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Josef Buchner & Miriam Mulders

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Still trapped in media comparison? A systematic review of comparative research on immersive virtual reality in education

Josef Buchner [a]* and Miriam Mulders [b]*

[a]Institute of Digital and Computer Science Education, St. Gallen University of Teacher Education, Rorschach, Switzerland; [b]Learning Lab, University of Duisburg-Essen, Essen, Germany

ABSTRACT

Immersive virtual reality (IVR) has garnered increasing attention in educational research, leading to a growing body of empirical studies. A recurring critique within the field concerns the continued reliance on media comparison studies, which are considered theoretically limited and confounded. However, systematic evidence supporting or challenging this assumption is still lacking. This systematic review aims to map the types of comparative research designs used in educational IVR studies, examine whether key IVR-specific constructs such as presence and cybersickness are assessed, and analyze how these patterns have evolved between 2016 and 2024 in leading educational technology journals. Across 20 journals, 130 studies met the inclusion criteria. Contrary to prevailing assumptions, media comparison studies were common but not dominant. They were increasingly complemented by value-added designs, learner-treatment-interaction studies, and mixed approaches. However, the analysis also reveals a critical shortfall: essential IVR-specific constructs are frequently neglected: only 39% of the studies assessed presence, and just 10% measured cybersickness. By systematically characterizing comparative designs and the treatment of core IVR constructs, the review provides a nuanced picture of current methodological practices and identifies concrete directions for improving theory-driven and empirically rigorous IVR research.

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KEYWORDS
Immersive virtual reality; media comparison studies; value-added research; presence; cybersickness

Introduction

Immersive virtual reality (IVR) is a contemporary technology that allows users to immerse themselves in entirely computer-generated worlds (software) via headsets and controllers (hardware). Indeed, the more effectively hardware and software are aligned, the more realistic the user experience is likely to be (Cummings & Bailenson, 2016). As a result, users experience presence – the feeling of being there – and are completely absorbed in the virtual world and interact naturally, for instance by using their hands, with the objects of this world. Consequently, IVR is also defined as *reality that is virtual* (Slater & Sanchez-Vives, 2016, p. 2). The use of headsets, also termed head-mounted displays (HMDs), and controllers in particular distinguishes IVR from other forms of virtual worlds, which are also referred to as VR. For example, games or 3D simulations on computer screens that are controlled via mouse and keyboard are also called VR in the literature (Freina & Ott, 2015; Merchant et al., 2014). In this study, we focus on IVR, with a particular focus on the context of educational technology research.

The potential of IVR for education was the subject of numerous research projects in the last decade resulting in manifold benefits and advantages compared to other educational technologies. For example, IVR instruction enables the training of dangerous and cost-intensive tasks in a safe space (Lee, 2023; Mulders et al., 2024), provides a simulated environment for skills acquisition (Jensen & Konradsen, 2018), and increases engagement by offering action-oriented learning opportunities (Conrad et al., 2024). Further, IVR can visualize complex and abstract concepts to support learners' understanding (Oje et al., 2025) as well as declarative and procedural knowledge acquisition (Conrad et al., 2024; Hamilton et al., 2021).

CONTACT Josef Buchner josef.buchner@phsg.ch
*Josef Buchner and Miriam Mulders contributed equally to this article and share the first authorship

Another benefit of IVR is the promotion of affective learning outcomes, like motivation, attitudes, and values (Jiang & Fryer, 2024). This positive impact of IVR was repeatedly found in studies conducted in diverse fields such as environmental education (Petersen et al., 2020; Spangenberger et al., 2025), history education (Mulders et al., 2025; Nachtigall et al., 2022), computer science education (Pirker et al., 2020), and language education (Keller et al., 2024; Parmaxi, 2023). The feeling of presence is named as decisive, and unique of IVR compared to other technologies, for the positive impact of IVR on learning (Dengel & Mägdefrau, 2019; Makransky & Petersen, 2021; Ochs & Sonderegger, 2022). For example, presence within IVR contributes to authentic learning (Lee et al., 2024) and is perceived as a driver for engagement (Yang & Liu, 2022). However, null or negative effects also emerged. For instance, technical problems, visual overwhelm, and symptoms of cybersickness limit the effectiveness of IVR (Makransky et al., 2019; Parong & Mayer, 2018; Weech et al., 2019).

Based on the high number of educational IVR primary studies published, researchers aggregated the findings in systematic literature reviews and meta-analyses. Such systematic reviews and meta-analyses found advantages for IVR instruction with a small to medium effect size compared to other educational technologies or media (Coban et al., 2022; Conrad et al., 2024; Howard et al., 2021; Howard & Gutworth, 2020; Jiang & Fryer, 2024; Parong, 2021; Villena-Taranilla et al., 2022; Wu et al., 2020; Yu, 2021).

An interesting detail of these studies is that all findings are based on studies comparing IVR to non-IVR conditions. This type of research is known as media comparison, an approach that has been criticized and controversially discussed for more than forty years (Clark, 1983, 1994; Honebein & Reigeluth, 2021; Kozma, 1994; Mayer, 2019; Surry & Ensminger, 2001; Warnick & Burbules, 2007). For instance, researchers argue that results from media comparisons are neither helpful for theory development nor for educational practice. Further, these comparisons confound technology with instructional methods and, thus, cannot draw conclusions about the effectiveness of a certain technology or media on learning (Reigeluth & Honebein, 2023).

