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Immersive VR-based instruction in vocational schools: effects on domain-specific knowledge and wellbeing of retail trainees

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Abstract

Immersive virtual reality (IVR) based simulation and training is gaining increasing importance in vocational education and training (VET). However, while IVR is primarily investigated and utilized in technical domains, its implementation and the resulting effects in commercial education remain largely unexplored. Moreover, the experience of motion sickness is a widely reported phenomenon while using IVR, which can interfere with cognitive processes and should therefore be considered more closely in terms of learning and instruction. This explorative study focuses on domain-specific knowledge acquisition in vocational apprenticeship for retailers and the accompanying side effects on students' wellbeing in an IVR-based learning environment. For this purpose, an IVR-based scenario in a virtual supermarket was developed and tested with trainees in the field of retail at a German commercial vocational school. Using a quasi-experimental pretest-posttest design, we compared the effects of IVR-based and conventional instruction on domain-specific knowledge acquisition in a sample of first-year trainees ($N = 79$). The findings indicate an advantage of IVR in the acquisition of domain-specific knowledge ($\eta^2 = .261$). Although moderate motion sickness symptoms were reported in the experimental group, no direct links between the experience of motion sickness and learning outcomes could be identified. These findings advance the current knowledge about learning-related effects of IVR-based instruction in the field of VET and provide further understanding about the special conditions of IVR scenarios conducive to learning.

Keywords: Virtual reality, Immersive learning, Motion sickness, VET, Wellbeing, Retail

Introduction

The development of immersive virtual reality (IVR) applications and equipment offers new opportunities and potential for innovative methods of teaching and learning (Buchner and Mulders 2020). Especially in vocational education and training (VET), where particular attention is paid to workplace-related and action-oriented instruction, the use of this technology is associated with instructional scenarios in the sense of *situated learning* (Zinn 2019). In such contexts, IVR can create virtual environments that allow trainees to experience workplace situations similar to reality, where processes or procedures can be simulated to foster the acquisition of specific professional skills and domain-specific knowledge (Hellriegel and Čubela 2018). Several studies have investigated the influence of IVR technologies on education and training, mainly in the fields of science, medicine, and industrial-technical professions (Concannon et al. 2019; Hamilton et al. 2021). Reviews of IVR-based learning and instruction show that this technology offers advantages, both in the acquisition of declarative knowledge and especially in the acquisition of procedural knowledge (Concannon et al. 2019; Jensen and Konradsen 2018; Hamilton et al. 2021). Despite these findings, the use of immersive applications is also accompanied by some challenges. While some studies indicate the risk of knowledge acquisition being limited due to *motion sickness* symptoms (e.g., Gallagher et al. 2019), the extent to which motion sickness can influence cognitive efficiency in formal teaching and learning contexts is yet to be clarified. Due to the technology's growing relevance, minimal empirical evidence currently exists regarding its effectiveness in commercial VET. Particularly in commercial vocational education of retail trainees, there is potential for IVR-based instruction to provide more practical and action-oriented teaching of key learning concepts. By simulating real-life work situations, learners can experience practical examples that help to bridge the gap between theoretical knowledge and practical skills (Schäfer et al. 2023). Furthermore, little is known so far about the relationship among the use of IVR, wellbeing, and knowledge acquisition. Thus, the present study is intended to make a contribution in this regard.

IVR-based learning environments

Virtual reality (VR) offers an entirely computer-generated environment that simulates the perception of users reality using appropriate devices and applications, which can be categorized as desktop-based VR and immersive VR (cf. Dörner et al. 2019). Desktop-based VR applications are also referred to as non-immersive VR systems, as they are usually projected on a computer screen and handled via traditional input devices (Lee and Wong 2014). Immersive VR (IVR) environments, in contrast, can be entered with the use of a head-mounted display (HMD) and special controllers (Burdea and Coiffet 2003; Buchner and Aretz 2020). Moreover, IVR differs from other simulation-based applications in terms of the specific degrees of *interaction* and *immersion* in virtual environments (e.g., Concannon et al. 2019). The aspect of interaction in virtual environments is a crucial determinant of the users' agency, as it is directly related to the accuracy and responsiveness of their actions within immersive settings (Makransky and Petersen 2021). The detection of ones' own body movements is done by motion-sensing gloves, controllers, or photo sensors that transfer the user's gestures to the virtual environment (Concannon et al. 2019). Immersion, on the other hand, describes the effect of taking users into a simulated virtual environment using HMD, while at the same time the external influences of the real environment are completely masked out. Thus, immersion is reduced when users perceive elements of the real world while acting in a virtual world. The more comprehensively the sensory impressions of users are addressed, the higher the sense of immersion they perceive. Immersion is thus identified as the defining feature that sets IVR apart from other simulation-based applications (Dörner et al. 2019). It should be noted that the degree of interaction and immersion strongly affects the respective illusory user's sense of presence in a virtual environment (Rebelo et al. 2012; Concannon et al. 2019). The concept of presence refers to users' belief that they are actually in a virtual environment, despite knowing they are physically located in the real world (Burdea and Coiffet 2003).

