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INTRODUCING AUGMENTED REALITY AT SECONDARY COLLEGES OF ENGINEERING

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ABSTRACT
In Austria there is a unique curriculum of technical education which is taught at Federal Secondary Colleges of Engineering (HTL). Despite mechanical engineering design with industrial standard 3D programmes being state of the art, techniques like Internet of Things (IoT) and Augmented Reality (AR) are still at the beginning. This paper describes the introduction of an IoT platform at Austrian HTLs with focus on Augmented Reality. In addition, a survey among students has been undertaken to get knowledge of whether students are familiar with and interested in using AR technologies and the results are presented in this paper.

Keywords: Internet of Things (IoT), Augmented Reality (AR), Design Education

1 INTRODUCTION INTERNET OF THINGS AND AUGMENTED REALITY

In their article, which was published in the Harvard Business Review, Porter and Heppelmann [1] describe how the introduction of Internet of Things will change the way smart products are developed. The business itself as well as the general requirements and therefore the organizational structures of companies [2] will be changing due to data from smart products becoming increasingly important. Concerning Augmented Reality, they [3] figure out the advantages of AR like reduction of errors and increasing of productivity and state that every company has to develop an explicit AR strategy. Describing the difference between AR and Virtual Reality (VR) which are both existing technologies, they give excellent examples of merging the real world with the digital world [3]. For one such example, see Figure 1.

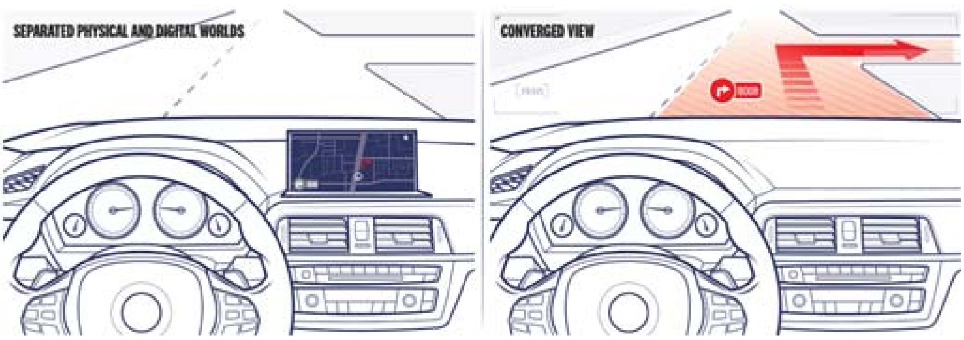

Figure 1. Separated and superimposed digital data into real world [3, p. 50]

The constantly changing situation in industry always has and will continue to impact on engineering education. Therefore, the implementation of IoT and AR possibilities and technologies seems to be an appropriate advancement to develop the engineering education curriculum for today's needs.
In their research study, Köhler et al. [4, p. 8] give a good overview about existing IoT solutions and state that the different solutions vary widely. Regarding the application that is planned to be used at Austrian HTLs the authors mention that "ThingWorx focuses on the integration, transformation and presentation of the created data. It does not provide a solution to the question “How is data collected?” but it addresses the problem of “What happens to the data after it has been collected?".

The research of Elsaadany and Soliman [5] investigates the different perspectives of learners, educators and learning administrators on IoT and argues that IoT can transform the educational environment due to the increasing amount of available connected devices, which will lead to changes in students’ and educators’ behaviours.

Felder et al. [6] state in their publication that active learning will facilitate long term retention of information and helping students to stimulate their interest in a subject. They also describe how students learn more from visible information in educational lessons than from verbal information, regardless of whether it is written or spoken.

According to Prifti et al. [7], who are doing research in IoT combined with Enterprise Relation Systems (ERP), researchers should not describe the IoT products of the key players in business. Instead, they should focus on educational services.

In summary, this research study focuses mainly on user experiences achieved so far and additionally gives important information about setting up and maintaining an IoT platform and using the software.

2 USING AR AND IOT IN ENGINEERING EDUCATION

2.1 Using Augmented Reality: a case study

The first experiments as well as a pilot project application were made within the existing hardware of the spindle press, which was developed by two students as part of a diploma thesis at HTL Linz Litec. Using already existing hardware gives the opportunity to focus only on IoT topics as planned instead of using additional time and resources for designing and manufacturing hardware for IoT applications first. The first step is to transfer CAD-data into the IoT platform and in this case to include the mounting and dismounting process for the machine. Next, is to change the design of the present hardware to apply sensors for measuring distances, speed and applied forces. The third step is to transfer generated sensor data to the IoT platform and overlay the real time sensor data with created AR information. Due to time issues this task was done during a summer job by a former HTL student, who is now studying mechanical engineering at the University of Technology Vienna (TU Wien). Asked which challenges she faced while working with the new IoT technologies and applications, the female student stated "Working on IoT technologies with ThingWorx is quite easy as long as you are using basic tools. Getting information about enhanced functionalities and programming additional functions with java script sometimes is a little bit tricky".