In a recent systematic review, Lawson et al. (2024) investigated the question on confounding for IVR studies in the Science, Technology, Engineering, and Mathematics (STEM) domain. Their analysis confirmed that the majority of media comparison studies in the field of IVR in STEM education are confounded and, thus, that the findings must be interpreted with caution. The Lawson et al. (2024) study and the above mentioned literature reviews seem to prove a hypothesis raised in Buchner and Kerres (2023): The authors claim, based on their findings of a dominance of media comparisons in research on augmented reality (AR) in education, that this must be true for other educational technologies, including IVR. Researchers like Mulders (2023), Glaser and Moore (2023), and Lawson and Martella (2023) voiced similar assumptions regarding the dominance of media comparisons in educational IVR research.

However, to date, researchers have neither substantiated nor refuted this assumption. Existing literature reviews fall short of answering the question, as they focus exclusively on studies comparing IVR to other media. Consequently, it remains unclear whether educational IVR research, similar to research on AR, is still trapped in a media comparison paradigm. Addressing this gap is the central aim of the present study. Further, we are interested in the interplay between research types and key factors that are closely associated with the effectiveness – or lack thereof – of IVR, such as presence and cybersickness. This focus builds on previous work by Makransky and Petersen (2021) and Petersen and Makransky (2024). In addition, we consider the publication year as a relevant factor, following the approach suggested in Buchner and Kerres (2023).

Conceptual framework and research questions

Research on educational technology and technology-enhanced learning is a multidisciplinary field informed by numerous methodological paradigms and epistemic views on how to generate new knowledge (Randolph, 2008; Schneider et al., 2025; Valtonen et al., 2022). In this study, we focus on comparative research, i.e. empirical studies in which researchers aim to investigate causes and effects by comparing different conditions to each other (Gray et al., 2007). Three main approaches can be identified from the educational technology literature: media comparison studies, value-added studies, and learner-treatment-interaction (LTI; also called aptitude-treatment-interaction, ATI; Kozlova et al., 2025) studies.

Media comparison studies compare the effect of different media, for instance IVR versus video, on learning outcomes (Lawson et al., 2024; Warnick & Burbules, 2007). As Honebein and Reigeluth (2021) reveal,

many studies mask the direct comparison of media by referring to the conditions such as, for instance, IVR instruction versus video learning, or IVR learning versus traditional learning (including conventional media). Such comparisons are still *media-oriented* (Honebein & Reigeluth, 2021, p. 475), as the effects found are explained by the different media used (Buchner & Kerres, 2023; Honebein & Reigeluth, 2021).

Value-added studies compare the impact of different versions of a specific media on learning outcomes (Mayer, 2020). For example, such studies investigate the effectiveness of an AR learning system with and without additional instructional support (Moser & Lewalter, 2024) or the effect of an IVR simulation with and without pretraining (Lawson & Mayer, 2025). Findings from value-added studies provide insights about the features that can support learning processes in IVR (Mayer et al., 2023). Thus, value-added research contributes to the question of how to design IVR learning environments.

LTI studies explore how individual differences among learners interact with different instructional treatments or interventions (Surry & Ensminger, 2001). Researchers examine how the effectiveness of an instructional method or intervention varies depending on characteristics of the learners, such as their prior knowledge, cognitive abilities, or socio-economic background. This often involves conducting experiments where different groups of learners are exposed to various instructional treatments, and researchers analyze how outcomes differ across these groups. For instance, learning in IVR might depend on working memory capacity (Lawson & Mayer, 2024) or is affected by characteristics like age and gender (Kothgassner et al., 2018).

As shown in a previous systematic review, researchers also combine the presented comparative research types (Buchner & Kerres, 2023). For instance, a study might investigate whether additional instructional support (value-added) within an IVR learning environment promotes learning for learners with high and low prior knowledge (LTI).

To date, no study has examined which of these research types are most prevalent in educational IVR research, leading to our first research question:

> Research question (RQ) 1: Which research types have been applied in empirical studies on IVR in the context of educational technology research?

One intriguing phenomenon associated with learning in IVR is the feeling of presence. Presence refers to the subjective experience of learners in terms of the degree to which they feel being present in a computer-generated environment (Slater, 2009). In the literature, presence is considered a pivotal factor for effective learning in IVR, particularly as a distinguishing characteristic of IVR when compared to less immersive media such as desktop-based applications (Dengel & Mägdefrau, 2019; Meyer et al., 2019; Ochs & Sonderegger, 2022). However, empirical evidence shows a more complex and sometimes inconsistent relationship with learning outcomes. While several studies report positive associations through increased interest and motivation, others find null or even negative effects when presence draws learners' attention away from essential instructional content (e.g. Makransky et al., 2019; Thomann et al., 2024). Another phenomenon linked to IVR is cybersickness, defined as a type of motion sickness induced by visual stimuli. The symptoms are akin to those of seasickness, including dizziness, headaches, and nausea (E. Chang et al., 2020). The experience of cybersickness can hinder learning in IVR. For instance, Ochs and Sonderegger (2022) discovered that cybersickness has a negative effect on retention.

We focus on presence and cybersickness not because they are the only relevant subjective experiences, but because they represent the most widely theorized and IVR-specific constructs. Their frequent mention as potential mediators or moderators of IVR learning makes them a meaningful starting point for systematic analysis. Nonetheless, we acknowledge that future research should extend this focus to a broader spectrum of experiential variables.