The Cognitive Affective Model of Immersive Learning (CAMIL), developed by Makransky and Petersen (2021), identifies the experience of presence and user's agency as major IVR affordances in IVR learning and describes how technological factors (immersion, control factors, and representational fidelity) are related to these affordances. According to the model, it is the aforementioned technological factors and IVR affordances that in turn also influence affective and cognitive factors and thus learning outcomes. Compared to other simulation-based applications such as augmented reality (AR) or desktop-based learning environments, IVR offers highly immersive and interactive learning experiences. This provides opportunities for integrating theoretical learning content with specific practical training applications, which can be beneficial to the learning process (Liu et al. 2022). However, there is a whole range of other factors that influence the individual experience and learning success in IVR-supported instruction (e.g., usability, social factors, age, tendency to experience motion sickness, working memory, personality, spatial ability) which are not considered in the CAMIL (Makransky and Petersen 2021).

IVR-based instruction compared to other media

Reviews of the effects of IVR usage on knowledge acquisition point to its positive impact on learning compared to non-immersive media (Hamilton et al. 2021; Conrad et al. 2022). This advantage can primarily be observed when the instruction aims to teach procedural knowledge (Hamilton et al. 2021) or practical skills (Jensen and Konradsen 2018). These effects are mainly attributed to experimental and explorative learning approaches that are supported by the use of IVR environments (Hamilton et al. 2021). The effectiveness of IVR in acquiring declarative knowledge, on the other hand, is less clear (Jensen and Konradsen 2018; Concannon et al. 2019; Hamilton et al. 2021). When interpreting these results, it is important to distinguish among specific types of reference media and instructional methods. For instance, IVR usage leads to better knowledge acquisition compared to teacher-centered instruction, textbooks, or desktop-based computer applications. In contrast, experimental comparisons to tablet-based teaching or AR applications indicate inconsistent results regarding the benefits of IVR (Conrad et al. 2022). Studies on IVR-based learning show particularly positive effects when a clear learning goal has been defined in terms of a job-related situation and when a working environment is available as realistic as possible (Conrad et al. 2022). In particular, the latter point is currently a major challenge of IVR-based scenarios in the field of VET (Buchner and Mulders 2020).

Until now, the use of IVR in educational environments has mainly been tested and researched in the fields of engineering, medicine, architecture and sciences (e.g. Radianti et al. 2020; Hamilton et al. 2021). Based on this finding, potential can also be derived from IVR to promote learning in commercial VET. Here, vocational skills are taught both at school and in the training company, while action orientation anchored and demanded in curricula can often only be insufficiently implemented in the classroom (Wirth 2013). When it comes to depicting corporate environments and domain-specific processes, vocational schools may encounter limitations due to the constraints of spatial resources and equipment. As a result, the learning content is often presented at a more abstract level and lacks a hands-on, action-oriented approach. The impact of these restrictions is particularly evident in retail vocational apprenticeship, as they pose significant challenges to teaching central areas of learning, such as the design of store windows or the sales-promoting design of a salesroom, in an action-oriented manner. In this regard, IVR offers the possibility to counter these limitations by providing the required resources in the form of a virtual simulation and thus allowing action-oriented and situated learning scenarios (Robben and Cermak-Sassenrath 2010; Janssen et al. 2019; Zinn 2019; Schäfer et al. 2023).

Impairments due to motion sickness

While IVR offers particular benefits in terms of learning and instruction, the use of this technology also carries some instructional challenges (e.g., Huchler et al. 2020). Further, it is vital to ensure that learners can cope with the physical and psychological challenges associated with use of this technology (Przybylka 2022). Physical symptoms that can occur when using IVR, such as *motion sickness* or *cybersickness*, are frequently discussed in the literature (Gallagher et al. 2019; Chattha et al. 2020; Kourtesis et al. 2023). Motion sickness describes the phenomenon of nausea or headache that occurs during travel (Reason and Brand 1975). However, motion sickness is not only associated with physical activities but also with the use of IVR which is why it is often referred to as *cybersickness* (Kemeny et al. 2020). The appearance of related symptoms is anchored in sensory conflict theory (Cobb et al. 1999; Harm 2002), which assumes that a discrepancy between a perceived movement (in virtual space) and an actual physical movement can trigger motion sickness symptoms (Kemeny et al. 2020). Typical body signals include general discomfort, fatigue, eye strain, blurred vision, or heightened stomach awareness (Solimini 2013). However, not every user experiences motion sickness when dealing with IVR, but the experience of physical discomfort can lower individuals' acceptance of this technology (Chattha et al. 2020). To date, no exact data are available on motion sickness rates among IVR users (Gallagher et al. 2019). However, some people are more prone to these physical symptoms than others, as they are mainly associated with personal dispositions, as well as the design of the virtual environment (Chattha et al. 2020). Studies show that more women than men report suffering from motion sickness (Häkkinen et al. 2006; Jaeger and Mourant 2016), which has been attributed to hormonal dispositions and the gendered ways illness is handled and reported (Biocca 1992; Ladwig et al. 2000). Other factors implicated in the development of motion sickness include the time spent in the virtual environment and the ability to move in a controlled manner in virtual spaces, which reduces the appearance of symptoms (Kemeny et al. 2020). This latter observation is influenced by training (Chattha et al. 2020; Chang et al. 2020) and there is evidence that motion sickness is positively associated with environments similar to reality (Gallagher et al. 2019).

