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Problem Space Identification for Developing Virtual Reality Learning Environments

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Abstract

Our study argues that the extant literature on virtual reality-based learning environments (VRLEs) currently lacks proper definitions and context descriptions for a problem space, which is fundamental for conducting design science research (DSR). Without properly conducted problem space identification, the most pivotal problems cannot be identified resulting solutions lacking validity and unreliable evaluations. This is a major challenge for the DSR in the educational field, but also for the research on VRLEs. The purpose of this paper is to introduce a novel DSR method to support rigorous problem space identification, which would allow rigorous and profound problem space analysis. The instantiation of our method is depicted with a VRLE development project. In the problem space identification –process we adopt the concepts of self-determination theory and learning path to study and consider individual and a system level of the current VRLE artifact. This theoretical lens enables us to identify the problem space for VRLEs and also suggest how the to-be-developed artifact to be later evaluated. This paper contributes by introducing a general problem space identification for VRLEs and a DSR method to guide the future DSR in the educational field.

1. Introduction

The use of Virtual Reality-based Learning Environments (VRLEs) are increasing both in educational institutions, but in workplace learning settings as well. In order to find effective solutions, VRLEs must be considered as part of the whole system i.e., learning path. By definition, learning path is a system defining learning objectives, user experiences and outcomes [1].

The pedagogical viewpoint is crucial when developing VRLEs. Therefore, it is usual that during the development, pedagogic professionals are needed to guide the pedagogical aspects of the learning environment being developed.

Design Science (DS) has been widely accepted within the educational sciences [4]. The methodologies used typically in the educational sciences include Design based research (DBR) and Educational Design Research (EDR). However, as indicated by Sandoval [4], the design research methodologies in the educational field have not matured and consolidated causing misconceptions and confusion in the field. Perhaps due to those reasons, the most of the existing VRLE studies have had quite narrow focus neglecting the system level i.e., the learning path [5]. Further, this has led to inappropriate context and problem definitions and hence suggested solutions have lacked validity and reliability.

Design Science Research (DSR) is an approach to study effective system solutions [2] and create design knowledge on how to develop them [3]. While it is also based on the same basic concepts as DBR and EDR, DSR has not been widely used in the context of educational sciences. Central for DSR is investigating the problem space and the ”fit” of the proposed solution artifact to the context, including e.g. technology-related considerations as well as socio-technical aspects in order to achieve a satisfactory solution [3]. These include e.g. the usability and accessibility of the technology, both from the user experience and wider social context –point of views. These components make DSR a viable method to be used in the educational context.

The main objective and research question is to study whether an interview-based method can be used as DSR problem cloud identification. The instantiation of the method is depicted with a VRLE development project in the context of flight personnel basic course training. The results of this study help not only DSR but all DS-based research methodologies, as the same problem cloud

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investigation -phase is central for all Design Science -based research methodologies, such as DBR and EDR.

2. Literature

2.1. Virtual Reality and Virtual Reality Learning Environments

According to Milgram and Kishino [6], Virtual Reality (VR) can be defined as an artificial, computer-generated environment in which users can interact with the environment. With VR, one is able to do activities and interactions which could be expensive, dangerous, or even impossible in the real world [7]. One of the most interesting use-cases for VR environments are their applications in educational settings.

Virtual Reality Learning Environment (VRLE) is a virtual reality -based learning environment [5]. Some of the use-cases of VRLEs include safety training simulations [8, 9] and conducting hazardous field test in science, technology, engineering and mathematics (STEM) [10]. One of the affordances of using VRLEs in learning is increased learning motivation and engagement [9, 11].

To assess student performance and accuracy during the tasks done inside VRLEs, built-in learning analytics can be used. Some of the learning analytics used in the previous studies and VRLEs include analyzing task performance [12] and eye-movement tracking [13].

2.2. Design science research (DSR)

Brocke et al. [3] provides a short and effective definition of the DSR in general:" The goal of DSR is to generate knowledge on how to build innovative solutions to important problems effectively (p.5)". DSR focuses especially on the construction of socio-technical artifacts, such as the implementation of VRLEs in organizations [18].

