ARBT: Augmented reality-based trainings for vocational trainers in the field of chemistry[1]

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Abstract

Vocational education and training measures in the field of chemistry are characterized by a close integration of theory and practice. With the changes of the occupational profile "chemical operator", a new technology, like Augmented Reality, becomes an integral part of the national training plan. This requires skilled VET trainers to use Augmented Reality in theoretical and practical training environments, to enrich current training measures. Based on a survey among VET trainers a blended learning training program is developed, to enable VET trainers to apply Augmented Reality during trainings in the chemical pilot plant, by carrying out remote trainings with relevant Augmented Reality glasses. The enrichment of existing teaching and learning scenarios with Augmented Reality based remote training is beneficial for the increase of media competence skills among trainers and especially the development of procedural skills among learners.

1 Introduction

The use of Augmented Reality (AR) in vocational education and training (VET) is in some industries still a terra incognita. There are scientific publications about the use of AR in the fields of hardware assembly [4, 7], in automotive education [6] and further application fields [9]. A use in the field of chemistry is not documented.

The application of AR is a result of changing occupational activities, which are partly technologically induced. This accelerates the change of educational contents and leads to new didactical options in terms of media and professional didactics [3]. The use of AR in VET is beneficial as it is a new option to analyse working environments concerning the learnability in terms of a better competence building of learners. AR provides a didactical value added if the interaction between trainers and learners is supported and the learning progress is documented [3]. This leads to new learning processes among learners e.g. by using AR for the augmentation

[1] Supported by the EU Program "Erasmus Plus" in the frame of the German project AR4VET. More under https://www.sbg-dresden.de/aktuelles/projekte/ar4vet.

Veröffentlicht durch die Gesellschaft für Informatik e. V. 2018 in
R. Dachselt, G. Weber (Hrsg.):
Mensch und Computer 2018 – Workshopband, 02.–05. September 2018, Dresden.
 https://doi.org/10.18420/muc2018-ws07-0415

of additional information on machines (visualisation of manuals) or the individualized learning between trainer and learner(s) by so called remote or expert training.

AR supports the procedural skills of learners by observing the augmented instructions and subsequently to carry out the task, by the development of the relevant skills and competences to perform the task and by a changed behaviour by repeating a task [8]. The training of apprentices in the chemical industry is time and resource intensive. There are a lot of complex processes which can only by explained but not shown, due to e.g. high temperatures and pressures. The training is very practical oriented, and a close integration of theory and practice exists. It is not only important to explain the technical functioning of the plant and the chemical reactions in reaction vessels, but also to integrate new technology in existing teaching and learning scenarios.

This paper deals with the development of a blended-learning training program for VET trainers in the light of the changing training requirements, caused by the realignment of the occupational profile "chemical operator", which **obliges** the use of **AR in training**.

In the next sections the problems and the demands will be presented, followed by the presentation of course contents (on AR hard- and software) and a subsequent discussion and outlook.

2 Problem and demands

The first occupational profile in the chemical industry, which will be a test-bed for the integration of AR, is the chemical operator. With the start of the new training year 2018/2019, each chemical operator can select the brand-new elective on „digitalisation and inter-connected production ". This elective focusses on plant planning, plant management and plant maintenance as well as process and quality management. AR is currently foreseen to be used for plant operation and maintenance [2]. The provision of the elective contents requires VET trainers, who a capable to know, to apply and to evaluate the use of AR in company training processes.

A training program for VET- trainers has to support them for the following reasons, as currently no or less experience exists:

1. which AR-glasses to use;
2. which AR-software to use to create new or alter existing AR models;
3. which legal aspects must be considered, when using existing AR models;
4. how to plan a class with integrating AR.

The training program is tailor-made for a VET provider like SBG Dresden. The design of AR training applications for other environments is widely discussed, e.g. for the field of manufacturing [1].

Before the learning scenario (see below) was created, in 11/2017, an online survey[2] was carried out among 10 VET trainers[3] for chemical occupations at SBG Dresden, which is a practical training provider, in order to determine:

1. Where are we now concerning hard- and software use and
2. What is the expected didactical value added by applying Augmented Reality?