Fig. 2 shows a ThingMark and the hardware of a spindle press. Using the mobile app "ThingWorx View", and scanning the ThingMark an AR experience is displayed on the mobile device, tipping on the 3d model explodes the assembly.

Figure 2. ThingMark connected to AR experience and hardware of a spindle press

2.2 Using Augmented Reality in Engineering Education

Felder et al. [6] stated that undergraduates are mostly sensing learners whereas professors are intuitive learners. According to Felder both types of learners are needed in companies. Sensing learners prefer to react to concrete examples and material with connection to real world scenarios. Therefore, AR seems to be a good opportunity to meet students' needs.

Using AR to support lessons, pupils and students can look at 3D models of complex technical engines like steam turbines or combustion engines combined with looking at pictures and drawings, which are very often hard to understand. According to the current state of the art, the application seems to make sense primarily for mechanical engineering, an application for other technical areas such as aerodynamics, stress analysis or thermodynamics seems to be questionable and should be investigated. For example, instead of only looking at a technical drawing in their course book or on a blackboard it seems to be easier for students to comprehend the functionality of a two stage gear transmission, by navigating through the 3D model within a mobile device and app they have on hand. This also gives the staff the opportunity to teach complex engineering design with different methods and it increases the fun within learning. Ebner et al. [8] used the term 'enjoyable factor' instead of 'fun' in a research study about game-based learning. Although an AR application is not a game, the approach of enjoyable learning seems to be important and is investigated within the survey. In a first trial 3D CAD model of several clutches (see Figure 3) were embedded in an AR experience with ThingWorx and used in the regular engineering education for learning about machine elements. The students gave positive feedback about learning these topics connected with AR in a field of study where students sometimes are lacklustre regarding their lessons.

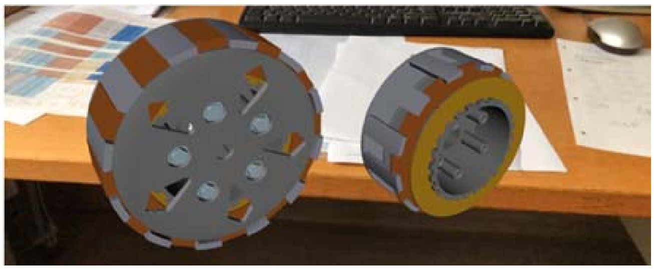

Figure 3. AR of multi-disc clutches used in engineering lessons

2.3 Using Augmented Reality in Engineering Design Lessons

Especially for engineering design lessons there are several scenarios for using AR technologies. There may be arguments that all this could be done by a 3D viewer, but AR and IoT technologies are quite easily accessible via the internet and provide more opportunities compared to a 3D viewer. A special code called ThingMark is used which connects the mobile device app with the data of the IoT server. AR technologies provide the following opportunities to supplement engineering design education:

- Displaying of mounting and dismounting of assemblies
- Displaying of machines kinematic motion
- Viewing 3D data within mobile device apps in general
- Displaying sensor data on the augmented 3D model, which are collected from an IoT application

All these scenarios, especially the mounting and dismounting of assemblies have the advantage of giving the opportunity to communicate nonverbally. In the case of service for a coffee machine, nowadays dismounting can be done by experience, trial and error or reading an instruction manual. Therefore, the manufacturer of the coffee machine has to write the manual in various languages (English, German, French, Chinese, etc.) and ensure that the correct version of the manual is available to the customer. Using Augmented Reality, the customer uses a mobile app getting the information to disassemble and afterwards the information to assemble the parts of the machine in the correct order. Transferring this aspect to complex machines like steam turbines or milling machines using AR technologies gives advantages to companies with different origin of workforce members, especially on facility sites, hence they spread all over the world.

3 SURVEY ABOUT AUGMENTED REALITY

Conducting an IoT activity has been done and published already [9]. In contrast to this paper, Abraham's work focused on the processing of collected sensor data as well as student groups consisting of university freshmen in the field of electrical and computer engineering. The major differences in our research study are that our research focus is on Augmented Reality and our groups consisted of students from secondary colleges with several years' experience in mechanical engineering.

