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Enabling Peer Feedback in Teacher Education: The Use of Virtual Reality-Based Microteaching

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Abstract

Virtual reality (VR) in teacher education offers an immersive environment for microteaching which, when coupled with peer-feedback can enhance pre-service teachers' competence. This study employed a mixed-method quasi-experimental design to compare VR-based microteaching with real-world microteaching among 150 pre-service teachers (n = 73 feedback providers, n = 77 feedback receivers). Quantitative analyses revealed similar perceptions of feedback across both conditions, but minor differences in feedback quality, particularly in the specificity of comments. Qualitative findings highlighted VR's potential for safe, standardized practice and guided reflection, while also pointing to limitations in simulating complex classroom interactions. The study highlights VR's potential for feedback-oriented teacher training and its potential to support the development of professional teaching competencies.

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Introduction

Research shows that feedback can have a positive motivational, cognitive, and meta-cognitive impact on learners (e.g., Hattie & Timperley, 2007; Narciss, 2013). Within teacher education, feedback is typically provided by peers and serves for developing core competencies (Prilop & Weber, 2023). It consists of a peer observing a fellow pre-service teacher's classroom interactions and, subsequently, providing them with feedback. Studies show that the effectiveness of peer feedback is influenced by the recipient's feedback perception and the quality of the feedback (Huisman et al., 2018; Prilop et al., 2021; Strijbos et al., 2010). High-quality peer feedback addresses agreed-upon goals, references observable classroom behavior, and includes clear criteria such as *specificity*, *suggestions*, *questions*, *positive* and *negative comments*, and *first-person* formulation (Gielen & De Wever, 2015; Narciss, 2013; Nicol & Macfarlane-Dick, 2006; Prins et al., 2006; Sluijsman et al., 2002). Feedback perception is the recipient's cognitive and motivational evaluation of the feedback. This includes the feedback's perceived *fairness*, *usefulness*, and *acceptance*, as well as the recipient's *willingness to improve* their instructional practice (Ilgen et al., 1979; Strijbos et al., 2021). However, expert-novice comparisons reveal a disparity in feedback quality between novices and experts, highlighting the need for targeted practice opportunities within teacher education programs to refine this essential skill (Jacobsen & Weber, 2025; Prilop et al., 2021).

Microteaching sessions have been identified as effective approaches for practicing feedback skills in an authentic context, emphasizing the rehearsal of specific teaching competencies (Benton-Kupper, 2001; Grossman et al., 2009; Klinzing, 2002). The implementation of and technological support for microteaching have significantly evolved, transitioning from traditional methodologies of just acting out a scenario to incorporating videography and digital video annotation (Cavanaugh, 2022).

In recent years, VR has emerged as an innovative option among various tools for microteaching, offering a promising solution to these challenges (Huang et al., 2023a). Comparative studies suggest VR can induce reflections of a quality akin to those derived from real classroom scenarios, with pre-service teachers valuing VR as a tool for critical examination of their teaching approaches (Richter et al., 2022; Seufert et al., 2022; Stavroulia & Lanitis, 2019).

Despite these promising findings, the capacity of VR to enable high-quality peer feedback sessions remains underexplored (Snelson & Hsu, 2020). Determining the comparability between VR-based and real-world microteaching in terms of quality and perception requires additional, comprehensive research efforts. Addressing this research gap, the current study employs a quasi-experimental mixed-methods approach to investigate the fidelity with which VR-based microteaching simulations replicate the complexities of real-world microteaching and their effectiveness in promoting effective feedback sessions.