Currently the instruction by standard hardware is common. Augmented Reality Glasses are not in use. Mainly black- and whiteboards and projectors are in use. It is important to note, that no real differences of using the aforementioned hardware between practical training in the lab and pilot plant as well as in theoretical training, in the classroom, exists. The use of software showed a similar picture: Mainly standard software application such as MS-Office, Search engines and Videos were common.

The expectation of the trainers concerning the benefits of using AR (see Figure 1 below), are less in presenting an issue, but more in the simulation of errors, to foster a more in-depth learning among learners.

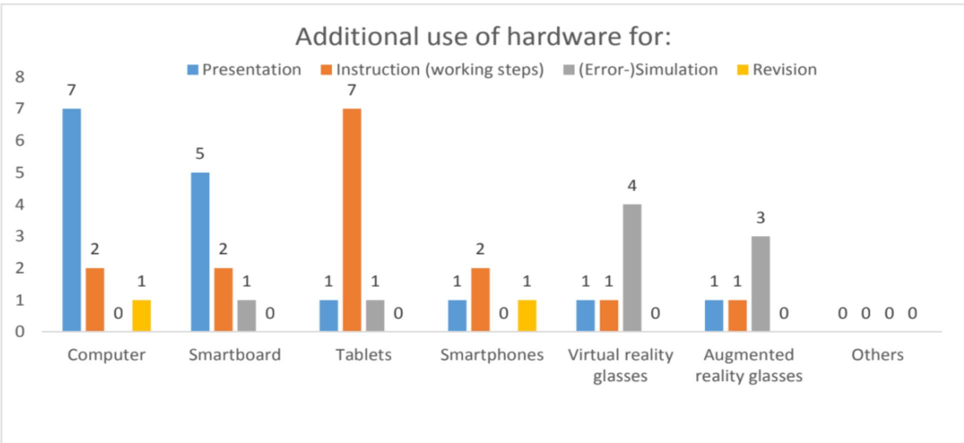

Figure 1: Value added of using Augmented Reality (own online survey results)

Future users, with rather less or no experience with AR, were involved early in the development of the learning scenario to focus at first solely on the didactical value added. The learning scenario aimed to enable trainers to carry out an AR-based training scenario, with simple

[2] The survey consisted of a structured questionnaire with the following questions: 1. Use of hard- and software in practical and theoretical training, 2. Experience with digital media, 3. Context of the beneficial use of digital media, 4. Support of skills among trainers, when using digital media, 5. Didactical value added of additional hard- and software use, 6. Visualisation needs of contents, 7. Further training requirements of trainers (how, measurement of acquired knowledge), 8. How to get in touch with new technology (workshop, blended learning etc.), 9. Expected qualification needs in 5 years from now, 10. Existence of internal working group for digital media.

[3] The group consisted of 6 female and 4 male trainers in the age range from 31-62 years. All trainers have an university degree in the field of chemistry or related natural sciences and pedagogical qualification (AEVO or pedagogical university degree). The years of working experience as a trainer ranged from 2 to 26 years.

knowledge on how to use an HMD[4], like the MS HoloLens, to implement a more individualized training (remote training approach) on the learning station AR, in the chemical pilot plant at the premises of SBG Dresden.

3 Conception

Hereinafter the teaching and learning scenario will be explained, which builds the base for the structure and contents of the module on “AR hard- and software” from the Erasmus Plus Project “AR4VET” (2017-2019). This module is the first out of five modules of the planned blended learning course. Other modules will focus on AR enriched communication and collaboration forms (module 2), creation of AR media (module 3), legal aspects (module 4) and on planning a complete lesson (8 hours) or course (2-3 weeks) with AR media and setting up a tailor-made lesson plan (module 5).

The core of the first learning module is the handling of various hardware and software for the use of AR. Aim is to create a tailor-made lesson plan to a remote training scenario on plant maintenance. This means that the trainer provides remote – instruction (voice and /or visually) through the AR glasses which the apprentices wears. This teaching and learning scenario has its advantages for explaining procedural procedures on special or complex technical equipment as the simulation of the steps would be to time consuming (to program).