While mostly used in the information systems research (IS), Design Science Research Methodology (DSR) has also been used in the educational sciences. According to com Brocke et al. [3], DSR knowledge can be divided into three main components: problem space, evaluation and solution space (Figure 1). To gain knowledge on the problem space, context domain and the goodness criteria of the problem needs to be specified. The context domain has three subcategories: stakeholders, time and space. Stakeholders are everyone involved in the problem space. In the context of a learning environment, stakeholders can include the teachers, students and other personnel in the educational institution. Time and space are related to e.g. to the geographical details of the context (e.g. rural or urban school) [3].

Vom Brocke et al. [3] further stresses out that any practical solution has socio-technical aspects when describing the goodness criteria. Therefore, on the goodness criteria -section of the problem space, one has to investigate the criteria related to the technology (e.g. performance and security), information (e.g. quality and accuracy of the information), interaction (e.g. accessibility, usability) and society (e.g. societal and fairness) -aspects in order to achieve a satisfactory solution [3].

The main goal of DSR is to develop prescriptive knowledge about design artifacts [2]. These artifacts can be methods, constructs, models and design theories [18]. Artifacts are designed to solve problems stated on the problem cloud. These artifacts are built in the solution space, using evaluation processes [3].

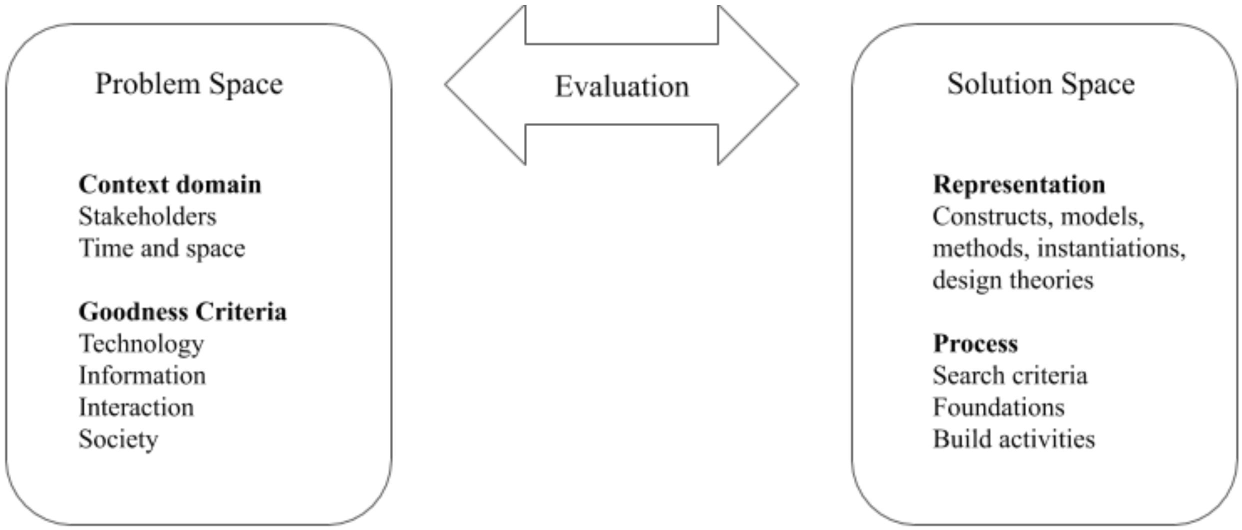
Based on the work of vom Brocke et al. [3], Lähtevänoja et al. [5] developed a practical model for examining and developing the DSR knowledge in the context of VRLEs. The model is based on questions investigating the level of DSR knowledge. While the conceptual model is more targeted to studies already completed, the first stages of the practical model 1) "What was the study context", 2) "How was the problem positioned to the problem space" and "Antecedents" (e.g. trainers' or teacher's attitudes, educational beliefs, available resources, skill levels etc.) are related to the investigating work before conducting a DSR project. Therefore, it is important to consider these before actually proceeding in the DSR process mainly to understand the problem context better. As Lähtevänoja et al. [5] found out, these antecedents are seldom considered in previous VRLE studies as a part of the problem cloud investigation.