Theoretical Background

Peer Feedback

In a teaching context, peer feedback competence can be characterized as the ability to provide constructive criticism of a colleague's teaching practice, thereby encouraging reflection and fostering professional development (Sluijsmans, 2003; Tripp & Rich, 2012). Research indicates that implementing peer feedback in higher education enhances student learning (Gielen et al., 2010), boosts critical thinking abilities (Lynch et al., 2012), and elevates engagement (Fan & Xu, 2020), motivation (Hsia et al., 2016; Zhang et al., 2014), and satisfaction (Donia et al., 2021; Zhang et al., 2014). However, peer feedback has to be of high quality to be fruitful. In a recent study, Kerman et al. (2024) found that students categorized as unsuccessful, less successful, and successful exhibited differences in the average quality scores of the peer feedback they received. Moreover, studies have shown that experts' and peers' feedback quality differ (i.e. Prilop et al., 2019, 2021). These expert-novice comparisons clearly indicate a need for practice opportunities for pre-service teachers in order to improve their feedback quality.

Peer Feedback Quality. To define high-quality peer feedback in teacher education, Sluijsman et al. (2002) extracted characteristics of constructive feedback from expert feedback. Building on these findings, subsequent research (e.g., Gielen & De Wever, 2015; Prilop & Weber, 2023; Prins et al., 2006) assessed peer feedback quality according to the presence of a set of necessary characteristics concerning feedback content and presentation. According to these characteristics, high-quality peer feedback takes the *assessment criteria* into account, is *specific*, provides *suggestions*, poses *reflective questions*, uses a combination of *positive and negative comments*, and is formulated in the *first person*.

Concerning *assessment criteria*, feedback to a peer needs to relate to previously agreed-upon observation goals. The peer feedback must comment on the actual classroom behavior of the teacher and refer to a specific focus of evaluation (Prins et al., 2006). Regarding *specificity*, peer feedback needs to specify the teacher's classroom behavior that was successful or could be improved upon (Gielen et al., 2010). Potential areas of improvement need to be elaborated on with constructive suggestions that enable the teacher to work on their skills. Constructive suggestions can consist of knowledge about task constraints, concepts, mistakes, strategies, or knowledge on how to proceed (Narciss, 2013). To actively engage peers in the feedback process, peer feedback should include *reflective questions* (Gielen et al., 2010; Nicol & Macfarlane-Dick, 2006). Furthermore, peer feedback should combine *positive and negative comments*, as teachers require critical comments for improvement. Finally, high-quality peer feedback should be formulated in the *first person* to indicate that the feedback is a personal opinion up for discussion rather than objective truth (Prins et al., 2006). In alignment with these findings, Wisniewski et al. (2020) underscore that the efficacy of feedback is optimized when it encompasses a substantial amount of information, guiding learners through task-specific, process-oriented, and self-regulatory levels of feedback to enhance their comprehension and performance.

Peer Feedback Perceptions. To ensure the effectiveness of feedback, it is essential not only to provide high-quality peer feedback but also to actively engage pre-service teachers in the feedback process. Feedback intervention theory postulates that individual characteristics such as perceptions have a greater influence on the impact of feedback on learning and achievement than the specific attributes of the feedback message itself (Alqassab, 2017). Peer feedback perceptions refer to how individuals experience the content of feedback given by a peer and can be broadly categorized into two dimensions: those related to the cognitive function of feedback, which include perceived *fairness*, *usefulness*, and *acceptance*, and those related to the motivational function of feedback, which include affective reactions such as *willingness to improve* and overall *emotional impact* (Strijbos et al., 2021). Ilgen et al. (1979) reviewed the processes by which feedback influences behavior. They argued that feedback needs to be perceived as useful and accepted by the recipient and that recipients need to be willing to respond to the feedback and to change their actual behavior. If pre-service teachers do not perceive their peers' feedback as valuable and helpful, there is a probability that they may not engage completely in the feedback process (Altstaedter & Doolittle, 2014). Similar findings were made by Tsui and Ng (2000). They found that students incorporated feedback only if it was perceived as helpful. Research indicates that more detailed and specific feedback including advice or explanations is generally favored by students and considered more useful (Shute, 2008; Straub, 1997). Also, a predominance of critical comments could lead to a negative perception of the peer feedback and a lack of uptake (Prilop et al., 2021). In general, the perceptions of pre-service teachers toward peer feedback are complex and multifaceted, influencing both the reception and uptake of the feedback provided.