As demonstrated, presence and cybersickness play a key role in understanding learning in IVR. However, it remains unclear to what extent presence and cybersickness are actually assessed in empirical IVR studies and whether educational technology researchers explicitly link them to learning outcomes. Addressing this gap motivates our second research question:

> Research question (RQ) 2: Are presence and cybersickness assessed in empirical studies on IVR, and are there differences depending on the research type applied?

Lastly, we are interested in the relation of research types and the consideration of presence and cybersickness with publication year. Two arguments may be put forward to justify our interest in this issue: First, even

well-known critics of media comparison studies acknowledge the need to initially conduct such comparisons when novel technologies emerge (Parong & Mayer, 2018). Second, as evidenced in the case of AR (Buchner & Kerres, 2023), research approaches can evolve over time, with new emphases such as the application of LTI studies gradually gaining importance. This leads to our third research question:

> Research question (RQ) 3: Is there a relationship between the year of publication and the research types applied, as well as the consideration of presence and cybersickness?

By investigating these three research questions, the present study addresses a relevant research gap and contributes substantially to advancing the field of educational IVR research, with a particular focus on the educational technology research landscape.

Method

To answer our research questions, we utilized the systematic review method. A systematic review is a literature review performed in a systematic manner with the aim of answering specific research questions. The method is characterized by a clear search strategy guided by inclusion and exclusion criteria. The included studies that meet the criteria are coded, synthesized, and used to answer the research questions (Newman & Gough, 2020).

Search procedures

To ensure the high quality of the studies that will be included in our analysis, we made use of a hand-searching strategy. This strategy involves examining specialist journals for a specified period of time (Alexander, 2020; Newman & Gough, 2020). In our case, we focused on the top journals in the field of educational technology research, based on h-index rankings from both *Google Scholar* and *Scimago* at the beginning of 2024. Additionally, we included *Computers & Education: X Reality* because this relatively new journal has a primary focus on XR technologies, like AR or IVR, aiming to provide a body of research exploring learning and instruction with XR (Chen et al., 2022). Our focus on leading educational technology journals reflects our aim to characterize comparative IVR research within the educational technology research community rather than across all disciplines that study VR. Journals such as *Virtual Reality*, while highly relevant for VR research more broadly, publish a substantial proportion of technically oriented work outside the pedagogical and instructional discourse. Including such outlets would have shifted the scope toward general VR research and diluted our focus on educational technology as a research tradition. We acknowledge that relevant studies appear in these venues and return to this limitation in the Discussion sections.

Furthermore, we deliberately excluded journals with a clear subject-specific or disciplinary focus outside the general field of educational technology, such as *Language Learning & Technology*, *Computer Assisted Language Learning*, and *Education in the Health Professions*. Furthermore, conference proceedings were not considered. Table 1 presents the ranked journals that were searched in October 2024.

The search was limited to articles available online via the journal's homepage between 2016 and 2024. The decision was driven by the release of consumer-grade HMDs (e.g. *HTC Vive*) in 2016, which triggered a substantial methodological and conceptual shift in educational IVR research (Radianti et al., 2020). We acknowledge that studies published in 2025 and beyond are not included in our coded dataset and address this limitation explicitly below.

The 20 journals' homepages were thoroughly searched for articles on IVR in teaching and learning. We applied the following search string: "virtual reality" OR "vr" OR "ivr" OR "immersive virtual reality" AND "head-mounted display" OR "head mounted display" OR "HMD" OR "glasses" OR "goggles". A total of 1598 publications were identified through this search and screened based on the inclusion and exclusion criteria.

Inclusion and exclusion criteria

We included primary studies with a comparative research design consisting of an experimental group and a control group. Further, we only included studies researching the impact of IVR on learning outcomes. Hence,

Table 1. Journals included in the search procedure with abbreviation, Google Scholar, and Scimago rank.

journal	abbreviation	*Google Scholar* rank*	*Scimago* rank*
Computers & Education	C&E	1	1
British Journal of Educational Technology	BJET	3	3
Education and Information Technologies	E&IT	2	8
Educational Technology Research & Development	ETR&D	6	–
International Journal of Educational Technology in Higher Education	ETHE	5	15
Journal of Educational Technology & Society	ET&S	15	6
Interactive Learning Environments	ILE	7	11
The Internet and Higher Education	IHE	12	4
Journal of Computer Assisted Learning	JCAL	10	5
Australasian Journal of Educational Technology	AJET	13	10
Journal of Educational Computing Research	JECR	11	–
Learning Media and Technology	LMT	16	–
TechTrends	–	17	–
Distance Education	Dist. Educ.	18	9
Government Information Quarterly	Gov. Inf. Q.	–	2
IEEE Transactions on Learning Technologies	TLT	–	13
International Journal of Artificial Intelligence in Education	IJAIED	–	14
Information Technology for Development	ITD	–	18
Learning Environments Research	Learn. Environ. Res.	–	20
Computers & Education: X Reality	C&E XR	–	-

Note: – = missing data; * data from June 2024.

only studies using a technology that creates a high level of immersion and interactivity involving an HMD and associated controllers, joysticks, data gloves, or similar input and output devices, and such in which learning outcomes were reported, were included.

