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An augmented reality training application for service and maintenance of a medical analyzer: A UX approach to usefulness and user satisfaction

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***Abstract*—This paper presents an experimental study on a mobile augmented reality application for immersive training of field engineers in service and maintenance of a medical analyzer (AQT90FLEX). Based on approaches from user experience design, we developed an AR training application with the aim of high level of relevance, ease of use, usefulness, user satisfaction, and learnability. Sixteen field engineers from the multinational company Radiometer participated in the study. The procedure was divided into three iterative stages: design, prototype, and evaluation. The methods consisted of questionnaires, interviews, and co-creation. The questionnaire was inspired by the technology acceptance model. The findings revealed that all the field engineers expressed positive feedback in terms of being able to see, train, and practice on the AQT90FLEX analyzer. Especially the usefulness and user satisfaction were positively evaluated. This study also shows the importance of using mixed methods, both qualitative and quantitative approaches, in order to develop an AR training application for field engineers across the world.**

Keywords—Augmented Reality, UX, medical analyzer, technology acceptance, content analysis

I. Introduction

The accelerated evolution of augmented reality (AR) has brought forth new possibilities for developing innovative applications and has diversified the modalities of interacting with them. AR has become a fast-growing interactive technology for improved training and learning within various applications [1], [2], [3], [4]. AR blends real-world and digital information [5], with a live view of a real-world environment whose elements are augmented by computer-generated content, such as sound or graphics [6]. This combination of the real world and virtual world has been applied for a wide variety of functions, especially in education and health care [1]-[7]. AR can display a physical environment that encompasses learners with virtual interactive information, which could enhance learners' perspective and sense in real-time interaction [7]. However, when designing AR applications, important user aspects sometimes are overlooked, which has already been problematized by other scholars [8] - [11]. One of the major challenges when designing AR technologies is to match the users' motivation, attention, and interest with perceived usefulness, learnability, and user satisfaction within a very specific context [9] – [11]. This study is applied research with the following research question: How can a mobile AR application be designed and developed for immersive training of Radiometer's field engineers in service and maintenance of AQT90FLEX medical analyzer with a high level of relevance, ease of use, usefulness, user satisfaction, and learnability?

The mobile AR application is defined as a minimum viable product (MVP) for online training experience for the field engineers at Radiometer to perform maintenance on the AQT90FLEX, an immunoassay analyzer. The AQT90FLEX analyzer is based on the quantitative determination of time-resolved fluorescence to estimate the concentrations of clinically relevant markers on whole-blood and plasma specimens to which a suitable anticoagulant has been added. It is intended for use in the medical industry, such as in point-of-care and laboratory settings. Radiometer is a Danish multinational company that develops, manufactures, and markets solutions within healthcare, especially blood sampling and other diagnostic tools. The company was founded in 1935 in Copenhagen, and today it has more than 3,200 employees and direct representation in more than 32 countries.

The Covid-19 pandemic has influenced the delivery of training for the service and maintenance of AQT90FLEX, being reduced from 5 days of face-to-face training to 5 hours of online training. The online training delivery led to a decrease in the quality of the training due to the lack of visual representation of guidelines for service and maintenance of the device and practical exercises. An AR application could bridge this knowledge gap and increase the functional and visual representation of the training materials, making it an online training experience that could replace face-to-face training even after the pandemic. In this specific context, AR can supply two significant advantages. First, the AR solution is capable of recognizing images immediately through the camera on a mobile device by focusing on the service and maintenance of AQT90FLEX. Second, the AR solution is capable of immediately projecting information concerning the service and maintenance of AQT90FLEX to provide visual help and guidance concerning the most important aspects. Potentially, the AR solution could even decrease the costs associated with the training; especially the travelling costs, as the field engineers are spread worldwide.