To date, the influence of motion sickness on learners' cognitive performance has scarcely been addressed in the scientific literature, with most studies confined to investigating the influence of motion sickness on the general performance of individuals. For example, Stanney (2014) concluded that motion sickness can reduce people's performance in general. Furthermore, Gallagher et al. (2019) emphasized that discomfort may affect personal performance in IVR training. In addition, Smyth et al. (2018) report a negative effect of motion sickness on cognitive and physical performance. These findings indicate that the occurrence of this side effect can influence learners' cognitive performance negatively when using IVR and may therefore also impair the related learning process as well as the associated learning outcome (Gallagher et al. 2019). It can be assumed that individual perceptual processing modes (Mayer 2005) can be impaired by motion sickness, which can hinder the overall learning process and thus the resulting learning outcome. Further research on this topic can benefit educators by providing further insights into how to counteract or reduce undesired physical symptoms in virtual learning environments, as well as identifying optimal instructional design strategies in the context of media use for enhancing learning experience and outcomes.

Research questions

Considering current findings on IVR-based learning and instruction and the need for action-oriented approaches in retail vocational apprenticeship, the question arises whether and to what extent the use of IVR can foster the achievement of domain-specific learning outcomes, especially in comparison to the instructional design in this learning field to date, using textbook and worksheets in a teacher centered instructional scenario. Despite the fact that media comparison studies are often considered of limited use due to the problem of fair experimental designs, a media comparison can provide specific indications of the relative advantages or disadvantages of certain technologies in terms of the intended instructional purposes and outcomes. Therefore, the objective of this study is to gain further insights into the comparative advantages of utilizing this technology to enhance specific learning outcomes, such as domain-specific knowledge and related skills, in comparison to traditional lessons on the same subject used as a baseline. In addition, investigating the relevance of motion sickness to learning outcomes is also important for evidence-based IVR instruction, as well as for designing conducive teaching and learning scenarios. Therefore, the study addressed the following research questions:

1. Does the implementation of IVR enhance the acquisition of domain-specific knowledge in an instructional setting in retail education and training?
2. Does the experience of motion sickness impair the acquisition of domain-specific knowledge in context of an IVR-based learning scenario?

By answering these questions, further information can be gained concerning the benefits of IVR-based teaching and learning in the areas of general and commercial VET.

Methods

Research design

In spring 2022 a quasi-experimental field study was conducted at a commercial vocational school in Germany to answer the above-mentioned research questions. The study was based on a pretest-posttest design that allowed to compare the effects of IVR-based and non-IVR-based instruction for trainees in the retail sector, as in retail, central topics of the relevant curriculum could often be taught in an insufficiently action-oriented manner so far. In addition, motion sickness typical and thus relevant aspects of well-being were recorded after each individual lesson. The sample consisted of first-year retail trainees ($N=79$) distributed over four school classes in total (four groups). Two groups took part in a series of IVR-based lessons ($n=42$), and two other groups partook in a comparable series of non-IVR-based lessons ($n=37$). Before the intervention, all trainees in the experimental (IVR) group (n = 42) took part in an onboarding unit to familiarize themselves with the Meta Quest 2 VR goggles, which were later used in the subsequent training units.

Intervention/procedure

For this intervention, the overarching theme "presentation of goods" was identified as an appropriate topic for the design of an IVR-based learning scenario. This topic was selected after analyzing the specific curricula in terms of the suitability of an action-oriented instruction that can be implemented using an IVR-based learning environment. As teaching in this subject area has largely been lacking in an action-oriented approach, IVR provides an opportunity to overcome this limitation by offering interactive simulations of workplace environments close to reality (e.g., Schäfer et al. 2023). The related subject area according to the relevant curriculum was divided into four superordinate topics*: sales zones, product carriers, routing in a supermarket,* and *shelf placement*. Thus, the intervention was carried out in four teaching units of 90 min each. The goal of the teaching series was to acquire domain-specific knowledge for the sales-promoting design of a salesroom in the area of retail (e.g., low- and high-turnover sales areas, different types of display units, general principles of customer guidance, and guidelines for product placement), making this topic particularly suitable for IVR-supported instruction. So far, the subject area has been taught with a rather high level of abstraction, as well as predominantly analog teaching aids, such as worksheets or textbooks. On the basis of paper sketches of a salesroom, for example, low and high sales areas should be identified. Due to the two-dimensional illustration of the sales area, these tasks were completed and presented abstractly, which is far from the reality of the trainees' salesroom environment. In this way, the theoretical and therefore often abstract way of teaching relevant learning content can be didactically expanded to include an action-oriented methodology, thereby overcoming a major criticism of the way this learning field has been taught up to now.