Consequently, we excluded secondary studies like systematic reviews or meta-analyses (e.g. Wu et al., 2020). The same applies to single-group studies (e.g. Georgiou et al., 2021), studies in which immersive VR was not used as an instructional technology (e.g. Buchner & Hofmann, 2022), and studies researching other forms of VR, not IVR. For example, studies determining the effectiveness of cardboard-based VR or spherical video-based virtual reality (e.g. Yang et al., 2021) were excluded from the analysis. Availability of the studies in the English language was not defined as a criterion because the searched journals only publish articles in the English language. To enhance transparency, all inclusion and exclusion criteria applied in this review are summarized in Table 2.

Final pool

Through the hand search strategy of the chosen journals and following the presented inclusion and exclusion criteria, we considered 128 records, comprising 130 studies, for the final analysis to address our research questions. The screening process is illustrated in Figure 1. Initially, 14 editorial records were excluded. Subsequently, we screened the abstracts of the remaining 1382 articles. After conducting abstract screening, we excluded 950 further studies that did not meet our inclusion criteria. We then read 432 full texts and assessed their alignment with our inclusion criteria. An additional 304 studies were excluded based on our inclusion and exclusion criteria. As a result, our final pool of studies for in-depth analysis consists of 128 records containing 130 studies (see Appendix 1).

Table 2. Inclusion and exclusion criteria applied in the systematic review.

Inclusion criteria	Exclusion criteria
Primary empirical studies using a comparative research design with at least one experimental and one control condition	Non-comparative study designs (e.g. single-group pre–post studies, qualitative-only studies)
Use of immersive virtual reality (IVR) employing HMDs with sufficient immersion and interactivity (e.g. controllers)	Use of non-immersive or low-immersion technologies (e.g. desktop VR, 360° video, cardboard VR)
Conducted within an educational or training context	Studies outside educational contexts (e.g. clinical, entertainment, rehabilitation)
Reporting at least one learning-related outcome	Studies without reported learning outcomes
Published in peer-reviewed journals within the defined time frame (2016–2024)	Secondary studies (systematic reviews, meta-analyses, theoretical or conceptual papers)
	Studies lacking sufficient methodological information to determine the nature of the comparison

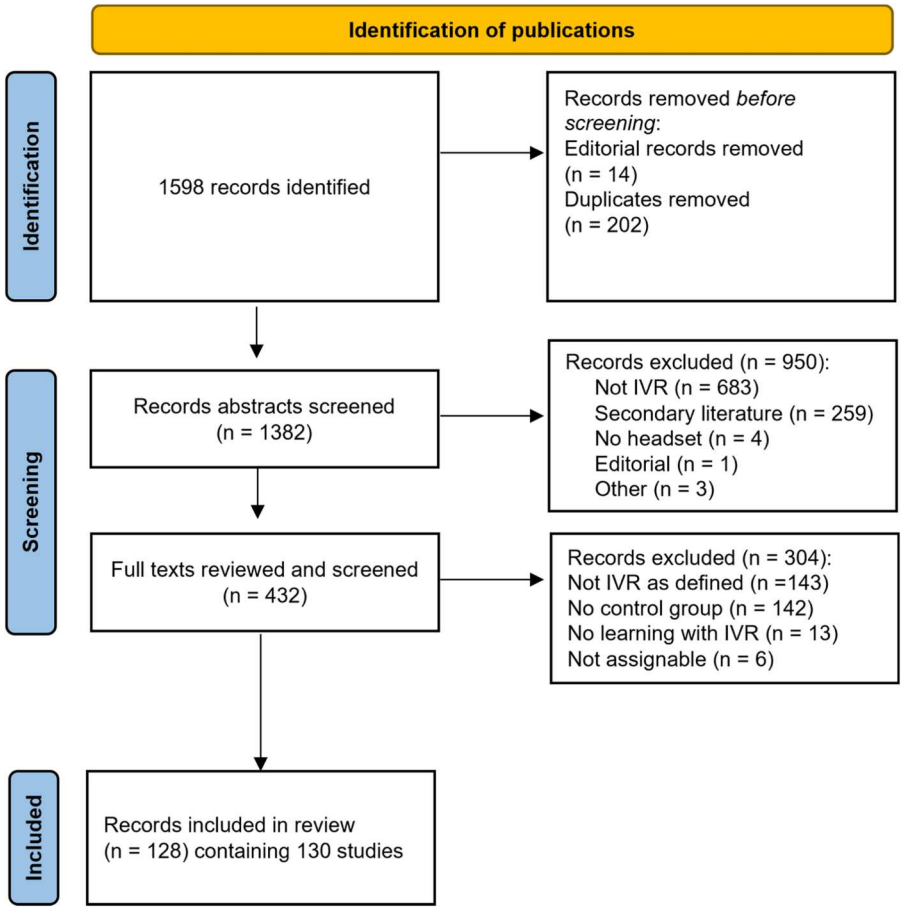


Figure 1. PRISMA flow chart of the screening process (Page et al., 2021).

During the entire screening process, two researchers collaborated closely. Both abstracts and full texts were independently assessed using the predefined inclusion and exclusion criteria. When screening the abstracts, several inclusion and exclusion criteria were used to decide which articles were suitable for full-text analysis. We checked the extent to which the two independent raters agreed in their decisions to include or exclude articles. To evaluate the consistency of their decisions, we calculated Cohen's kappa, which yielded $k = .96$, indicating strong interrater agreement (Altman, 1991). Any disagreements at the abstract stage were discussed until a joint decision was reached, thereby reducing the likelihood of individual errors.