2.3. Design based research (DBR) and Educational Design Research (EDR)

Design Research -based methodologies have been used in the educational sciences previously, mainly by using Design Based Research (DBR) or Educational Design Research (EDR), which is based on DBR.

DBR is a paradigm, which has been described using different terms in the previous literature, including design experiments, design research, development research, developmental research and formative research. While each of these terms include a different focus, the underlying approaches and goals are the same [14]. Furthermore, The Design-Based Research Collective [15] proposes five characteristics which good design based research exhibits: 1) That central goals of designing learning environments and developing theories of learning are intertwined, 2) that the

Figure 1. Components of the design knowledge for a specific project. Adapted from vom Brocke et al. [3].



development and research take place through continuous cycles of design, enactment, analysis and redesign, 3) that research on designs must lead to sharable theories which helps to communicate relevant implications to practitioners and other educational designers, 4) that research on designs must account on how the designs function on authentic settings, reporting not only successes and failures but also the interactions which refine our understanding on the learning issues involved and finally, 5) that the development relies on methods that can be document and connect processes of enactment to outcomes of interest [15].

Based on DBR, Kopcha et al. [16] introduced the phases of the educational design research approach (EDR), originally presented by McKenney & Reeves [17]. EDR has three central phases: 1) analysis and exploration (understanding educational problems through analysis of literature, stakeholders and context), 2), design and construction (presenting design frameworks together with the theoretical and empirical grounding that gives them shape and 3), evaluation and reflection (describing the practical and scientific implications that result from formative and/or summative evaluations of designed interventions) [16].

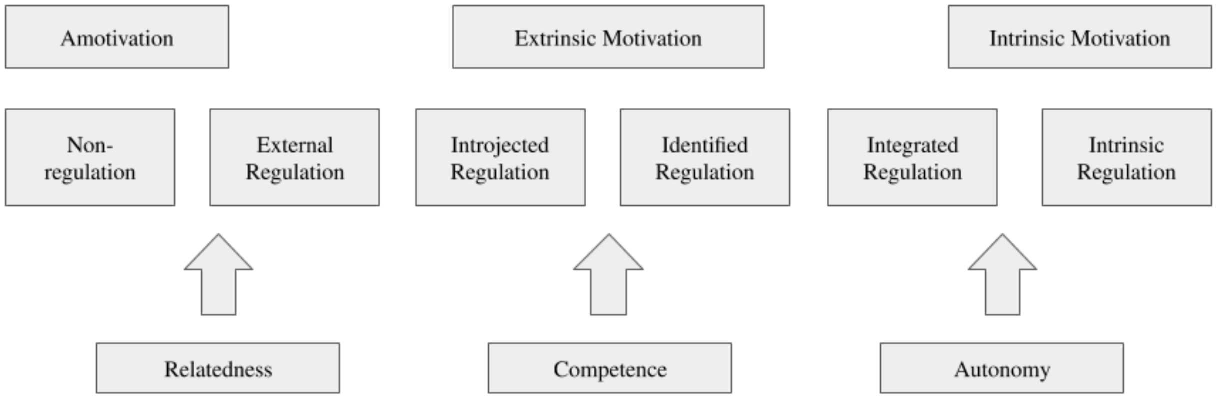
While the focus of EDR is only on the educational sciences, DSR is more general and multidisciplinary in its nature. According to Nunamaker et al. [20], the strength of DSR in IS is the multidisciplinary and holistic approach in testing and creating new technologies and techniques. This multidisciplinary approach allows taking multiple perspectives and takeaways from different fields also into consideration.

2.4. Previous research

Some previous research on the field of VRLEs has applied Design Research-based methodologies. As previously stated by Lähtevänoja et al. [5], the problem space investigation has been quite insufficient, by not exploring the problem positioning in terms of context and goodness criteria. Not many studies exist on the field of VRLEs who have used DSR, DBR or EDR methodology, but those who have, contain the presentation of the problem space in a general level and go quite straight to the solution and evaluation-phases of the design process. This is quite a common shortage in IS research in general as well, as addressed by vom Brocke et al. [3].