II. Previous work

A prevalent and significant number of use cases of AR technology is encountered in education and training across various subject areas in both a formal and informal context. There is significant research on AR capabilities within the healthcare industry, addressing the opportunities AR has, especially to improve or replace some conventional training methods [11], [12]. AR has been found useful and with strong affordances in healthcare education and training [4], [9], [13] due to its potential to make the learning process easier [12], decrease the time for training [19], provide trainers an outlet for assessment, and increase success rates [14]. Research has shown AR is cost-effective training in which everyone can practice real-world tasks [15], reduces human errors [17], provides feedback and navigation, provides remote assessment and training [12], and increases learners/employees' engagement and motivation [20]. Research has already highlighted the importance of considering the user experience (UX) when designing and developing mobile augmented reality [8] - [11]. However, examples in the literature of a UX methodology used within an applied AR online training for internationally widespread field engineers are limited. The novelty in this study is the target group of geographically spread field engineers, for which the AR application needs to have highly accurate design details within a highly specific and complex training context. In the literature, UX is used as well as defined quite differently [8]-[9], with no coherent taxonomy. For this study, we define and apply UX within the ISO standard for human-centered design for interactive systems [21], in which the focus is on users' perceptions and responses that result from the use and/or anticipated use of a system (in this case, the mobile AR application). The users' perceptions and responses include their preferences before, during, and after use [21]. The UX approach also emphasize the importance of the users of the technology, rather than designing the technology itself [29]. The usage, user perspectives, and benefits for industrial AR applications were already described back in 1997, when Azuma introduced potential AR applications, which also included service and maintenance [36]. Despite Azuma's focus on the technology [36], there are some early interesting user elements in an AR technology context, such as simplicity, resolution, safety, no eye offset, and flexibility. Even more important might be the description of how to reduce complexity with the need to accept the fact that the AR system may not be robust and may not be able to perform all tasks automatically [36]. Due to hardware and software advances AR has been used more and more frequently, also in industrial contexts, including used HMD's (Head-Mounted Displays), wearable smart glasses (e.g., Microsoft Hololens 2), and mobile devices such as smartphones or tablets [20, 37-39]. One of the most important takes from the past research in the context of service and maintenance, is the necessity for developing a mobile AR application. Service and maintenance are inherent as mobile and needs flexibility [36, 41], and requirements [36, 40]. We agree with Jetter al., [40] already pinpointing those studies in the field of industrial AR applications are focusing on single industrial process. This is also due that each of the respective industrial areas and single product phases having their own requirements, limitations and consequently performance driver [40]. Therefore, it is also important not neglect the users' perceptions and responses that result from the use and/or anticipated use of an industrial AR application. The users' perceptions are important as to improve the AR application/system with complex interactions, perceptions, interpretations, and learnings in various and broader contexts.

III. METHODS

A. Participants and ethical considerations

Sixteen field engineers voluntarily participated in this study. All the participants were from the Technical Service Department at Radiometer. The participants were from countries where Radiometer commercializes the AQT90FLEX analyzer. There were 12 participants from Europe, and 4 from Australia. All participants gave informed consent, and they were informed that they could withdraw from the study at any time. In addition, all participants were provided with anonymized ID numbers, and all data were labeled with these IDs. We applied special considerations when recruiting participants across countries, in accordance with the international code of conduct [22] and ethical approval from Radiometer.

B. Procedure

The procedure was divided into three stages: design, prototype, and evaluation. Each of the phases included different methods.

Design: A 20-item questionnaire that included 15 open-ended questions was developed with the purpose of identifying user characteristics. The questionnaire included demographic information, work experience, tool set skills, AQT90FLEX training experience, and preferred learning styles. All 16 field engineers replied to the design questionnaire. Furthermore, within the design process, seven field engineers were interviewed in depth to identify the possible features of and use cases for the AR training. At the end of the design stage, three co-creation sessions were conducted [23] with two groups (Group A had 3 participants, Group B had 5 participants), lasting 90 minutes each. Based on the questionnaire, interviews, and co-creation, there were outlined personas, application features, and design considerations.

Prototype: The prototype development was within an iterative process, and it included pilot testing, conducted with field engineers in Denmark ($n = 6$). The pilot testing included usability testing (with used observations and questionnaires) with a follow-up interview with discussions for improving the designed AR experience. The improvements especially included reduced waiting time in the application, text subtitles, implementation of a help menu, and minor bug fixes.