For the full-text screening and subsequent coding, the same two researchers worked collaboratively in a detailed negotiation process. Each study was reviewed together, and coding was finalized only after both researchers reached full consensus. All discrepancies were resolved through structured discussion until complete agreement was achieved.

Coding scheme

To answer the three research questions, the following codes were applied:

For RQ 1, we used the codes for research types (1) media comparison studies, (2) value-added studies and (3) LTI studies established in previous studies (Buchner & Kerres, 2023; Surry & Ensminger, 2001). In Buchner and Kerres (2023), as well as in an article specific on IVR in education by Meyer and colleagues (2019), it is described that these research types are now being combined more frequently in educational technology studies. Therefore, we have considered additional codes for various combinations of research types: (4) media comparison and value-added study, (5) media comparison and LTI study, (6) value-added and LTI study, and (7) media comparison and value-added and LTI study.

For RQ 2, we considered presence and cybersickness measures if they were reported.

For RQ 3, the year of publication was examined and coded as a number, for example 2023.

The final table with the included studies and all codes is available via https://osf.io/t8vqu/overview?view_only=4a37848adaad46beaccbcca4f97e455f

Results

First, we present some basic information about our final pool of studies followed by a detailed presentation of the results for each research question.

In Table 3, the distribution of the 130 studies among the 20 examined journals is given. Most of the studies are published in *Computers & Education* ($n = 25$), followed by *Journal of Computer Assisted Learning* ($n = 19$), *Education and Information Technologies* ($n = 15$) and *Interactive Learning Environments* ($n = 15$). In nine out of 20 journals, no study was published that met our inclusion criteria.

Further, as Figure 2 shows, there is an ongoing trend to conduct studies on learning in IVR. In 2024, nearly twice as many studies were published as in the previous year. Overall, a rapid increase in the number of published IVR studies has been observed since 2020.

The data further show that most studies were conducted in the field of Natural Sciences, Mathematics, and Statistics. This is followed by the fields of Arts and Humanities, Generic Programmes and Qualifications, and Engineering, Manufacturing, and Construction. The complete distribution is presented in Table 4.

RQ1: Which research types have been applied in empirical studies on IVR in the context of educational technology research?

The primary aim of this study was to systematically examine the research types employed in empirical studies on educational IVR. As the data show, three of the analyzed studies did not include an active control condition. Consequently, these studies were not classified under any single research type or

Table 3. Distribution of the 130 studies among the 20 journals.

Journal	*f*	%
C&E	25	29.8
JCAL	19	19.2
E&IT	15	17.0
ILE	15	14.9
BJET	13	8.5
TLT	11	4.3
JECR	11	2.1
ETR&D	9	2.1
CEXR	8	2.1
ET&S	3	0
TechTrends	1	0

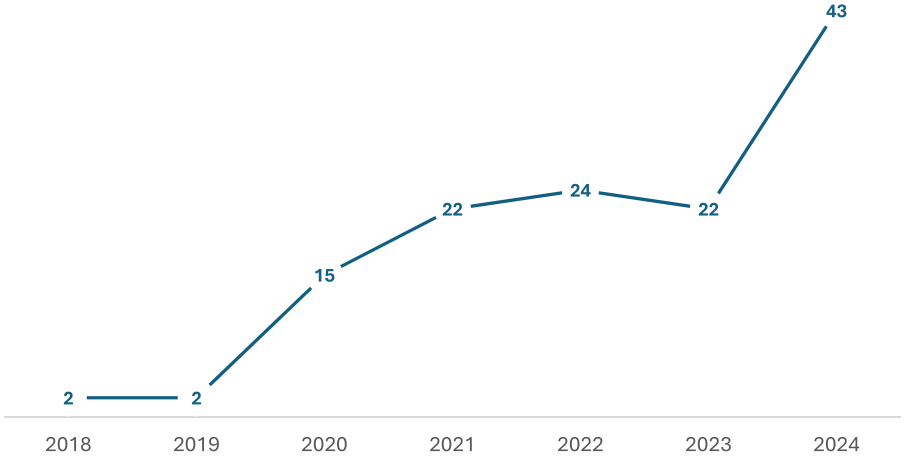


Figure 2. Distribution of studies per year of publication. Note: The long titles of the journal names and their abbreviations are shown in Table 1.

Table 4. Distribution of the 130 studies by field of education and training.

Field	*f*	%
Natural Sciences, Mathematics and Statistics	43	33.1
Arts and Humanities	27	20.8
Generic Programmes and Qualifications	18	13.8
Engineering, Manufacturing and Construction	16	12.3
Health and Welfare	9	6.9
Education	8	6.2
Information and Communication Technologies	7	5.4
Agriculture, Forestry, Fisheries and Veterinary	1	0.8
Business, Administration and Law	1	0.8

Note. Classification is based on international standards provided by UNESCO Institute for Statistics (2015).

combination thereof. This reduces the number of studies coded according to the proposed coding scheme by three. Accordingly, the following analyses refer to a total of 127 studies that included active control conditions. An overview of the results is presented in Table 5.

In 54 studies (42.5%) researchers compared IVR exclusively with another educational medium (media comparison), 29 studies (22.8%) employed a value-added research design, and nine studies (7.1%) adopted the LTI approach. A combination of media comparison and value-added type was used in 23 studies (18.1%). In eight studies (6.3%), the media comparison approach was combined with the LTI type, and in four studies (3.2%), researchers employed a combination of the value-added and the LTI approach. None of the analyzed studies combined all three research types.