The instructional design used in this study was developed, tested and carried out by the involved teachers. All lessons were conducted during regular school hours in a German commercial vocational school between February 2022 and July 2022.

Experimental (IVR) group

The structure and sequence of all four teaching units were consistent. At the beginning of each unit, relevant basic information was given by worksheets and a textbook to ensure that all trainees received the necessary information. The following teaching sequence took place in the virtual environment. The challenge here was to work largely in a self-directed manner on tasks related to the particular topic and to design and set up a virtual salesroom along the four teaching units. For this purpose, the participants worked collaboratively in small groups of three to four people. The task in each of the

Fig. 1 Screenshots of the virtual salesroom with different shelves and avatars

four teaching units was to set up jointly a virtual supermarket according to topic-specific sales-promoting guidelines. For this purpose, all group members met in a virtual supermarket using HMDs (*Oculus Quest 2*) to work on the tasks. This means that the participants worked collaboratively within the virtual environment at the same time (Fig. 1). With the help of the built-in earphones, the learners could communicate within the respective group. The average processing time in the virtual learning environment was approximately 37.50 minutes ($SD = 4.54$) per teaching unit. After each IVR sequence, the unit was followed by a teacher-centered analog consolidation consisting of reflection tasks, feedback and discussion with the whole class. For this purpose, the results of each of the virtual salesroom set up were presented to the entire class. This approach allowed a visualization of the results of all groups and thus critical evaluation and analysis of other salesrooms. In this way, the participants were able to deepen their understanding of the respective topic.

Control (non-IVR) group

The control group consisted of two groups ($n = 37$) that were instructed by the use of analog (paper-/textbook-based) teaching methods. The lessons in the control group were also divided into four units of 90 min each, where the basic learning content was also worked out using a textbook. In contrast to the IVR group, all content was applied via paper-based media, in which, for example, sales zones or different types of routing in a salesroom were drawn on a floorplan. As in the IVR group, the execution of these tasks was also carried out in small groups of three to four trainees. Afterward, the results were also discussed and consolidated in plenary.

A comparison of the lessons between the experimental (IVR) group and control (non-IVR) group can be seen in Table 1. The main difference between the instructional designs of both groups can be found in phase 3 (processing work orders).

IVR-based learning environment

The virtual learning environment utilized for this purpose was the *ToolBox VR* application, incorporating a specially designed 3D salesroom reminiscent of a discount store. This virtual salesroom was expertly crafted by professional IVR programmers to emulate real-world physics, including elements such as gravity, thereby facilitating a truly immersive and lifelike spatial experience. The environment, which could be entered by using an avatar, enabled a true-to-scale representation of the surroundings, whereby any perspective could be adopted. Hereby the HMDs and controllers facilitated widely natural body movements (e.g., walking, standing, bending and lifting). The salesroom was initially equipped with a counter and a selection of shelves and displays and allowed for a short onboarding scenario to familiarize the trainees with general movement and handling of different objects. During the lessons the salesroom could be arbitrarily furnished and equipped with a large selection of different shelf types and consumer goods (e.g., coffee packages, detergent packs and beverage cans). In this way, trainees were able to design the virtual salesroom according to predefined requirements. Consequently, this approach enhanced the teaching process by offering more realistic and action-oriented instruction, aligning with the requirements of the curriculum. Figure 1 depicts two screenshots of the virtual salesroom as viewed by a learner, showcasing the arrangement of products and shelves.

Sample

Table 2 provides some basic information about the sample ($N=79$), which is distributed between the experimental (IVR; $n=42$) and control (non-IVR; $n=37$) groups. In total, 38 trainees were male, and 41 were female. On average, the participants were 19.84 years old ($SD=2.73$). Due to the grouping of participants based on their classes, it was not possible to implement a randomized allocation of subjects.

Meanwhile, 59.5% of the trainees in the experimental group had no previous experience with this technology. An overview of the IVR-related prior experience within the experimental group can be found in Fig. 2.