Cochrane et al. [21], while building a DBR-based framework for studying mobile VRLEs, illustrated the framework with two example projects. The first project (immersive VRLE for paramedic students) contained a summary of the problem (visualizing an emergency situation) and a presentation of a possible solution for it (authentic 360-video based view of the emergency scene). The context nor the problem position is not very widely explained. Although a preliminary survey was conducted about prior experience and conceptions about VR, it is not connected clearly to the DBR process. The analysis and exploration stage builds therefore mainly from the previous literature. Cowling et al. [22] studied XR-based application to enhance paramedic skills using DBR-framework. Cowling et al. presented a ”Pedagogy Before Technology” -worksheet for educators and educational designers. In the worksheet, ”What is the problem” phase covers the problem identification. However, the analysis and the problem position, context

Figure 2. Self-determination theory, adapted by Cook and Artino [28].



presentation and evaluation of the goodness criteria lack from the model. Holopainen et al. [23] studied learning outcomes in VRLEs using various technologies (immersive VR, 3D-video and 2D-video) using affordance-theory and DSRM-methodology. The article is explorative in its nature, and the problem cloud identification and problem position inside the problem cloud is lacking, building mostly only from previous research on the field. van Wyk et al. [24] used a DBR-based research approach to develop VRLE for the mining industry. van Wyk presents a new DBR-based model where the first stage is ”Problem analysis within context”. While the worksheet presents the problem identification well, it does not contain much of the context nor the problem positioning necessary for utilizing the existing design knowledge, developing fit solutions and conducting credible evaluations [3]. Teräs et al. [34 studied e-learning using EBR. The analysis and exploration stage of the EDR process was done by conducting negotiations and web conferences, where the stakeholders could share their views and express their expectations. These discussions were combined with a curriculum analysis to help the customization of the e-learning content developed during the process [19]. However, the discussions were not connected to previous literature during the analysis and exploration stage to allow more rigorous and profound analysis.

3. Theoretical framework and approach

3.1. Self-determination theory and learning path

Effective learning requires balancing one’s cognitive skills, affective and metacognitive conditions [25, 26], which essentially means that one needs to understand the content, is willing to invest effort in studying and is able to regulate the learning process [26]. In this article, the affective component is further studied, following the research of Ten Cate et al. [26]. Much like in the article of Ten Cate [26], theory of self-determination (SDT) is used to investigate the affective component - by using SDT, the successes and failures of education can be understood [26]. The theory of self-determination (SDT) is an empirically derived theory of human motivation and personality [27], and it is one of the major motivational theories in psychology [26]. SDT seeks to investigate how humans internalize regulation that initially has been external in order to develop autonomous and self-determined behavior [26].

The self-determination theory framework consists of three main motivation types: amotivation, extrinsic motivation and intrinsic motivation. In addition, the framework includes six regulatory styles. The framework is presented as a scale, from lowest amount of motivation to the highest amount of motivation. Amotivation is positioned on the left extreme of the scale, indicating a complete lack of motivation. Amotivation results either in inaction or action without real intent. On the right extreme is intrinsic motivation, the highest form of motivation. Intrinsic motivation is entirely internal motivation and emerges from personal interest, curiosity or enjoyment of the task. Extrinsic motivation is located in the middle of the scale. Extrinsic motivation is driven by social values. When values become integrated and internalized, the extrinsic actions can become self-determined. On the scale, the four regulatory styles indicate these value changes (external regulation, introjected regulation, identified regulation and integrated regulation, respectively) [28]. These motivation types are affected by the physiological needs, main components being relatedness, competence and autonomy [29]. These three motivation types and psychological needs are illustrated in Figure 2.

Relatedness is related to one's desire to feel connected with others, to be cared for and to have a sense of belongingness, with significant other individuals and a significant community. While relatedness is enhanced by security, respect, caring and inclusive environment, it is undermined by criticism, cliques, traditions and competition [28].