RQ2: Are presence and cybersickness assessed in empirical studies on IVR, and are there differences depending on the research type applied?

The second objective of this study was to explore whether presence and cybersickness are measured in IVR studies, and whether this depends on the type of research design employed. As shown in Table 6, presence was assessed in 51 out of 130 studies (39.2%), whereas no measurement of presence was conducted in the remaining 79 studies (60.8%). Cybersickness was measured in 13 studies (10.0%), while in 117 studies (90.0%) no data on cybersickness was collected. Presence was measured in one study without an active control condition. The remaining 50 studies that assessed presence were distributed across research types as follows: Presence was measured in 21 media comparison studies, in seven value-added studies, and in five LTI studies.

Regarding the combinations, presence was assessed in 11 studies that combined the media comparison and the value-added research type, in three studies combining media comparison and LTI, and in three studies combining the value-added and the LTI approach.

Table 5. Overview of the research types employed, sorted by frequency.

Research type	*f*	%
Media comparison studies	54	42.5
Value-added studies	29	22.8
Media comparison and value-added study	23	18.1
Learner-Treatment-Interaction (LTI) studies	9	7.1
Media comparison and LTI study	8	6.3
Value-added and LTI study	4	3.2
Media comparison, value-added and LTI studies	0	0.0

Note. The results are based on 127 studies including active control conditions.

Table 6. Overview of the used research types together with measure of presence and/or cybersickness.

Research type	Presence	Cybersickness
Media comparison studies	21	7
Value-added studies	7	4
Media comparison and value-added study	11	1
Learner-Treatment-Interaction (LTI) studies	5	1
Media comparison and LTI study	3	0
Value-added and LTI study	3	0
No active control condition	1	0
Total measures	51	13

For cybersickness, none of the three studies without an active control condition included a corresponding measure. Among the studies with active control groups, cybersickness was assessed in seven media comparison studies, four value-added studies, and one LTI study.

The only combination of research types in which cybersickness was measured was a study employing both the media comparison and the value-added approach.

RQ3: Is there a relationship between the year of publication and the research types applied, as well as the consideration of presence and cybersickness?

Finally, this study examines whether the year of publication is associated with the research types used and with the measurement of core IVR constructs such as presence and cybersickness.

We first analyze the distribution of research designs by year of publication (Figure 3). The data show that pure media comparison studies have been published consistently over time. Since 2020, there has been a growing number of value-added studies, whereas no such trend could be observed for LTI studies. An exception is the year 2024, in which four standalone LTI studies and five studies combining LTI with other research types were published.

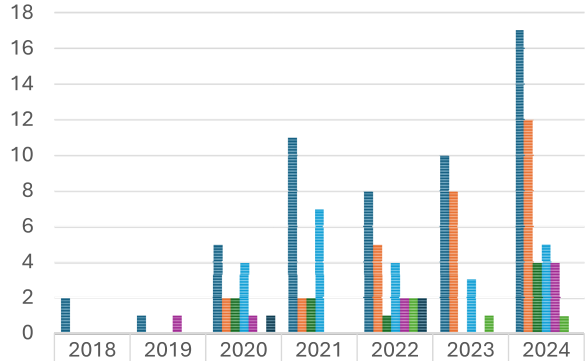
Overall, combined research designs appear to be receiving increasing attention from researchers and have been published at a steady rate.

An overview of the measurement of presence and cybersickness by year of publication is provided in Figure 4. The data indicate an increase in the measurement of presence since 2020. However, with the exception of 2021, the omission of this core construct remains noticeable across all years. A similar pattern is observed for cybersickness, which has only started to receive more attention since 2023.

The data also show that some studies assess both constructs, particularly in 2023 and 2024. Overall, the non-measurement of both presence and cybersickness remains consistently high over time, which may be surprising given the importance of both constructs reported in educational IVR research.

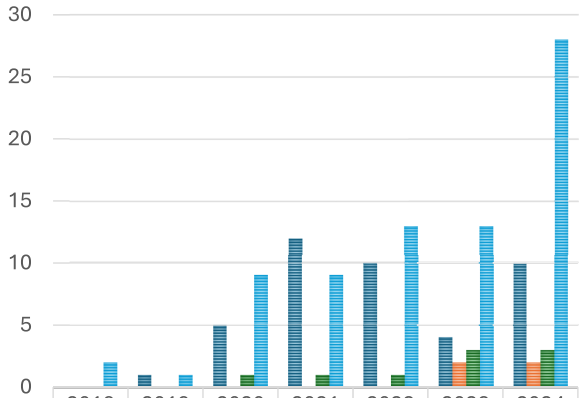
Discussion

The aim of this study was to analyze how researchers have investigated learning in IVR in the context of educational technology research. The significance of this research interest arises from recent concerns raised regarding methodological shortcomings in educational IVR research (e.g. Buchner & Kerres (2023); Glaser



	2018	2019	2020	2021	2022	2023	2024
Media comparison	2	1	5	11	8	10	17
Value-added	0	0	2	2	5	8	12
LTI	0	0	2	2	1	0	4
Media comparison & Value-added	0	0	4	7	4	3	5
Media comparison & LTI	0	1	1	0	2	0	4
Value-added & LTI	0	0	0	0	2	1	1
no active control condition	0	0	1	0	2	0	0

Figure 3. Distribution of research types per year of publication.