Instruments

The pre- and posttests combined a topic-related test of domain-specific knowledge with an additional questionnaire to gather socio-demographic data and relevant performance factors (e.g., motivation, self-efficacy, and interest). To control for cognitive performance, a part of the *CFT-20-R intelligence test* (completing rows) was included in the survey (Weiss 2008). In addition, a short post-session questionnaire assessed the participants' perceptions of each lesson, including to what extent they had experienced typical motion sickness symptoms as a consequence of IVR usage. Because this paper focuses on learning output and wellbeing, the instruments used to assess these variables are presented in more detail below.

The participants' domain-specific knowledge was assessed at two measurement points (pretest and posttest). This knowledge test consisted of 27 items to be completed over 30 min in a forced-choice format that tested the full subject matter, which was previously covered in class (*sales zones, product carriers, routing in a supermarket,* and *shelf placement*). One point was awarded for each correct answer, for a maximum score of 27 points. The overall measurement accuracy of the scale was assessed using *EAP/PV* reliability measurements, resulting in obtained values

Table 1 Schematic course comparison between the experimental and control groups

Instruction phase	Experimental (IVR) group	Control (non-IVR) group	Social form
1) Introduction	Introduction by the teacher; presentation of the task	Introduction by the teacher; presentation of the task	Plenary
2) Elaboration of relevant theory	Trainees work on textbook and work sheets	Trainees work on textbook and work sheets	Individual work
3) Processing work orders	Trainees work in a IVR-based salesroom by organizing customer routing and arranging virtual shelves, virtual merchandise displays, and virtual products	Trainees work on a 2D sketch of a salesroom by drawing customer routing, shelf arrangement, merchandise displays and product placement	Group work (3-4 trainees)
4) Consolidation	Trainees present, evaluate and discuss the results in terms of strengths and weaknesses of their salesroom designs	Trainees present, evaluate and discuss the results in terms of strengths and weaknesses of their salesroom designs	Plenary

of 0.69 (pretest) and 0.71 (posttest). At this point it should be mentioned that the objective was not simply to attain the highest score possible, but rather to create a change-sensitive test that enables a suitable range of scores and accurately reflect progress in terms of learning over time.

Further, an additional survey was carried out after the first three sessions (due to school organizational reasons, no survey could be conducted after the fourth lesson) to obtain more information about the participants' wellbeing regarding the experience of motion sickness symptoms in the experimental (IVR) group. This survey consisted of nine items from the *Motion Sickness Questionnaire* (MSQ; Bimberg et al. 2020). Due to test economic reasons and therefore to reduce response time only the items related to *general discomfort*, *headache*, *fatigue*, *nausea*, *stomach awareness*, *difficulty concentrating*, *head fullness*, *blurred vision*, and *vertigo* were used for this purpose. These symptoms can be considered particularly detrimental

Table 2 Socio-demographic characteristics of the sample

		Experimental (IVR) group ($n=42$)	Control (non-IVR) group ($n=37$)	Total ($N=79$)
Gender				
Male	*n*	24	14	38
Female	*n*	18	23	41
Age	*M (SD)*	19.74 (2.62)	19.95 (2.88)	19.84 (2.73)

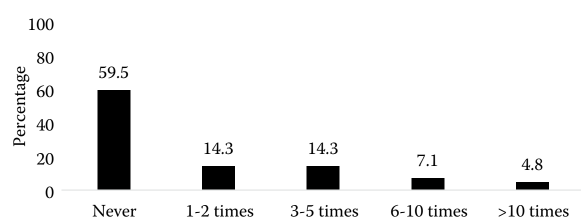

Fig. 2 Prior experience with IVR in the experimental group

to the learning process, as they may impair physical sensory and therefore interfere information processing and resulting learning outcome (Mayer 2005). Since we had only used a subset of the MSQ items, an additional exploratory factor analysis was performed to verify whether the typical MSQ subdimensions (oculomotor strain, nausea, disorientation) could be represented in the data. Thereby only one general factor *motion sickness* could be found, under which all nine selected items are subsumed. The Cronbach's alpha values for the three measurement time points were between 0.88 and 0.94, indicating the instrument's generally high reliability (Blanz 2015). An overview of the instruments is provided in Table 3.

Data analysis

To address research question 1, which examines the acquisition of relevant knowledge, we conducted a two-way repeated measures analysis of variance (rmANOVA). This analysis allowed to compare the performance on the domain-specific knowledge test between the two groups over time and to investigate a potential interaction effect associated with the use of IVR. Finally, linear regression was used to answer research question 2 concerning the effects of motion sickness on domain-specific knowledge acquisition, as recorded in the knowledge test. Because this latter analysis was only performed in the IVR group, a subsample of 34 participants was included here. Missing values were handled via listwise deletion and all analyses were run on the SPSS software (version 28).

Results

Research question 1: effect of IVR on knowledge acquisition

The first question compared the domain-specific knowledge acquisition between the trainees of the experimental (IVR) and the control (non-IVR) group. The comparison refers to the test results of both groups before the intervention (pretest), as well as those after the intervention (posttest). The achieved pre- and posttest scores are given in Table 4.