Evaluation: The evaluation of the application was conducted using a questionnaire and follow-up interviews ($n = 7$). The participants received a questionnaire for the assessment of the ease of use, visual interface, user satisfaction, learning outcome/usefulness of the AR application, and the application's learnability. On 5-point Likert scale, the participants could choose between *strongly disagree*, *disagree*, *neutral*, *agree*, *strongly agree*. The theoretical framework behind the questionnaire was inspired by the technology acceptance model (TAM) [24] – [25], which emphasizes technologies and the ways users (in this case field engineers) come to accept and use (AR training) technology. The TAM suggests that when users are presented with a new technology, a number of factors influence their decisions regarding how and when they will use it; notably, these include perceived usefulness and perceived ease of use [24], as well as satisfaction, and general perceptions [25]. Using TAM as in evaluation of AR tools for industrial applications is already performed by other scholars [40]. TAM can be used as an indicator of the users (AR-technology) acceptance, as the users only briefly interact with the application [24] in a pre-adoption process. The foundation in TAM is that 'perceived ease of use' and 'perceived usefulness' are antecedents of 'behavioral intention to use', which consequently leads to 'usage behaviour'. Perceived usefulness is defined as the degree to which an individual believes that using a particular system would enhance his or her job performance [24], while the perceived ease of use is described as the degree to which an individual believes that using a particular system would be free of physical and mental effort [24]. The basic relationships of the TAM model have been well-investigated and validated by various meta-analysis [42, 43]. The questionnaire was followed by interviews with seven field engineers to gain further in-depth insights into their AR experience.

C. Data analysis

Researchers analyzed the questionnaires using cumulative frequency (i.e., the total number of answers to specific questions). They analyzed the interviews using traditional coding [30], and content analysis [31]. The traditional coding followed four steps: organizing, recognizing, coding, and interpretation. They transcribed the interviews verbatim to be organized and prepared for data analysis. The researchers read the transcripts several times to recognize the concepts, which also included a general sense of the information and an opportunity to reflect on its overall meaning. There was found 17 themes. Researchers then categorized and interpreted each interview statement by following an interpretation and content analysis of positive and negative statements within each of the 17 themes.

IV. DESIGN AND IMPLEMENTATIONS

The AR application was built for both Android and iOS. For recognizing and tracking objects, we used the Vuforia AR [26] engine for Unity3D. Vuforia uses computer vision technology to recognize and track planar images and 3D objects in real time. The final application (Figure 1) consisted of troubleshooting, hands-on library, and how-it-works features, as well as a video module. In this paper, we will focus only on the troubleshooting feature within the specific AR training for the AQT90FLEX analyzer.

Fig. 1. Front page of the AR application

The troubleshooting consisted of three steps: (a) retrieving and saving a service dump file, (b) determining the error code from the ACT90FLEX analyzer, and (c) inserting the code in the AR application (Figure 2).

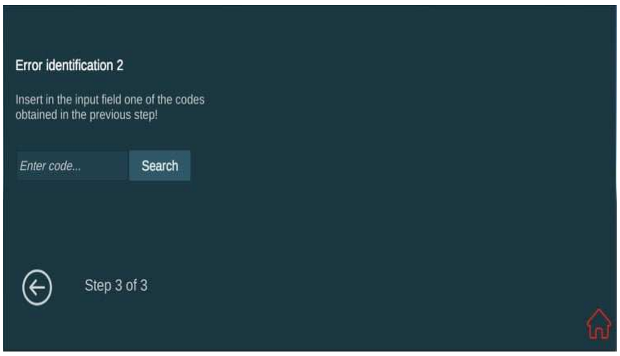

Fig. 2. Interface of entering the error code

It took some effort to create an object for declaring the error code specifications (Figure 3), which on a later stage should be used in the dictionary of objects to determine the displayed information (after the input of the error code). There was also included feedback, if the field engineer inserted a wrong/ not recognized error code.

```
public class ErrorCodes
{
    // Start is called before the first frame update
    public string errorDescription;
    public string errorSolution;

    16 references
    public ErrorCodes(string newDescription, string newSolution)
    {
        errorDescription = newDescription;
        errorSolution = newSolution;
    }
```

Fig. 3. Error code specifications

After inserting the detected error, the application displayed the reason an error might occur as well as the service action needed. In this paper, we will follow error code 1267 as an example, accompanied by a service action involving a needle-wash procedure. Error code 1267 has 12 steps, each of which is an activity the field engineer should follow in solving the error. Each of the 12 steps can be individually played, and there is no dependency or need to wait for the animations to be finished before going to the next step. This freedom of movement between activities was considered to target specific steps in their training exercises or maintenance activities.