	2018	2019	2020	2021	2022	2023	2024
presence	0	1	5	12	10	4	10
cybersickness	0	0	0	0	0	2	2
presence & cybersickness	0	0	1	1	1	3	3
no measure	2	1	9	9	13	13	28

Figure 4. Distribution of presence and cybersickness measures per year of publication.

& Moore, 2023; Lawson et al., 2024). To address this aim, we explored the research types employed, documented the measurement of presence and cybersickness – two constructs central to IVR research – and considered the publication year as a potential influencing factor.

A total of 130 studies were coded and analyzed to address the research questions. Regarding RQ1, the data reveal a more differentiated picture compared to previous reviews, which primarily focused on pure media comparisons (Conrad et al., 2024; Wu et al., 2020). While pure media comparison studies were indeed the most frequent, they were not as dominant as demonstrated by reviews of educational AR studies (Buchner & Kerres, 2023; Chang et al., 2022). This becomes evident through the substantial number of value-added studies and the relatively high number of studies combining the media comparison with the value-added approach. This represents another important distinction from AR research, where combined and value-added approaches have remained relatively rare to date (Buchner & Kerres, 2023; Chang et al., 2022). One potential explanation for this finding could be that many of the analyzed studies are grounded in theoretical frameworks addressing how people learn with digital media (e.g. cognitive–affective theories of multimedia learning; Mayer, 2020; Moreno, 2006), or more specifically, with IVR (e.g. Mulders et al., 2020; Johnson-Glenberg, 2018; Makransky & Petersen, 2021). For instance, several studies use CAMIL (Makransky & Petersen, 2021) or embodied learning (Johnson-Glenberg, 2018) to examine how instructional media and methods influence cognitive and affective processes during learning in IVR environments (e.g. Petersen et al., 2022; Spangenberger et al., 2024). This theoretical grounding – and consequently the contribution to the validation and further development of educational theories – represents a fundamental distinction between value-added research and (pure) media comparison studies. Another important difference concerns the relevance of the results for educational practice. Specifically, value-added studies have the potential to provide concrete design recommendations for practice, for instance by demonstrating that learning with IVR-based games can be improved through guidance (e.g. Ferguson et al., 2020).

No substantial differences between IVR and AR research were identified regarding the frequency of studies using the LTI approach (Buchner & Kerres, 2023; Chang et al., 2022). Within educational technology research, only a few IVR studies have adopted this approach thus far – neither as a standalone nor in combination with other approaches. This represents a significant finding of our analysis, explicitly highlighting an existing gap within educational IVR research. Therefore, we call for more studies using the LTI approach. A recent study by Lawson and Mayer (2024), for instance, can serve as good practice. Insights from LTI studies can also contribute meaningfully to theory development and educational practice. For instance, such studies can identify learner characteristics that influence learning processes in IVR, potentially prompting adaptations or refinements of existing theories. Regarding educational practice, these studies may yield valuable insights on how IVR-based learning environments should be designed to accommodate different learner

groups. For example, it may be important to provide learners who have limited IVR experience with foundational knowledge or introductory sessions before engaging them in the intended IVR learning activities (Kablitz et al., 2023).

Regarding RQ2, it is notable that presence, a key factor in IVR learning experiences, was measured in a limited number of studies, highlighting a potential gap in controlling this influential variable. Similarly, cybersickness was rarely assessed as a factor influencing learning outcomes, although a multitude of studies indicate that experiencing aversive physical symptoms in IVR affects its usage and hence learning processes as well as learning outcomes (Ochs & Sonderegger, 2022; Servotte et al., 2020; Tian et al., 2022; Weech et al., 2019). Therefore, we would like to draw attention to this research gap and encourage researchers to include the factors of cybersickness and presence in future studies to investigate their mediating and moderating effects. Notably, even among studies that measure presence or cybersickness, only a minority statistically relate these constructs to learning outcomes. This limits the field's ability to assess whether and how cognitive, affective, and other variables actually explain learning differences across IVR conditions. Future research should therefore not only examine whether presence and cybersickness are measured but also investigate the complex ways in which these constructs relate to learning outcomes, for example, as potential mediators, moderators, or suppressor variables within more comprehensive explanatory models.

With regard to research designs, it became evident that media comparison studies, in particular, frequently measure presence. This aligns with assumptions found in the literature, which posit presence as the key distinguishing factor between IVR and other educational media, although its role in learning is neither uniform nor consistently positive. However, it is somewhat surprising that presence was assessed in fewer than half of the pure media comparison studies. This could indicate that researchers implicitly assume higher presence due to the technology used. Yet this assumption may be insufficient, given that, as many researchers argue, technological factors of IVR only partially affect presence experience (Cummings & Bailenson, 2016; Felnhofer & Kothgassner, 2022; Schlochtermeier et al., 2015). For instance, the meta-analysis by Cummings and Bailenson (2016) has found that technological features influence presence with a medium-sized effect. Consequently, media comparison studies on learning with IVR should not only vary the medium (e.g. video) in the control condition, but also other factors influencing presence experience. For example, it would be interesting to investigate whether an interactive video or a video with an emotionally stimulating story generates similar presence and, subsequently, comparable learning outcomes.