The test scores of both groups ranged from $min = 2$ to $max = 19$ points in the pretest and $min = 3$ to $max = 25$ points in the posttest. At the pretest, the experimental (IVR) group achieved approximately 8 points on average ($M = 8.07$; $SD = 3.56$), and the average for the control group was slightly higher ($M = 8.38$; $SD = 4.19$), while the experimental (IVR) group scored markedly higher on the posttest ($M = 14.98$; $SD = 4.03$) than the control group ($M = 12.49$; $SD = 4.36$). Figure 3 shows the achieved test performances over time for both groups.

The findings of the two-way rmANOVA indicate a significant main effect of the factor *time* ($F[1,63] = 148.52$; $p < 0.001$; $\eta^2_p = 0.702$). In contrast, no significant group effect can be identified here. Nevertheless, a significant interaction effect (*time*group*) is determined ($F[2,63] = 22.19$; $p < 0.001$; $\eta^2_p = 0.261$), demonstrating a significantly higher increase in the experimental (IVR) group's test score (see Table 5).

These results show that the experimental (IVR) group performs significantly better in the deployed posttest. The addition of control variables, such as gender, age, motivation,

Table 3 Instruments and reliability

Scales (number of items)	M (SD)	Reliability	Example item	Source
Domain-specific knowledge		*EAP/PV*		In-house development
Pretest (27)	8.22 (3.84)	0.69	Which of the following areas is typically found in a salesroom?	
Posttest (27)	13.81 (4.34)	0.71	What is understood by the term "secondary placement"?	
Motion sickness		α		Bimberg et al. (2020)
T1[a] (9)	2.49 (0.99)	0.88	During today's IVR lesson, i experienced *general discomfort*	
T2[a] (9)	2.69 (1.16)	0.94	During today's IVR lesson, i experienced *headache*	
T3[a] (9)	2.67 (1.11)	0.92	During today's IVR lesson, i experienced *blurred vision*	

M mean, *SD* Standard deviation, α Cronbach's alpha, *T* point of measurement

[a] 5-point Likert scale (*strongly disagree-strongly agree*)

Table 4 Trainees' pre- and posttest scores

	Experimental (IVR) group	Control (non-IVR) group
M (SD)		
Test score (pretest)	8.07 (3.56)	8.38 (4.19)
Test score (posttest)	14.98 (4.03)	12.49 (4.36)

M mean, *SD* standard deviation, Range of the scale: 0 points (min.) - 27 points (max.), *M* mean, *SD* standard deviation, Range of the scale: 0 points (min.) - 27 points (max.)

cognitive ability, or subject-related self-concept have no significant impact on test scores in our sample.

Research question 2: motion sickness and test achievement

To investigate the influence of typical motion sickness symptoms on knowledge acquisition, we initially examined the occurrence of these symptoms within the experimental (IVR) group. The mean values for all 3 measurement points (*T*) were observed to be 2.49 (*T1*), 2.67 (*T2*) and 2.69 (*T3*) and thus below the theoretical mean value of 3.00 (= "partly") on the 5-point Likert scale used. The analysis of motion sickness symptoms across all three measurement points reveals that a total of 12 participants reported experiencing physical symptoms at least "partly" in each assessment. This suggests that about 35.29% of the sample can be associated with some motion sickness experience based on these values, which can be interpreted as moderate overall.

To answer research question 2 regarding the impact of motion sickness symptoms on knowledge acquisition within the experimental (IVR) group, we conducted a linear regression analysis (see Table 6). As the dependent variable (DV), we chose the achieved score of the knowledge test (posttest), while the scores of the pretest and the reported

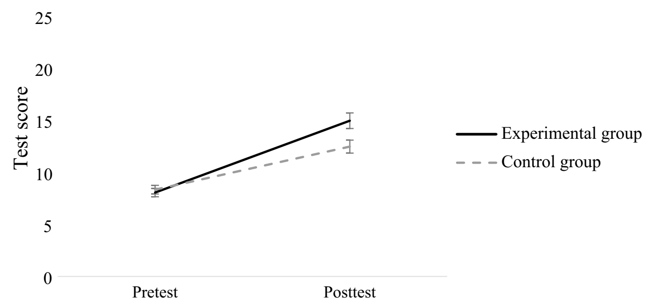

Fig. 3 Score in the knowledge test before and after the intervention

Table 5 Repeated measures ANOVA

(DV: posttest score)	*F*	*p*	Partial eta squared
Time	148.52	< 0.001	0.702
Group (IVR/non-IVR)	0.55	0.462	0.009
Time*group	22.20	< 0.001	0.261

DV = dependent variable

motion sickness were used as predictors. Because motion sickness is strongly correlated with all measurements, we chose measurement point *T1* as a representative.