Besides the survey questions, data about the students’ current class and year of HTL education as well as their gender were collected within the survey. Although the survey is continuing, currently 88

students including 6 female students have participated in the survey up to now consisting of four classes in three HTLs.
The survey was done in four steps:

- In the first step, students did a pre-activity assessment
- In the second step, the lecturer gave an introduction on IoT and AR to students
- In the third step, students created an AR experience following given instructions
- In the fourth step, the students completed a post-activity assessment

3.1 Survey Questions and Hypotheses

The aim of the survey questions (SQ) about Augmented Reality was to get knowledge of whether students are familiar with and interested in using AR technologies. Moreover, we tried to figure out if students rate the AR technology to be helpful for understanding complex machines and processes. Additionally, we wanted to know if students of mechanical engineering departments face problems when working with new applications to create an AR experience, and if they enjoy it.
The survey questions for all these points are listed below and were used in a pre-activity assessment and a post-activity assessment and rated with a five point Likert scale.
SQ3: I am familiar with AR technologies and applications
SQ4: I am interested in learning AR technologies
SQ5: AR is useful for better understanding of technical machines and processes
SQ6: AR is a good supplement for understanding industry assembly or maintenance processes
SQ7: Using AR is more attractive to students learning new technical subjects.
SQ8: Generating an AR experience was easy to use
SQ9: Using AR is fun
On the basis of the survey questions the following hypotheses were formed:
H1: The advantages of Augmented Reality are easy to grasp for students
H2: It is easy for students to learn to work with Augmented Reality technologies and tools
H3: Students realize the advantages of Augmented Reality technologies for teaching and lecturing
H4: Students realize the advantages of Augmented Reality technologies for industrial applications
H5: Students enjoy working with Augmented Reality technologies and tools

3.2 Pre and post-activity assessment

The pre-activity assessment and the post-activity assessment were conducted by using Google Forms to offer students easy access via computer or mobile devices and increase the willingness to participate in the survey. The pre-activity assessment included the survey questions SQ3 to SQ9, and no additional information was given to the students before finishing the pre-activity assessment. In order to quantify the test results a questionnaire was created. The questionnaire relies on a five point Likert [10] scale: 1 – Strongly Disagree, 2 – Disagree, 3 – Neither Agree nor Disagree, 4 – Agree and 5 – Strongly Agree.
After an introduction about AR and IoT and creating an AR experience, the students had to complete the post-activity assessment, which was a copy of the pre-activity assessment using the same Likert scale. The whole survey was done within two or three hours, depending on the speed of the internet connection and the students' pace.

3.3 Introduction of IoT and AR to Students

After the pre-activity assessment the lecturer gave a short introduction and overview about IoT and AR technologies as well as the differences between them. The information included a definition about the difference between Virtual Reality and Augmented Reality as well as the differences between AR and IoT. Several scenarios were demonstrated and discussed, for example displaying the needed info for assembly of an industrial product like a car engine or displaying the different sensor information from a production line.

3.4 Description of the AR - Student Activity during the Survey

The activity session begins after an overview about IoT and AR technologies, and is demonstrated by usage of the programme ThingWorx from PTC. The session is interactive. Students have to work in groups with a focus on teamwork for AR applications or using sensor data within IoT experiences in real world scenarios. The initial step for the AR activity is to download the ThingWorx View app from the app store on each student's mobile device. The second step is to install the programme ThingWorx Studio and activate the academic access for it. This programme is supported by provided installation videos on every student's computer. The third step is to create an AR experience with a provided two-stage gear transmission on every student's computer and setting a ThingMark for identification. The final step is to retrieve the AR experience on the students' mobile devices, giving the students a brief glimpse into Augmented Reality technologies.

3.5 Survey results

Due to this paper focusing on Augmented Reality, only the results for the survey questions are displayed below. In order to get a better overview, the pre-activity assessment and the post-activity assessment of all survey questions are shown together in Figure 4. All results show major improvements in the post-activity assessment with fare more than 50% having agreed/strongly agreed.