Classroom Simulations

Microteaching in Teacher Education. The necessity for practice opportunities aligns well with the implementation of classroom simulations, such as microteaching, which can provide a platform for pre-service teachers to apply and train their feedback skills in a controlled, yet authentic, educational environment (Benton-Kupper, 2001; Calonge et al., 2013). In microteaching, learners plan a teaching episode, which they then carry out and, if necessary, record on video (Karlström & Hamza, 2019). Thus, microteaching enables pre-service teachers to acquire complex competencies in authentic situations by practicing specific skills during classroom simulations (Grossman et al., 2009). This method is particularly well suited to teach situation-specific skills and to practice both social and didactic competencies, as well as to promote the transfer of these competencies into later professional life (Klinzing, 2002; Kramer et al., 2017; Remesh, 2013). While acquiring such complex competencies the learning process can be divided into several stages: (a) introducing and learning about the activity; (b) preparing for and rehearsing the activity; (c) enacting the activity with students; (d) analyzing enactment and moving forward (Kavanagh & Rainey, 2017; McDonald, 2020; McDonald et al., 2013). Microteaching is particularly valuable for the enactment phase and for structured feedback and reflection in later phases (Benton-Kupper, 2001; Remesh, 2013).

Overall, there is consensus among researchers and teacher educators that microteaching can be a valuable tool for teacher education (Blomberg et al., 2014; Klinzing, 2002; Kramer et al., 2017; Remesh, 2013). Nevertheless, implementation challenges persist, including (a) lesson design and execution time, (b) resource constraints, (c) student motivation, and (d) effective feedback strategies (Calonge et al., 2013; Dayanindhi & Hegde, 2018). This study addresses several of these issues by developing an intervention that systematically trains pre-service teachers in evidence-based feedback strategies and applies them in a VR-based teaching simulation. This setting provides authentic, standardized opportunities for deliberate feedback practice while reducing the logistical demands typically associated with real-world simulations. In addition, VR-based instruction may foster task-related interest and engagement (see Huang et al., 2023b; Richter et al., 2022).

Virtual Reality in Teacher Education. The above-mentioned restrictions of the physical world are no longer the limit for microteaching experiences. In recent years, teachers and pre-service teachers have been enabled to engage in authentic classroom experiences within VR-based environments (Huang et al., 2023a). VR is a collection of technologies that create “synthetic and highly interactive three-dimensional (3D) spatial environments” (Mikropoulos & Natsis, 2011, p. 769). These virtual environments can effectively simulate both real and non-real classroom scenarios. Widely employed across various professional fields to train procedural and situational knowledge, VR provides two significant advantages for learning: presence and agency (Jensen & Konradsen, 2018; Makransky & Petersen, 2021; Slater, 2018). Presence refers to the immersive experience of “being there”, while agency encompasses the sense of initiating and controlling actions according to one’s own volition (Moore & Fletcher, 2012).

VR not only offers authentic training opportunities but also provides a practical solution to common challenges associated with microteaching. By leveraging VR technology, the environment, situation, and personnel involved in microteaching can be freely and adaptively customized. For instance, the class size can be configured (Huang et al., 2022) student actions and speech can be controlled (Seufert et al., 2022), and the high personnel costs associated with employing and training actors can be circumvented. Hence, VR offers a cost-effective alternative to real-world microteaching that enables users to engage in realistic teaching scenarios without compromising on the quality of the learning experience. However, Makransky and Lilleholt (2018) found that although students felt more present in immersive VR environments, they experienced a higher cognitive load.

