore

3.intermediate

4.i can not say

5.the robot looked nice and it was surprising

6.No idea.Perhaps little deeper what there is inside

7.It is possible to explore robot more detailed way inside.

8.You can turn,zoom the robot so perhaps it gives more information than for example same info in PDF Format.

9.The robot could give some sounds ,voice,info when the user explore some part of it.

10.This was perhaps 3rd time when I used AR technique so I don't have much experience perhaps for me real robotics would be better way to learn about them hands on.

11.it was some how difficult to understand what to do in generally.

12.No I wouldn’t recommend.

13.6

GU2:

User 3 U3

1.i can see inside the robot

2. It sometimes looses the robot

3.easy to use

4.the exploded view didn’t work.

5.Not too many controls visible.

6. Like to learn manufacturing and assembly , changing parts.

7.it really helps to visualize and perhaps the motion ranges

10.yes useful to learn

11.challenge is better tracking.

12.likely

13.7

User 4 U 4

1.like X-ray function

2.that it’s implemented on the tablet.

3. From scale of 1-5 I would say 3

4.Perhaps more cool animations.

5.”quite useful” you could use it to showcase 3D models.

6.perhaps how to use a certain product ,robot demos, the usage

7.you could teach the robot itself , your reward is seeing the robot succeed.

8.for sure has better interaction

9.perhaps voice for simple voice commands would be other modality

10.for sure, as I was mainly interested in the components so it’s useful

11.perhaps finding of all the possible functions

12.I would recommend, as it is quite an interesting experience.

13. 9

Group 3 G 3:

User 5 U 5:

1.Its pretty straight forward

2.it doesn't give hints about how to use it and controls are little of

3.pretty easy once you got the hang of it

4.missing hints in the start of the app.

5.was interesting

6.like to learn info about specific parts.

7.it could make the some abstract thing more concrete

8. No better interaction

9.can introduce vibrations to give it more tactile feedback.

10.kind of a guess whether it's useful.

11.i had a problem understanding the controls ,the hints should be given in the start.

12.at this state probably won't recommend

13. 5

User 6 U 6

1.interesting it creates the robot on top of the QR CODE, also it is very detailed.

2.it lags a little and don't have clues what parts are removable.

3.if you read the instructions first then it's quite easy

4.Maybe highlighting removable parts when tapped by finger?

5.Thought I could host multiple robots at 1 session.

6.would like to learn disassembly of motors /gearbox etc. Physics?(particle)

7.Progress car? Not sure for university but for cars you don't need to get your hands dirty.

8.compared to manual it has potential to put display the object in the right place in its correct position and how it goes there.

9.highlighting of parts

10.somewhat useful yes

11. Didn't notice the menu at first and didn't know how much it could be disassembled.

12.With more objects and more removable parts and tutorials then yes, I would recommend it.

13.8

GROUP 4 G 4

User 7:

1. The idea and the visuals I like
2. Least liked the bugginess
3. Ratherly easy, though we need to read the instructions
4. Missing: can't make anything up
5. I was surprised in a good manner
6. Like to learn how robots are assembled ,I guess it is already done in the app .
7. Some kind of experience points when you learn something.Sounds and visuals also.
8. Yes it is much more handy and amusing than doing it in real life.
9. Other modality can be concept in VR glasses.
10. Now I didn't learn much but I think after this develops, it will be very useful.
11. Bugs
12. Would recommend very likely after it is fully ready
13. 8

User 8 U 8

1. It is quite simple and straight forward to use
2. The app has some performance issues
3. Quite, the instructions are clear and intuitive
4. More interactions would be nice
5. It's quite bare with little clutter
6. What goes inside robots and how they're assembled.
7. Achievements for finding certain parts and locations
8. Yes, having a virtual version gives more confidence to explore and test.
9. Having some virtual buttons and adjusters could make interacting a bit more intuitive
10. Yes. Of course the content was limited , by still.
11. Performance issues (jittering, lagging)

Could be fixed with optimization and a more powerful device

12. In its current state it doesn't offer too much but further in development definitely.
13. 5.5

User 9. U 9

1.Zooming in and out the robot is nice . The robot also looks quite real moving along the picture

2.Quite difficult to understand gestures to make robot move or rip the parts off

3. Not too difficult but gestures could have been more easier

4.maybe it could be more interactive like sounds when you poke robot on head or something

Nice

6 how something moved like when the breast plate is off you could see how arms move up and down etc.

7 maybe some pairs when putting things back to where they belong?

8.i don't know

9 may be colorful coding different type of parts used in robot?

I don't know if I learned anything.

11.I expected these would be more parts to come off than there was.

12 . Maybe when it is more multifunctional I would.

13 . 7

Affinity Diagram: Could be found in the video