Competence is related to one's desire to feel effective in actions one performs and the desire to seek challenges which are optimal for their capacities [26]. While competence is enhanced by positive performance feedback and optimal challenge, it is undermined by negative performance feedback and excessive challenge [28].

Autonomy is related to one's experience that behavior is an expression of the self, generating a complete feeling of free will. It is therefore a desire to be one's own origin or source of behavior [26]. While autonomy is enhanced by acknowledgment of feelings, explanation and choice, it is undermined by imposed goals, control, threats, deadline and tangible rewards [28].

The theory suggests that these three needs specify the necessary conditions for psychological growth, integrity and well-being [30]. The theory is widely used in the field of education, e.g. in physical education [31], medical education [26] and gamified e-learning design [32].

3.2. Research approach and questions

The case of the study was an airline's basic course for flight personnel. The airline in question trains students to work as flight attendants. The basic course is 8-week long, involving theory classes, practical training and familiarization flights. Training consists of three main subject matters: first aid, safety and service. First aid prepares students to give first aid to passengers in case of sickness or emergency. Safety concentrates on the safety-related situations, such as emergency landings and disturbing passengers. Service focuses on the passenger interaction. The course takes place physically in the airline's premises, where physical simulators can be used as a part of the course. The course also involves online learning and contact classes.

While the airline's training has got good feedback from the students, there are some things which cannot be taught in real life (e.g. complex emergency situations involving components from all of the subject matters). In addition, physical plane visits for training purposes are wanted to be reduced due to logistical reasons. Students are also constantly asking for more hands-on training. Based on these requirements, a Virtual Reality (VR)-based learning environment (VRLE) would work as a possible solution. In order to get a good understanding from the learning path as a whole for the development of the VRLE(s), a general interview framework was designed (not specified to VRLEs).

Prior to the interviews, some proof of-concept VRLEs have been developed and tested within the airline, but these are not in every-day use.

In order to investigate the problem cloud of the flight personnel learning path, several interviews with the trainers of the basic course were conducted. The interviews were conducted in two rounds. The first round was a free-form interview, and the second interview round had a framework, based on the results obtained from the first round. In the first round, a total of four trainers were interviewed. In the second round, two trainers from each subject were interviewed (except first aid only 1), totaling 7 interviewees on the second round. The first round of the interviews was conducted in December 2019, and the second phase was conducted in March 2020.

After the first round of interviews, it was evident that the overall learning process of the airline's basic course, including the student motivation and learning activities was the main focus area. Therefore, SDT and overall learning path assessment were used as a base to conduct the problem space identification in order to investigate the course not only from the socio-technical perspective [3], but also from the intrinsic motivation model perspective (SDT). These frameworks are applicable to conduct DSR for many reasons. For example, as defined by vom Brocke et al. [3], DSR studies constructions of socio-technical artifacts.

SDT also recognizes this social level of analysis, however, it also dives into deeper levels of individual motivations i.e. intrinsic regulation and mental models. In terms of the learning path, by the definition it describes a system which brings the system perspective into our analysis also following the DSR approach [20].

Interview framework for the second phase was built using the Self-Determination theory (orig. Ryan & Deci [29]) and general questions about the learning path. The interview results were analyzed using qualitative methods. The interview questions are illustrated in Table 1.

Table 1. Interview questions.