Professional training programs in various occupations have embraced the implementation of VR environments, as highlighted in a comprehensive review by Jensen and Konradsen (2018). However, the use of VR-based microteaching specifically for teacher education is a relatively recent development, emerging within the last decade (Huang et al., 2023a). Several companies and research groups have contributed to the development of software for VR-based microteaching, for instance, simSchool (Deale & Pastore, 2014), TLE TeachLivE™ (Dieker et al., 2014), Mursion (Kaufman & Ireland, 2016), Breaking Bad Behaviors (Lugrin et al., 2016; Seufert et al., 2022), and Teach-R (Wiepke et al., 2019, 2021). These VR-based software environments offer pre-service and in-service teachers opportunities to engage in authentic teaching practice within a simulated and safe setting (Huang et al., 2023b). Such environments facilitate the development of skills through customizable training programs, which can be standardized or tailored to individual needs (for a review, see Huang et al., 2023a). Furthermore, their efficacy in providing cost-effective, repeatable, and consistent training is well documented and may allow for immediate and realistic feedback (Dieker et al., 2014; Pottle, 2019).

While the potential of VR for microteaching, reflection, and feedback in teacher education is frequently emphasized, empirical evidence supporting these claims remains limited. Recent reviews by Snelson and Hsu (2020) as well as Huang et al. (2023a) highlighted the scarcity of studies focusing on reflection or feedback in VR-based teacher education. Previous research by Huang et al. (2022, 2023b) examined the effects of VR-based microteaching on pre-service teachers' stress responses and classroom management strategies, demonstrating VR's potential to provide an immersive training environment that encourages active engagement and skill application. These findings underscored the need to further examine how VR-based microteaching supports complex teaching skills, such as reflective practice and peer feedback, which the current study seeks to address.

Similarly, Richter et al. (2022) compared pre-service teachers who reflected on recordings of VR-based microteaching with those who reflected on recordings of real-world classroom teaching and found that VR-based videos elicited a comparable quality of reflection. This finding aligns with the results of Seufert et al. (2022), who discovered that pre-service teachers perceive VR as a valuable tool for reflecting on their teaching practices and evaluating their strengths and weaknesses. Furthermore, Stavroulia and Lanitis (2019) examined self-reported attitudes toward reflection among pre-service teachers, comparing those trained in a real classroom environment to those trained in a VR classroom. The study revealed that pre-service teachers in the VR environment demonstrated a higher inclination toward engaging in reflective practices.

By immersing themselves in a realistic virtual environment, pre-service teachers can actively observe, analyze, and critically reflect on their teaching practices, thereby enhancing their pedagogical skills and decision-making abilities. Although VR experiences hold great promise, compared with traditional methods they often demand more of users' cognitive resources, leaving less room for in-depth thinking and reflection (Albus et al., 2021; Poupard et al., 2024). Thus, it remains uncertain whether VR-based microteaching experiences can effectively enable high-quality feedback sessions. Further research is required to determine whether feedback provided by observers in VR-based microteaching experiences carries the same level of quality and is perceived as equally useful, fair, and thus, acceptable, and whether it leads to a willingness to improve, compared with feedback from colleagues who observed real-world microteaching sessions.

The structured nature of VR-based microteaching also offers a unique opportunity to address resource limitations and provides consistent conditions for practicing critical teaching skills, such as classroom management and reflective practice (Jensen & Konradsen, 2018; Makransky & Petersen, 2021; Pottle, 2019). By controlling student interactions and enabling adaptable settings, VR allows pre-service teachers to safely experiment and improve skills that are often challenging to replicate in real-world settings. The current study aims to fill this research gap by systematically analyzing the quality, perception, and impact of feedback in VR-based microteaching, contributing to a deeper understanding of VR's role in supporting high-quality peer feedback in teacher training (Seufert et al., 2022; Snelson & Hsu, 2020; Stavroulia & Lanitis, 2019).

Research Questions and Aims of the Study

In the current study, we investigated whether peer feedback sessions based on VR-based microteaching can be compared to peer feedback sessions based on real-world microteaching in terms of peer feedback quality and pre-service teachers' perceptions of peer feedback. Furthermore, we analyzed the extent to which pre-service teachers perceive VR as an effective tool for feedback sessions.

Hence, the following research questions were investigated:

(1) How does VR-based microteaching influence the quality of pre-service teachers' peer feedback compared to real-world microteaching?
(2) How does VR-based microteaching affect pre-service teachers' peer feedback perceptions in comparison with real-world microteaching?
(3) How do pre-service teachers perceive the effectiveness of VR in facilitating high-quality feedback sessions?