To aim of the learning module is to train the VET trainer accordingly to carry out the remote-training scenario, by acquiring basic knowledge on the application of AR hard- and software, based on didactical value added. The learning module covers and includes:

1. Augmented Reality use in VET: a framework – didactics (HOW?), learning content (WHAT?) and technology (WHICH?)
2. Differences between augmented reality, virtual reality and mixed reality
3. Benefits of AR-use and lesson planning (determine specific learning value added of AR, by using Blooms taxonomy, and characteristics of the learning station AR in the practical training environment)
4. Comparison of different AR glasses
5. Comparison of (freely) available software for creating 3D/AR models (like: sketch-up, blender) and platforms for freely available 3D models (like: 3D warehouse, Sketchfab)

The module took 30 min and the subsequent quiz took, with ten questions, took the one selected trainer ten min to finish.[5] The trainer[6], who was selected to pilot test the first module,

[4] Head mounted display

[5] Quiz questions (selection): 1. Important parameters, when planning lesson with AR? (didactics, content, kind of AR glasses, …), 2. Elements of the lesson plan? (learning contents, duration, teacher activities, learners activities, 3. Selection criteria for AR glasses.

[6] Male, 51 years old with 10 years’ experience in training.

had to answer at least 80% of the questions correctly to pass. After completing the module, the VET trainer was ready for designing a tailor-made lesson plan for an existing lesson. This plan, which was set up, describes the initial situation / prior knowledge of the apprentices (chemical operators), the general learning objectives and the operational learning objectives (according to Blooms taxonomy [4]). The existing course was taken and AR was integrated in the course. The trainer could use the existing course materials and the AR glasses (with the already downloaded remote training app) to prepare the course.

Initial situation: 2nd year apprentices, max. 10 person in a class, only one pair of AR glasses available, theoretical instruction of the functioning of the plant by verbal and visual (whiteboard) instruction.

General learning objectives: Apprentices are able to use AR glasses, Apprentices are able to follow remote instruction of the trainer (voice and visualisation) to repair chemical plant, Apprentices are able to explain the repairing procedure to other apprentices

Operational learning objectives: Apprentices carry out repair, Apprentices create lab records

The learning scenario looked like that:

The Microsoft HoloLens was chosen as it allows a hand-free and cordless, respective mobile training as well as the reservation against the household name Microsoft were lower then against other AR glass producers. The trainer downloaded the “remote assist”- app.[7] With the app and the AR glasses the VET trainer chose one of the 10 apprentices[8] in the class to wear an AR glass and carry out the following task: “Starting and stopping of the semi-technical distillation DN 80 in the chemical pilot plant”. The task is normally provided by paper-bases instructions. This time only AR based remote training was used. The task involves the following working steps (selection):

a) Open ball valves for compressed air, cooling water supply and nitrogen
b) Flush the distillation unit with nitrogen by operating valve 28 in the 5 m operating level
c) Take the absorption system into operation, by pressing he "Absorption" button.
d) Put a pump (No. P2) into operation.
e) Put the thermostat into operation.

To carry out the task takes normally one working day. For training reasons, the remote training

scenario was repeated each day with a different apprentice out of group of 10 persons, during that 2 weeks course. Each day only one apprentice could use the AR glasses. When the trainer

[7] The app allows an individual training. The trainer can instruct the apprentice by voice and simple markings in the field of view of the learners, which wears the MS HoloLens.
[8] Male, 17-20 years old.

and the selected apprentice where using the AR glasses, the other apprentices worked independently on another working task. The chosen setting allowed a comparability between the learners.