AUTONOMY	COMPETENCE	RELATEDNESS	GENERAL QUESTIONS ABOUT THE TRAINING PATH
Is the learning path of the students being controlled?	Is the training demanding enough for the students/trainers?	Is caring atmosphere being shown towards the students and if so, how is that being manifested?	How well the learning situations and materials are linked to the real world, work-life situations?
Which kind of freedom do the student/trainers have regarding the training?	Are the students/trainers being given feedback about their performance?	Do the trainers feel that they can ask or fail?	Does the current training path prepare the students for making their own conclusions and realizations?
How the learning goals are presented? Can the trainer affect to the learning goals?	Are students/trainers being given negative feedback about their performance?	Is there any competitive position being formed within students/within trainers?	Does the current training path make it possible to develop the situational awareness?
How the feelings of the students/trainers are managed?	Do the students wish to have more feedback about their performance/Can the trainer give enough feedback?	Are there any harmful traditions being formed within students/trainers?	How the current training path could be improved? What are the biggest shortages of the current training path?
Are student/trainers rewarded about their accomplishments?		Do the students criticise the training/the airline?	What cannot be taught during the current training path?
Which kind of threats do the students/trainers have in their minds?			
Which kind of goals and targets students set for themselves/are being set for them?			

4. Results

4.1. Autonomy

Regarding Autonomy-component, it seems that the training is quite controlled. The timespan of the training is quite short (8 weeks), and there are lots of topics regulated by the authorities (e.g. safety training), which has to be done in a given way, using a given method. The curriculum is quite strict, and the learning path is the same for everyone, largely due to the regulations described above. The learning goals are presented in the beginning of each lesson. Trainers mention that there are emotional bursts among students, due to stress and workload. During training there are two longer feedback interviews (mid-term and final assessment), where students can open up. Among trainers, emotions are managed during coffee room discussions. Regarding rewarding, students pick one student who has been keeping the group spirit high. Regarding threats, it comes as a surprise to many students that if you do not pass a certain safety test, you are out from the course. In addition, the wide scope of the studies come as a surprise to many, especially on the safety-subject. Trainers are pretty used to stress regarding the field, but for younger trainers the COVID-19 situation is the first real catastrophe. Regarding personal learning goals, the learning goals of the course are pretty much pre-determined. Self-assessment tool exists as well, but the use of this depends much on the student's abilities to use them. Regarding the use of discipline, the amount needed depends on the students, e.g. differences between nationalities, in general the amount of discipline needed is quite low.

Trainers mention that there is a need for taking different types of learners into consideration. One of the few ways to do self-learning are videos on the online-learning platform. Students are stressed about deadlines, especially regarding the online learning -platform.

One of the most prevalent comments was if the student has problems regarding the assignments, or with the course in general, questions can be raised if the student is suitable for the field at all.

4.2. Competence

Regarding the Competence-component, trainers agree that the requirements are quite hard for the students and that the course is demanding enough. One trainer said that there's no point to have a training where half of the students fail, but not on the course which is really easy to pass either. Furthermore, one trainer said that the starting point is different for students who have already experience on the field versus students who does not have any experience. The trainer further suggests that a different course should be modified to these two groups - at the moment, the material is the same for both groups. Trainers feel that the training is demanding enough for the trainers - the changing learning materials seems to bring the biggest challenges. Regarding feedback, the amount and type of feedback depends on the type of training. Most of the training drills are done in groups and the feedback is given to the whole group at once. Regarding service situations (e.g. customer service situations) the feedback can be personalised and comprehensive. Negative feedback is given face-to-face in a private situation.Trainers mention that there's a need for giving more personalised feedback for the students, especially during the course (and not just at the end of the course).

4.3. Relatedness

Trainers mention that there is a caring atmosphere between the trainers and students. As the 8-week course is very intensive, the group grinds together strongly and the team spirit is good. Trainers also mention that the peer support is strong. Trainers mention that students were able to form groups surprisingly well, even though students have different backgrounds. Regarding the feeling that the students and trainers can fail and ask, the trainers say that students are very nervous about the exams as the exams must be passed in order to continue on the course. The trainers try to relieve the tension and say straight that questions can be asked if anything is uncertain. Regarding competition between the students, trainers mention that very little competition exists, though it is dependent on the person in question - some students want to be the best in class. One trainer mentioned that there have been some bullying cases but they are handled quickly. One trainer also mentions cultural differences on competitiveness - for example, Asians are more prone for competition. Competition between trainers is nonexistent. Regarding cliques, trainers mention that sometimes cliques and negative traditions exist between students and the class is sometimes divided. Cultural differences exist, and for example Asians are more prone for cliques. Regarding trainers, no cliques exist. Regarding feedback from the students, there's not much negative feedback. Some constructive feedback about the strict deadlines and related to some trainers. Regarding trainers, trainers do criticize sometimes the changes made in the learning path, schedule and learning materials. Some learning materials are quite old.