In Step 1 (Figure 4), the field engineer using the AR training application was asked to open the back of the analyzer, provide a back view, open three screws at the top, and open two screws at the bottom, followed by some safety information.

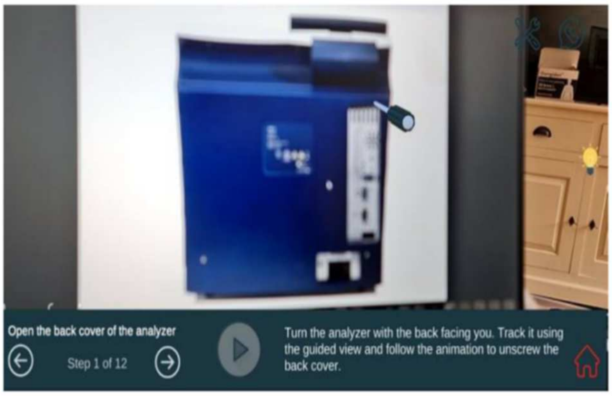

Fig. 4. Step 1 in the AR training

In some of the steps, the AR representation of the training activities included further information and helpful media elements (Figure 5), including videos, text box instructions, 3D models, figures, tables, and pictures.

Fig. 5. Included additional media elements, in step 3 an example of an implemented video clip.

Most 3D models used were representations of the AQT90FLEX analyzer and its various parts (e.g., the inlet wheel and the needle wash unit; Figure 6). Different independent 3D models were also implemented for use (e.g., the front cover, back cover, and screen). The lack of accuracy of the 3D models led to a time-consuming amount of work for some fixes to be implemented for improving similarity.

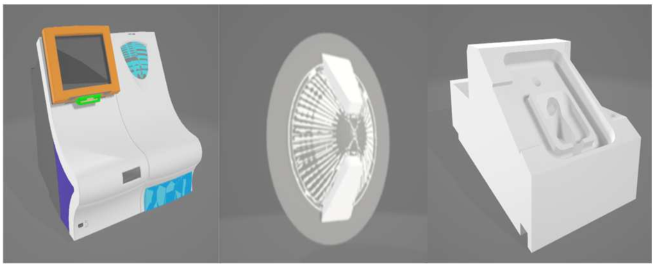

Fig. 6. Examples of developed context-specific 3D models, the analyzer, the inlet wheel, and the needle wash

Other 3D models were easier to implement, such as the screwdriver, the tube, the cotton swab, and the recipient beaker (Figure 7), which were freely accessible online and could be perceived being less context specific.

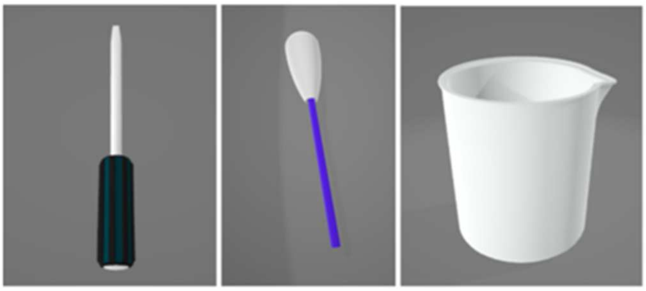

Fig. 7. 3D models being less context specific with a general representation

The overall design of the AR application was inspired by Donald Norman's six UX design principles [28] including visibility, feedback, constrains, mapping, consistency, and affordance.

Visibility is about the users need to know what all the options are and know straight away how to access them. The AR application was developed to have the most import elements in sight when the field engineer was performing the training sessions. This could be with e.g., the screwdriver or cotton swab (Figure 7) as within the training in step 1 (Figure 4). However, this was also one of the most difficult design principles to implement, as the users' preferences and context could be very different.

Feedback is the principle of making it clear to the field engineers what action has been taken and what has been accomplished. Therefore, we made it clear for the field engineers at which step they were at now, and what to do next. This was implemented in the AR application as "Step X of Y" in the lower-left corner of the screen (Figure 4 and 5) and providing leftwards and rightwards arrows in order to indicate a moving step back or forward (Figure 4 and 5). Further, there was indicated text of what to now, and what to next (within the specific step) (Figure 4 and 5).