In total, the model explains 38.1% ($p < 0.001$) of the variance in the dependent variable, while at the same time, no link between motion sickness and posttest performance can be found, as motion sickness does not explain variance in the posttest score significantly ($p = 0.571$). The addition of further control variables (e.g., gender, motivation, age) do not result in a significant change of variance explanation in the dependent variable.

To investigate whether correlations between test performance and motion sickness can be observed only for participants experiencing higher levels of motion sickness (rated ≥ 3.00 on the 5-point Likert scale), we split the variable "motion sickness" at the mean value (3.00) of this scale, indicating that at least moderate motion sickness effects can be inferred based on the scale from this point onwards. On this basis, participants were classified into two groups, such that those reporting scores of 3.00 or higher on the scale formed the "high motion sickness group" ($n = 12$) according to which all participants below this scale mean value were assigned to the "low motion sickness group" ($n = 22$). The subsequent regression analysis using the additionally created dichotomous variable (*0 = low motion sickness; 1 = high motion sickness*) also reveals no significant effects on posttest performance. These findings suggest that no significant relations can be observed between the occurrence of motion sickness symptoms and posttest performance, irrespective of symptom severity.

Summary and discussion

The aim of this study was to investigate the effects of an IVR-based learning environment in vocational apprenticeship of retailers on the acquisition of domain-specific knowledge and physical wellbeing. An explorative quasi-experimental field study with

Table 6 Effect of motion sickness on the achievement in the posttest

DV: Posttest	*β*	*SE*	*p*
Pretest	0.605	0.154	< 0.001
Motion sickness[a]	0.080	0.495	0.571

$R^2 = 0.381$ (ajd. $R^2 = 0.343$); $F(2,32) = 9.86$; $p < 0.001$; $n = 34$

DV dependent variable

[a] Measurement at *T1*

an experimental and control group design was used to answer the research questions formulated in this context. For this purpose, we designed a series of IVR-based teaching units, which were realized with trainees in the retail sector. While the experimental (IVR) group designed and organized a virtual salesroom using an HMD-based IVR application, which was exclusively developed for this purpose, the control (non-IVR) group completed similar tasks using a paper-based floor plan of a salesroom. We then measured and compared the learning outcomes of these groups over time using a topic-related knowledge test. Moreover, we examined the effects of motion sickness and tested to what extent the occurrence of relevant physical symptoms is related to overall learning outcomes. The results of this comparison are consistent with previous comparative media studies on the relative advantage of IVR-based instruction compared to paper-based types of media, including textbooks or worksheets (e.g., Chittaro and Buttussi 2015; Sundar et al. 2017; Villena Taranilla et al. 2019). Although such comparisons should be received and interpreted with a certain degree of caution, useful conclusions with regard to teaching practice can be derived from these results.

Despite the small sample size ($n_{experimental} = 42$; $n_{control} = 37$), we still find a significant interaction effect of *time*group* on test performance ($\eta^2_p = 0.261$; $p < 0.001$), which points to a greater improvement in test performance over time in the IVR group. These findings indicate that the use of IVR can be suitable to foster domain-specific knowledge acquisition in the apprenticeship of retailers. At the same time, the particular individual and didactical conditions that influence IVR-based learning processes remain largely unclear. Kim et al. (2020) show in their study that IVR provides an advantage over non-IVR-based approaches, particularly when tasks are first solved on paper and then elaborated in IVR. These findings may be considered in further studies with regard to learning-promoting conditions of IVR-based scenarios for education and training.

Regarding the occurrence of side effects some degree of motion sickness was expected within the experimental (IVR) group (e.g., Chattha et al. 2020). This effect can be confirmed by analyzing the experience of typical motion sickness symptoms in our sample. The mean values of motion sickness symptoms experienced by the experimental (IVR) group range within the middle of the 5-point Likert scale ($2.49 \leq M \leq 2.69$) indicating that typical motion sickness symptoms can be observed when using IVR in this scenario but not to a high degree on average. These findings can be interpreted as indicative of a moderate level of motion sickness. However, we find no evidence of a correlation between the occurrence of motion sickness and test performance. The results thus indicate that motion sickness symptoms induced by the use of IVR do not significantly influence the trainees' topic-related knowledge acquisition in our sample, even in learners who report more severe motion sickness symptoms. A possible reason for this non-existent connection can be assumed by the preparatory onboarding measure and the relative short sequences of IVR-usage during the lessons (the average time in IVR was 37.50 min per lesson). A reduced feeling of discomfort by spending only short periods in IVR and a possible familiarization effect when using IVR repeatedly are in line with previous studies on the topic (e.g., Chattha et al. 2020). These findings may be considered when implementing IVR in education and training.

Conclusion

The findings of this study contribute to a better understanding of IVR-based learning and instruction, especially in vocational apprenticeship of retailers. At the same time, some limitations should be considered and addressed in further research.