4.4. General questions about the learning path

Trainers mention that the current learning path is linked to the real world work-life quite well, though there are some hardships. For example, simulating the customer service situations can be hard. In addition, one trainer mentioned that even though students know the severe situations well, milder situations which occur daily (e.g. passenger stomach ache) could be trained more.

Regarding the question whether the current learning path prepares the students for making their own conclusions and realisations, trainers mention that the current learning path could prepare the students better. For example, all emergency situations cannot be scripted - there could be more training drills, where the students are thrown to the middle of the action (surprise element). In addition, drills which combine different subjects (e.g. safety and service) would be beneficial. Furthermore, one trainer mentioned that one shortage of the current learning path is that due the limited amount of training drills, only a few students are able to train in the leading position and thus make decisions or problem-solving.

Related to the situational awareness of the students, trainers mention that during training it is important to prepare students for different situations. The situational awareness itself develops during work-life after graduation.

Regarding how the learning path could be improved, trainers mention the need of more resources and materials, especially hands-on training. The tight schedule of the course causes challenges. Related to the things which cannot be taught during the current learning path, trainers mention emergency situations in large, wide-body airplanes. In addition, more training in an authentic environment could be done, including airplane visits during training. For smaller airplanes, physical simulators exist but the situations differ in a larger airplane. Furthermore, large-scale emergency situations and situation assessment of the patients are hard to conduct using the current materials and methods.

5. Discussion and conclusions

Following vom Brocke et al. [3] the possible solutions, how valid they are tackling the problems, and what are the strict and reliable measurements to evaluate the solutions (i.e. context and goodness criteria definitions) are discussed next. The problems, together with the proposed solutions, features and evaluation methods, are presented in Table 2.

Table 2. The proposed solutions, features and evaluations for the problems presented.

PROBLEM	SOLUTION	FEATURE	EVALUATION
Student stress about exams and tests	Location- and time-independent extra training with VR	Training simulator to prepare students for exams, e.g. safety drills	Surveys and interviews about the possible stress decrease
More personalised feedback to students	Built-in learning analytics (e.g. performance, accuracy) in VRLE	VRLE gives personalised feedback to student and data for trainers about overall student performance	Observation and trainer's administration to see the validity of the built-in learning analytics of the VRLE
Suprising emergency situations	VRLE consisting of complex, suprising situations which combine different subjects	Configurable VRLE, which has different emergency situations in modules - the trainer or AI can combine a package which gives a student a training simulation of an unexpected emergency situation	Observation and learning analytics inside VRLE
More hands-on training and authentic learning environments	3D-modelled airplane and its interiors	Training simulator where students can familiarize themselves with the work environments and conduct different tasks, e.g. service situations and practical tasks	Real-world skills tests in a physical airplane e.g. during student test/familiarization flight and learning analytics inside VRLE

It is proposed that the solution artifact, a VRLE or a set of VRLEs, are designed to tackle the main problems which appeared in the problem cloud definition.

From the results it can be concluded that overall the education from the trainers' point of view is good. The learning path, most due to the regulations from the authorities, is quite controlled. For the development of the VRLEs this means that the design of the tasks and 3D-environment needs to be designed together with the trainers and by following the guidelines of the regulatory authorities. In addition, it needs to be checked whether the regulatory authority approves the VR training at all.