Constrains is about limiting the range of interaction possibilities for the field engineers to simplify the interface and guide them to the appropriate action. The constraints are clarifying, since they make it clear what can be done. An example of one of the constrains is the input of the error code (Figure 2); which also provided a systematic procedure, process, and identification.

Mapping is about having a clear relationship between controls and the interactions and behavior. This was implemented in the AR application by clear icons, e.g. the leftwards and rightwards arrows (Figure 8), and the "house" in the lower right corner for main/home menu (Figure 8). Further, there was implemented an icon for troubleshooting and help support call in upper right corner (Figure 8). The well-known icons allowed the field engineers to know where to go to.

Fig. 8. Implemented icons and 3D models

Also, the home/front page (Figure 1) with its structured and systematic approach in four boxes was design to provide a clear mapping.

Consistency is about to restrict a particular form of user interaction with an interface. The consistency was implemented by having similar operations and similar elements for achieving similar tasks in the AR application. Different error codes followed the same overall stepwise procedure, and within the same design. This could potentially be very important, as this AR application was new, and not used and tried out before.

Affordance refers to an attribute of an object that allows people to know how to use it. Besides the implemented well-known icons in the mapping, we also provided a "how it works" (Figure 1), a tutorial accessible from the front page. This was implemented in order to get the field engineers high affordances within this new technology development.

V. FINDINGS

A. Ease of use, visual interface, user satisfaction, usefulness, and learnability

The AR training application was positively evaluated. In particular, the usefulness and user satisfaction were perceived as high, both from the questionnaire results (Table 1) and the interviews (Table 2). The usefulness items in the questionnaire covered questions concerning perceived enhanced skill level of performing the tasks as well as whether the AR training application was a valuable training tool and whether the AR training could improve the skills transfer between experience and everyday work tasks. The usefulness had a mean of 4.3 (SD = .50) from the questionnaire (Table 1), and the user satisfaction had a mean of 3.8 (SD = .90) (Table 1). The user satisfaction covered questions such as, "I enjoy the time I spend using the AR training application," "I am satisfied with how the activities are presented by the AR training application," and "I would recommend this AR training application to my colleagues."

TABLE I. FINDINGS FROM THE QUESTIONNAIRE (N=7)

Items	*Range (minimum-maximum*	*Mean*	*SD*
Ease of use	2.83 – 4.83	3.63	.55451
Visual interface	3.00 – 5.00	3.78	.55277
User satisfaction	2.00 – 5.00	3.81	.89925
Usefulness	4.00 – 5.00	4.33	.50000
Learnability	3.00 – 4.50	3.58	.46771
Average		3.83	.595

It is interesting that in spite of the positive usefulness and user satisfaction ratings, the learnability was evaluated with the lowest score ($M = 3.6$, $SD = .48$; Table 1). The learnability was evaluated positively, but participants included further suggestions for improvement, including in the interviews. In the questionnaire, it also appeared difficult to ask the right questions within the learnability because the learnability comes with many individual preferences and specific context, which might be difficult to cover and answer in a questionnaire. The questions asked in the questionnaire concerning the learnability aspect were, "It takes too long to learn the functions in the AR training application," "The AR training disrupted the way I normally like to arrange my learning/work," "There is not enough information provided on the screen," and "The AR application presents the information clearly and understandably". The wording "too long to learn," "disruption," "normally," and "enough information" might be very differently perceived as well as used/interacted with in various contexts. The ease of use item ($M = 3.6$, $SD = .55$) mainly covered questions concerning usability: understandable and ease to use buttons, icons, menus, settings, instructions, and error/mistake codes. The visual interface item ($M = 3.8$, $SD = .55$) covered questions concerning perceived visual interface consistency and the aesthetics of the interface.

The positive results concerning the usefulness and user satisfaction items were validated by the interviews. From the interviews, four themes within the usefulness item and three themes within the user satisfaction item were categorized, and participants made no negative statements within either the usefulness or the user satisfaction items (Table 2).