The first limitation of this study is its small sample size, especially at group level, where only two school classes in each group could be analyzed. In addition, due to the school conditions in the field, randomization of the sample was not possible. Further, the post-test scores may have been influenced to a certain extent by participants' memorization of the items from the previous test. This memory effect could have been avoided by conducting a parallel test. Furthermore, it must be mentioned that for reasons of test economy we only used a selection of nine items from the original MSQ, so that a weighting and thus a comparative rating, as originally intended in the MSQ, was not possible. Nevertheless, the data provide indications of a moderate incidence of motion sickness in parts of the sample. In addition, the measurement of motion sickness was carried out at three measurement times in order to obtain indications of the robustness of these symptoms. When considering the individual measurement times, it must be borne in mind that the results of the different measurement times are interrelated and cannot be seen separately from each other. Moreover, in future studies, it is advisable to utilize the complete scale of the MSQ to enable more precise and comparable assessments of motion sickness occurrence. By using the complete scale, more accurate and standardized conclusions can be drawn and comparisons can be made regarding the prevalence of motion sickness in different studies and populations.

Further, future studies on IVR-based instruction should also consider other relevant impact factors (e.g., cognitive load or experience of presence) according the Cognitive Affective Model of Immersive Learning (CAMIL) by Makransky and Petersen (2021). Such inclusions of cognitive and affective factors would allow a more detailed investigation of the extent to which IVR applications affect cognitive processes, which will in turn determine learning outcomes.

Investigating the learning-promoting effects of immersive virtual reality (IVR) and the conditions for successful implementation in the classroom is essential for a successful integration of this technology into school practice. However, it is equally important to weigh costs and benefits of using IVR in schools. A significant advantage of IVR-based applications is their high scalability potential, as they can be easily accessed by a large number of learners regardless of their location. On the other hand, it is crucial to acknowledge that IVR applications should not be regarded as a one-size-fits-all teaching medium, but rather as a valuable supplement to traditional teaching methods. They can be particularly beneficial when they offer additional learning opportunities, such as action-oriented experiences, which can enhance the overall classroom learning experience. Another advantage of

IVR as an educational medium lies in its ability to visualize abstract concepts and provide opportunities for learners to rehearse and practice workflows. In this regard, IVR provides unique advantages compared to augmented reality (AR) or desktop-based VR (Hamilton et al. 2021). However, there are certain challenges associated with the adoption of IVR in educational settings. Firstly, the costs of acquiring hard- and software solutions, along with the necessary training for teachers, can pose a barrier for schools considering investment in this technology. Additionally, there is currently a lack of well-established and evidence-based didactic concepts for IVR-integrated teaching (Buchner and Mulders 2020). These factors contribute to the prevailing hesitation and cautiousness regarding the widespread adoption of IVR in educational institutions. Further research should therefore investigate instructional aspects that must be considered in IVR-based teaching. In addition, it could be useful to investigate variations in IVR settings instead of conducting a media comparison to learn more about the relevant aspects and conditions for successful IVR implementation. In this regard, particular attention should be paid to instructional quality regarding *cognitive activation*, *teachers' support* and *classroom management*, when using IVR environments. Future studies should also address learners' relevant predispositions in relation to successful IVR-based instruction.

In summary, this study indicates that IVR-based instruction can foster the acquisition of domain-specific knowledge compared to an analog form of instruction. In addition, the study indicates that motion sickness side-effects do not necessarily lead to an impairment of learning success. However, it appears that IVR should initially be used in a time-limited context to prevent motion sickness and to slowly accustom learners to the realities of IVR and the associated virtual environments (cf. Chattha et al. 2020). Further studies should clarify how the effects of motion sickness can be reduced with appropriate instructional designs and accompanying technical and suitable didactic support measures. Additionally, it would be beneficial to conduct a more comprehensive examination of the effective application of IVR-based instruction in real-life workplace scenarios, with a particular focus on the successful transfer of acquired knowledge and skills.

Abbreviations

AR	Augmented reality
DV	Dependent variable
HMD	Head-mounted display
IVR	Immersive virtual reality
MSQ	Motion sickness questionnaire
rmANOVA	Repeated measures ANOVA
VET	Vocational education and training
VR	Virtual reality

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Author contributions
All authors developed the research questions and were involved in the conception of the study design, the questionnaires, and the knowledge test. DK performed the data analysis and wrote the first draft of the manuscript. All authors reviewed and approved the final manuscript.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
We adhered to all relevant standards regarding the data provided by the participating adolescents. Participation in this study was voluntary. Before starting the study, the school administration approved the survey per school survey standards. All participants were older than 16 years of age and could therefore provide informed consent to participate based on complete and detailed information about the study, its purposes, and the use of their data. As our research project did not involve any risks or burdens, no additional consent from legal representatives was required.

Competing interests
The authors declare that they have no competing interests.

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