Value-added and LTI studies have largely neglected the measurement of presence, thus highlighting another important gap in the research literature. Measuring presence in value-added studies could clarify whether variations in IVR-based learning environments consistently evoke high levels of presence. However, it might also be anticipated that, for instance, the integration of generative learning strategies could reduce the sense of presence yet still enhance learning outcomes. LTI studies could furthermore explicitly test for whom presence facilitates, hinders, or has no effect on learning. Findings from such studies would substantially advance our understanding of the role and importance of presence for learning in IVR environments.

Regarding cybersickness, due to the generally limited number of assessments, it is difficult to draw firm conclusions about potential associations with specific research types. Nonetheless, it can be stated that the measurement of cybersickness has thus far been inadequately addressed across all research types. Future research needs to address this shortcoming by systematically investigating whether cybersickness poses varying degrees of impediment depending on the research type employed.

Regarding RQ3, our findings point to gradual shifts in research practices over time. While media comparison studies continue to be used consistently, value-added designs have become more common in recent years. This may indicate an increasing effort to investigate more differentiated instructional questions. LTI approaches, by contrast, remain rare and have only recently begun to appear more frequently. A similar pattern can be observed in the measurement of presence and cybersickness. Although recent studies show a slight increase in the inclusion of these constructs, they are still not systematically assessed. This suggests that pivotal factors influencing IVR-based learning remain underrepresented, despite their established relevance (e.g. Makransky & Petersen, 2021; Ochs & Sonderegger, 2022). Overall, the results point to a slow but positive development in the field, with potential for further methodological refinement.

Limitations and future research

The study's findings are constrained by the methodological approach we utilized. In this systematic review, we specifically targeted 20 of the leading journals in the field of educational technology and focused on studies published between 2016 and 2024. It must be assumed that additional IVR studies will be published in these journals in 2025 (and thereafter), which may slightly alter the distribution explored in the present study. Furthermore, we did not include journals dedicated exclusively to VR without an educational focus, nor did we search broader psychology or human–computer interaction outlets. Future research should therefore consider including additional journals in the analysis, for instance, the *Journal of Research on Technology in Education, Virtual Reality, Technology, Knowledge and Learning,* or *Computers in Human Behavior* and extend the temporal scope of the review. Therefore, very recent work published in 2025 (e.g. Spangenberger et al., 2025; Stenberdt et al., 2025) is not systematically covered in our coded sample.

One rather general limitation of systematic reviews is the reliance on available literature, which may be subject to publication bias, as studies with statistically significant results are more likely to be published. Furthermore, we only considered journals in the field of educational technology research, even though significant findings on learning with IVR may also be published in conference proceedings or journals with a broader scope (e.g. general education journals, human–computer interaction journals).

Next, our analysis only included studies employing a comparative research design, thus excluding those utilizing design – or development-oriented approaches without a control group. Another limitation is our focus solely on IVR studies in education. However, given our role as researchers dedicated to advancing knowledge about the effectiveness of IVR in education, we believe this focus is justified. Future studies should explore whether similar use of specific research types is evident in research focusing on other educational technologies like video, digital games, and artificial intelligence (AI).

Furthermore, our study is limited as we only controlled for two influential factors, namely presence and cybersickness, even though other variables such as engagement (Yang & Liu, 2022) and absorption (Chiquet et al., 2023) may also play important roles in IVR learning. Further reviews might investigate the extent to which studies measure other VR-relevant constructs, for example, agency or cognitive load.

Another promising direction for future IVR research lies in the integration of AI, particularly adaptive systems that personalize learning experiences in real time. For example, recent developments in AI-based feedback systems allow for dynamically tailored support during immersive learning tasks (Obourdin et al., 2024). In a potential study, an AI agent could monitor learners' actions and provide adaptive, context-sensitive feedback (e.g. hints, explanations, or motivational prompts). Compared to a condition without AI support, this value-added approach would enable researchers to examine how real-time AI adaptation influences learning outcomes. Such approaches would also align with LTI-oriented designs by examining how intelligent technologies – adapted to learner characteristics – affect learning.

In general, future research in the field of IVR in education should aim for greater methodological diversity, including the incorporation of design – or development-oriented approaches, additional control factors, and the expansion of the scope beyond studies published in top journals to capture a more comprehensive understanding of IVR's educational potential.

Conclusion

While Lawson et al. (2024) drew attention to the prevalence of confounded research designs, our findings deepen this critique by showing how these confounders manifest in terms of prevalence of certain research designs and lack of presence and cybersickness control. A noteworthy trend emerges in our findings: There appears to be a temporal shift away from exclusive reliance on media comparison studies toward more diverse research designs. While media comparisons still represent the most frequently used research type, their dominance is less pronounced than initially expected. This is particularly relevant in light of longstanding theoretical and methodological critiques of such designs, including their susceptibility to confounding variables and limited instructional relevance. At the same time, we observed a clear increase in the use of value-added designs, both as independent approaches and in combined forms that integrate elements of media comparison with pedagogically grounded questions. These designs are often more theory-driven and better suited to identify specific instructional affordances of IVR. Therefore, while the field shows

promising growth and diversity in methodologies, there are opportunities for further refinement and standardization to enhance the quality of research in this area. Future studies should aim to address the identified gaps and challenges to advance our understanding of the educational potential of IVR technologies.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Josef Buchner http://orcid.org/0000-0001-7637-885X
Miriam Mulders http://orcid.org/0000-0003-0683-2310

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