TABLE II. FINDINGS FROM THE INTERVIEW DATA

Content analysis, Interview data				
Items	***Themes***	***Nega-tive***	***Neutral***	***Positive***
Ease of use	User flow	2	2	14
	AQT recognition	8	0	0
	Content	8	5	1
	Other	0	3	0
Visual interface	Aesthetics	3	0	1
	Animation	1	0	8
	Media	3	0	1
	recommandation	0	6	3
	Text	1	0	5
User Satisfaction	Content	0	0	7
	Enjoyment	0	0	3
	Media	0	0	2
Usefullness	Multipurpose	0	0	5
	Accessability	0	0	4
	Service	0	0	2
	Training	0	0	2
Learnability	Learnability	1	0	1

Despite the positive comments, the interviews revealed that the AR application could be improved, especially the ease of use and elements with the content as well as the advanced query tool (AQT) recognition. The comments for the content improvements mainly concerned difficult field engineering terminology, which in a few places was incorrect. The comments regarding the AQT recognition indicated a problem recognizing the medical device and identifying the optimal distance to keep from the device from triggering the recognition. The reasoning behind the issues recognizing the AQT was the use of iPhones for testing that appeared to cause problems related to keeping the dimension ratio/animation accuracy. The interviews revealed the field engineers were generally positive about the AR application, especially the training for the AQT90FLEX analyzer because it is one of the most complicated machines. Further, almost all the field engineers expressed being more comfortable fixing the analyzer with the AR application because they rarely do maintenance on this specific analyzer.

B. User, context and technology

Interactions, perceptions, learning activities, and learning outcomes, can be revealed within three overall factors (user, context, and the AR system) as part of a user experience in the developed AR training application. In between the factors there are not only interactions, but also various perceptions and behaviors, learnings outcomes dependent on some sub-elements within each factor. Figure 9 shows a model of the factors and sub-elements revealed by the participants. The model is inspired from [32] and [44], also described within a user experience perspective. However, we have added to and modified the model with the user inclusion of learning styles, co-presence, interruptions, experience, involvement, novelty, aesthetics, technology acceptance and trust [33], and specified elements within the AR training system.

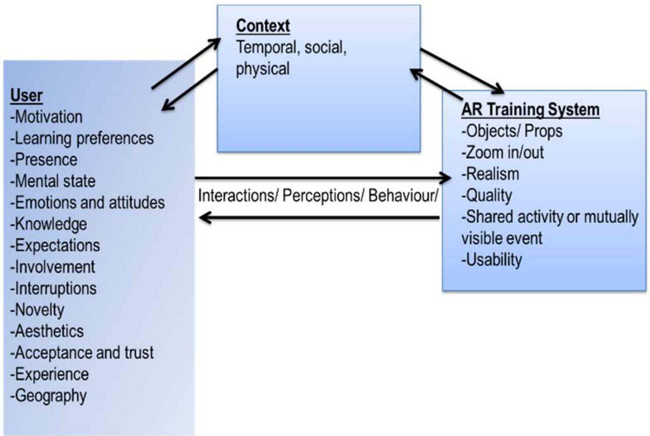

Fig. 9. Factors and sub-elements within user, context, and the AR training system.

One of the main motivations from the field engineers (FE) was in the interviews and co-creation expressed as reduced complexity, and a supplement for the training at highly complex system which was rarely used.

"The AQT90FLEX analyzer is by far the most complicated instrument…and by that the AR could potentially reduce or help this complexity." (FE: K2).

"Engineers are not always that comfortable in fixing the equipment because they don't see the issues quite often." … This application provide an understanding of how everything works together." (FE: K1)

"There is great potential for training in maintenance and troubleshooting with a hand-on." (FE: A1)

Another element frequently mentioned was a common accommodator and converger [34] learning style, with much emphasis on the hands-on:

"We tend to learn much faster when the hands-on experience is included in the training." (FE: K1)

"I tend to actually like to try something before I step into the field." (FE: A3)

"Some engineers learn by doing, not listening." (FE: K2)

In the user category, some of the sub-elements that impacted interactions and perceptions include the degree of co-presence from others (how many and whom), the degree of motivation, mental state, emotions, attitudes, knowledge (e.g., IT skills and knowledge), expectations, involvement, novelty, aesthetics, technology acceptance and trust, and geography/ cultural differences). It was commonly mentioned that doing service and maintenance training is not an isolated individual task, but can often be in co-presence and collaboration with others; both e.g. trainees (young professionals), help support, other employees, and clients. Involvement is a psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities and events [35]. Involvement depends on the degree of significance or meaning that the individual field engineer attaches to the ongoing stimuli in the AR training. The involvement can though also be challenged by interruptions, e.g. phone calls, missing elements, or physical conversation interruptions.