The application of AR glasses showed, that the learning module is sufficient for trainers to carry out the remote training scenario. For the first start of AR Glasses (HMD) and the use of Remote assist app support a first hands-on, guided by a more experienced person is beneficial. The impact of the remote training learning scenario can be measured by[9]:

- Speed of carrying out tasks (efficiency in min)
- Quality of carrying out subsequent working tasks (increase of procedural knowledge)
- Number and quality of questions of learners (increase of motivation)
- Duration of use in min (comfortability of wearing AR glasses, battery life time)

The apprentices displayed different reaction. The most beneficial effects showed the top performers and underperformers in the class. The top performers could carry out the task according to their own learning speed and could ask additional questions to the trainers. The rather underperformers among the apprentices were able to catch up to the average learning apprentices as a more individualized learning focusses more on the strengths and weaknesses. For the average learning apprentices, the AR glasses showed no real effect on quality and time to carry out tasks.[10]

In comparison to the paper-based scenario, which was carried out the last years, the apprentice has got max. 8 hours to complete all working tasks. By using AR glasses, the apprentice was able to carry out the task max. 30 min - 45 min faster, as chemical processes cannot by speed up.

4 Discussion

AR glasses were used for the first time in practical training at SBG Dresden. The use of theoretical input (blended learning module) and practical assistance for using the hard- and software are necessary.[11] The enrichment of an existing course by AR (learning station) and the upfront creation of a relevant lesson plan is beneficial.

The training program responds to building up skills among trainers and apprentices to use AR glasses and relevant AR-software (Remote Assist app), to integrate AR in an existing lesson. AR trainings are an option to respond to a heterogeneous group of learners as faster learners can deepen their knowledge and slow learners are more assisted by obtaining professional

[9] Planned to be measured by an evaluation form in further tests.

[10] No. of top performers: 2 persons, No. of underperformers: 3 persons, normal performers: 5 persons.

[11] The application in more technical environments, such as chemical pilot plant training, reduces the risk of refusal among trainers. The trainer has to ensure that glasses, the Wi-Fi and the software, for providing remote assistance, work properly and the instruction, verbally or visually, have to be precise and transferred without any delays.

skills, with the focus on applying procedural, practical knowledge. Furthermore, it is expected that completing the blended learning module and carrying out the quiz will lead to the same results among further trainers of the same field or even in different fields.

The legal aspect was of rather less importance as no AR models were used and the protection of learner's personal data were covered by existing agreements between SBG Dresden and the learners / training company.

The results show, that AR provides a didactical value added, if the interaction between trainers and learner is supported and the learning process is recorded (video[12], test, exam talk with trainer).

There are limitations of the results:

1. A reference group of learners with paper-based instruction, without using AR glasses is necessary to record the effects on time efficiency, quality of results and motivation.
2. The degree of obtained procedural skills vs. in-depth skills how something works shall be measured, to prevent a solely and rather linear development of professional skills.
3. The exchange of information among apprentices during the course could not be prevented. Some apprentices might have a knowledge advantage, and processed faster in carrying out the tasks.
4. The use of further AR glasses (Vuzix, Meta 2, Daqri etc.) could show hardware limitations of the MS HoloLens, like field of view, voice quality, battery duration etc., which affected the quality and time of carrying out of tasks.
5. The differences of obtaining procedural knowledge for carrying out the selected task with and without prior knowledge should be taken into account, also for planning further observations.
6. The selection of a simpler or a selected working task, could lead to different results.
7. Further possible limitations, such as the duration and quality of remote assistance could lead to different results. It is expected that top performers can cope with a changing intensity better, then normal learners or underperformers.
   It is important to mention, that prior to the practical use of AR glasses to simulate a remote training scenario, the theoretical introduction concerning the functioning of the pilot plant and the chemical processes are needed.

5 Outlook

The remote learning scenario is an easy way to integrate new technology in existing teaching and learning methods. The simplicity to use existing hardware and software, and the need of no complex visualisation, helps to foster further application in VET. The test in further courses

[12] Videos of prior session for the subsequent instruction of learners were not used.

and among further VET trainers will provide more insides concerning the didactical value added of Augmented Reality.

The effect on learner's preparation solely with recorded videos of prior remote assisted training shall be tested to compare experience-based learning (AR glass + real-time trainers instructions) and a rather passive learning (video + paper-based instruction). In addition, the viewing of each learners remote training videos could also lead to beneficial learning effects. It is expected, in the mid-term, that when AR glasses become cheaper, more of them could be used in one class and this will also increase the number of tailor-made contents available. Augmented Reality is going to be an option for enriching existing teaching and learning scenarios in practical training.

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