Trainers do mention that the students stress a lot about certain exams and tests. VR training could be one way to do extra training on a student's own time to be prepared for the physical exams and situations because VR allows location and time -independent training. In addition, if VR training is used through the learning path, the VR training could also give personalized feedback about the performance of the students and thus help the student to see where she/he already does good, and which skills need to be improved. This would also help for the need of more personalized feedback, as stated by the trainers. The performance from the students could be gathered to a database using built-in learning analytics in VRLE (e.g. performance, accuracy and eye-tracking). Using this database, trainers could see the overall performance of the students. Using this data as a base the trainer could design the lessons more effectively, keeping in mind the things which need to be further trained/explained better. However, the downside of this kind of analytics is that students may begin to be more competitive as they could then compare their results more easily. The evaluation for the possible stress reduction could be conducted using surveys and interviews. The evaluation for the personalized feedback solution would be observation of the student performance and trainer's administration to see the validity of the built-in learning analytics of the VRLE.

The trainers also mentioned that if a student has a lot of challenges and problems regarding the course assignments, it can be questioned if the student is suitable for the field at all. If VR-based stress/performance tests would be used in the entrance examinations, the airline could test the suitability of the students for the course a bit better.

From the results of the general questions about the learning path it can be concluded that the situations which cause challenges on the current learning path consist of simulating real-world situations and emergencies and the need for more hands-on training. Especially challenging in the current learning path is to create complex emergency situations, where there is an element of surprise and students need to act accordingly. At the moment, when a student enters a physical simulator at an airline's training premises, the coming situation is quite obvious (e.g. emergency landing). In addition, trainers note that combining subjects on these emergency situations are not always easy (e.g. combining a first-aid situation with a service situation where you need to interact with two passengers who have very different health conditions).

One possible solution for these is to use VR as a part of the learning path to bring more individual training and simulations of different situations, including emergencies. The complex emergency situations could also be randomized with VRLE using configurator or Artificial Intelligence, so when entering the emergency drill the student has no idea which kind of situation there will be. The evaluation for this solution can be conducted with observations during the emergency drills and using the built-in learning analytics of the VRLE.

In addition, trainers wish to have more authentic learning environments. For example, sometimes it is hard to arrange a physical airplane visit due to logistical difficulties. Airplane visits would help students to see their future workplace and train their tasks in the right environment. With a VRLE consisting of an airplane and its interiors, students could train service situations in an authentic learning environment without logistical difficulties, for example. Furthermore, students would like to have more hands-on training. Making a VRLE-based training simulator containing an authentic environment and practical, hands-on tasks would be one solution for this problem. Evaluation method for this solution would be a real-world skill test in a physical airplane during the student familiarization flight and using the built-in VRLE analytics.

As for the general evaluation of the proposed solution artifacts, iterative field testing needs to be conducted together with the trainers and students in a form of interviews and surveys. Especially important would be studying how the VRLEs fit to the overall learning path - which things are important to be taught in real life, and which things can be conducted using VRLEs. It would be also beneficial to conduct pre-and post-intervention tests to seek whether VR training actually increases the student performance in the skill tests at the end of the learning path.

Overall, from the results it can be seen that using an SDT-based questionnaire together with some general questions about the learning path revealed a lot about the learning path in general. It is therefore suggested for future research as a possible method for investigating the problem cloud. While the problem cloud investigating can be done using various methods, it seems that interviews work well. In addition, interviews can work as a good tool for engagement for the trainers:

as the DSR methods contain iterative development of the artifacts [33], it is beneficial that the stakeholders in the destination organization (here, the trainers) are engaged in the process.

A look to the highly cited articles using DBR [21] and EDR [19] reveals that the investigation of the problem cloud (or analysis and exploration in DBR/EDR) is quite short and not going very deep into the context of the studies. Our proposed method would bring a new approach to the investigation process. However, this is just one method, and it can be assumed that it does not work in all situations and contexts. Other problem cloud investigation methods exist as well. Future research should study whether our proposed method can be used more generally in the development of VRLEs, and whether it is really important for the development process of VRLEs.

Based on the previous literature, it seems that the problem cloud (or analysis and exploration in DBR) is usually conducted from the first round of literature review/interviews, but no specific frame is built based on the results, which would allow rigorous and profound problem space analysis. This notion is one of the main findings of the present study.

The limitations of the study include notions from the sample; the sample size is quite low, and only the trainer's point of view was taken into consideration. In the future research also, the students will be interviewed, together with a larger sample of the trainers.

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