The context of the training can be very different, including both remote and physical/location-based training, and be in different social contexts as well. The field engineers were very specific in terms of the different requirements they would like in the AR system; including e.g., the right objects, the ability to zoom in and out, a high degree of realism and quality, good usability, as well as the possibility for having it as shared experiences.

VI. LIMITATIONS

The main limitation of this study is the imperfect study design with a small sample size, lack of randomization, missing proper baselines, and the lack of control groups. In that regard, we had difficulties reporting the specific learning and training effects of the designed AR application. However, an imperfect study design is a very common limitation in many other AR training studies [1], [4], [16], [17], [18]. Future work is needed to create significant evidence of and insight into the training and learning outcomes of AR. The exact methods of interaction with the field engineers were difficult to describe in detail due to being within an iterative design process within a very context-specific AR application. Therefore, even though we followed a rather systematic methodology, it is difficult to repeat the study. Thus, we should be careful about concluding the cause of any effect was due to the AR technology. Further, as within many other experimental technology studies, we also need to consider the novelty effect. Many AR studies (including this one) are not longitudinal enough to exclude these novelty effects.

Many scholars across disciplines have used the Technology Acceptance Model (TAM) in many different contexts [47], [48]. In spite that the TAM model [24, 25] was useful in this study, there are some limitations towards the model, which should be considered. One limitation of the TAM is the variable of user behavior, which is evaluated through subjective means like behavioral intention and interpersonal influence [45]. We mitigated this limitation and critique towards the TAM model by including not only TAM-questions in the questionnaire, and especially by used interviews. The interviews provided lots of further beneficial insights and complexity – in contrast to the simplicity of the TAM model. The insights from the interviews included (as it appears from the quotes) also some subjective reflections towards (engineering) norms and personality traits. Another limitation in the TAM is the missing external variables [46] like age, education, and skills, which was mitigated by asking for exactly those variables. However, with sixteen field engineers included in the study, one should be very careful of making statistical analysis on these external variables.

VII. DISCUSSION AND CONCLUSION

The existing literature on mobile AR training is covered within many design guidelines and frameworks, such as the mobile augmented reality education design framework [7]. However, there is often a lack of clear basis on learning theories [3], [11] combined with an approach or process to guide the design path [27]. We suggest taking greater advantage of UX approaches, including co-creation and other related methods to improve the AR training. With the developed AR training application in this study, all the field engineers expressed positive feedback in terms of being able to see, train, and practice on the AQT90FLEX analyzer. A reason for the positive evaluation of the AR training application, especially within the usefulness and user satisfaction items, could be due the high degree of effort to include the users (i.e., field engineers) at a very early stage and throughout the entire design process. Further, much effort was made to design the AR application based upon an explicit understanding of the users, tasks, and environments. In the literature, there seems to be some challenges with matching design ideas, implementation, and data quality in AR studies. The big question is how to incorporate elements concerning users, contexts, and AR systems, as well as gathering the right data for the research questions/theories within a new AR field of technological development. One of the major challenges when designing technologies for users is to match users' motivation, attention, interest, and need with the context and technology. It is important to motivate the field engineers to use this AR training system on a more regular basis or as part of everyday work life. An important element in this motivation could be to continue the co-design of the AR training system with design input from the field engineers. Moreover, there could even be harder questions concerning ways to provide better research designs in a field/company context, where the given user groups come with diverse variables (e.g., motivation, learning styles, skills, or feedback opportunities). Even if one has the right data and a good research design, the data might still hide conclusions. This experimental study has shown an extremely complex AR training application for field engineers across the world requires mixed methods using both qualitative and quantitative data throughout the entire design process. Logdata, analysis of variance, high F-scores or standard deviation are not enough to understand in full the users' perceptions and behavior in AR training facilitations.

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