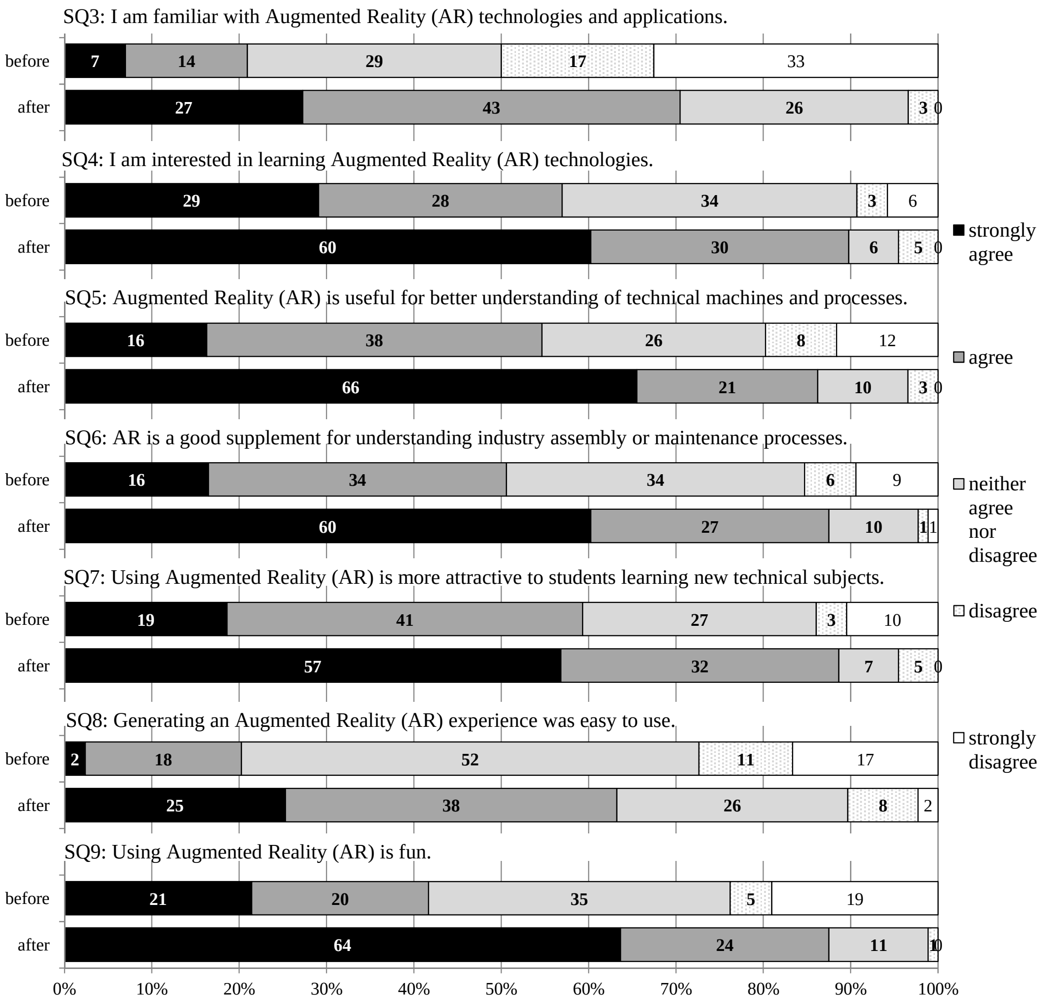

Figure 4. Results in the answers to the survey questions in the pre-and the post-activity assessment

It can be observed that for SQ3 in the post-activity assessment 70% of the students agreed/strongly agreed that they are familiar with AR technologies, while 3% disagreed with this statement. Looking at the post-activity assessment of SQ3 the hypothesis H1 seems to be supported.

Survey question SQ4 asked students if they are interested in learning AR technologies. It can be observed that in the post-activity assessment 90% of the students agreed/strongly agreed and only 5% disagreed that they are interested. Looking at the post-activity assessment of SQ4 the hypothesis H5 seems to be supported.

Survey question SQ5 asked students if AR is useful for better understanding of technical machines and processes. It can be observed that in the post-activity assessment 89% of the students agreed/strongly agreed and only 3% disagreed. Looking at the post-activity assessment of SQ5 the hypothesis H3 seems to be supported.

Survey question SQ6 asked students if AR is a good supplement for understanding industry assembly or maintenance processes. It can be observed that in the post-activity assessment 87% of the students agreed/strongly agreed and only 2% disagreed/strongly disagreed. Looking at the post-activity assessment of SQ6 the hypothesis H4 seems to be supported.

Survey question SQ7 asked students if AR is more attractive to students learning new technical subjects. It can be observed that in the post-activity assessment 89% of the students agreed/strongly agreed and only 5% disagreed. Looking at the post-activity assessment of SQ7 the hypothesis H3 seems to be supported.

Survey question SQ8 asked students if creating an AR experience was easy to do. It can be observed that in the post-activity assessment 63% of the students agreed/strongly agreed that and 10% disagreed/strongly disagreed. This was the lowest percentage of agreement, although 10% is quite high and the highest percentage of disagreement in the whole survey, learning and working with new software is always a challenge for students. Looking at the post-activity assessment of SQ8 the hypothesis H2 seems to be mostly supported.

Survey question SQ9 asked students if using AR is fun. It can be observed that in the post-activity assessment 88% of the students agreed/strongly agreed that they are interested, whereas 12% answered neither agree nor disagree/disagree and no students answered strongly disagree. Looking at the post-activity assessment of SQ9 the hypothesis H5 seems to be supported.

4 CONCLUSION AND OUTLOOK

Internet of Things and Augmented Reality are technologies which might have a positive impact on all fields of engineering technology. Especially for engineering education there seems to be a good opportunity to include these technologies into the curriculum and use them in engineering design education as well as in engineering labs and diploma theses. In addition to enjoying working with them, students seem to recognize some potential in these technologies. These technologies could potentially make several fields of engineering more attractive for different people and especially potential female students. In order to be able to exclude long-term novelty effects, further investigations in the future are of course necessary.

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