Method

Study Context and Participants

This study was conducted within the framework of the project *My Virtual Reality Teaching Partner (My VRTP)*, funded by the Stiftung Innovation in der Hochschullehre (Innovation in University Teaching Foundation). The project aims to strengthen digitally supported practice elements in teacher education by introducing a train-the-trainer approach. Specifically, pre-service teachers are trained as "VR Teaching Partners" who, in the first phase, participate in a seminar to acquire competencies in criteria-based classroom observation, the design of constructive and supportive feedback conversations, and the independent implementation of VR-based microteaching. In the second phase, the VR Teaching Partners independently organize and deliver VR-based microteaching for other pre-service teachers outside the formal seminar setting and jointly reflect with them on the quality of the lessons taught. In this way, the project contributes to expanding digital practice formats in teacher education and creates meaningful moments of peer-to-peer learning.

The sample of this study was generated from the participants involved in the project. It comprised two subgroups: (1) feedback providers and (2) feedback receivers. The feedback providers were all pre-service teachers enrolled in the My VRTP seminar, which is designed to develop competencies in professional classroom observation and the delivery of high-quality, teaching-related feedback. As part of the seminar, these students received targeted training on how to observe classroom instruction, identify key aspects of classroom management, lesson structure, and student engagement, and formulate constructive and actionable feedback.

After completing the preparatory training, the feedback providers were assigned the task of applying their newly acquired skills in practice: they independently organized microteaching sessions with other pre-service teachers, observed their teaching performance (conducted either in VR or real-world settings), and provided structured peer feedback. Importantly, the feedback providers did not conduct microteaching lessons themselves within the scope of this study. Their role was limited to observing the feedback receivers' teaching and providing structured feedback, as part of their practical application of the competencies acquired in the My VRTP course.

The feedback receivers were pre-service teachers who participated in these microteaching sessions by conducting simulated lessons. They did not receive any specific preparatory training or instruction for these sessions; their role was solely to teach a prepared lesson within the microteaching simulation. While most feedback receivers were external students not enrolled in the My VRTP course, some were concurrently enrolled in the course but took on the receiver role for the purpose of the study. Thus, although the roles of feedback provider and feedback receiver were clearly separated within each microteaching session, there were few participants who took both roles in different sessions.

Feedback Providers. In total, 73 pre-service teachers (M_{Age} = 23.7 SD_{Age} = 3.4) participated as feedback providers. The group included 42 individuals who identified as female ($N_{VR\text{-}Sim}$ = 32, $N_{real\ Sim}$ = 10), 30 identifying as male ($N_{VR\text{-}Sim}$ = 17, $N_{real\ Sim}$ = 13), and one individual who chose not to specify their gender. Most pre-service teachers were enrolled in a bachelor's degree program in teacher education ($N_{VR\text{-}Sim}$ = 25, $N_{real\ Sim}$ = 24) at 67.2%, while 32.8% were enrolled in a master's degree program in teacher education ($N_{VR\text{-}Sim}$ = 21, $N_{real\ Sim}$ = 3). On average, pre-service teachers were in their sixth semester of teacher education (M = 6.1, SD = 2.4). Concerning teaching experience, most participants reported 1–10 independently taught hours (40.8%), followed by no teaching experience (25.4%), over 30 independently taught hours (21.1%), and 11–30 independently taught hours (9.9%).

Feedback Receivers. The group of feedback receivers included a total of 77 participants (M_{Age} = 23.8, SD_{Age} = 3.4). The group included 40 individuals who identified as female

($N_{VR\text{-}Sim}$ = 31, $N_{real\ Sim}$ = 9) and 37 as male ($N_{VR\text{-}Sim}$ = 21, $N_{real\ Sim}$ = 16). The majority of participants, 70.1%, were completing a bachelor's degree program in teacher education ($N_{VR\text{-}Sim}$ = 32, $N_{real\ Sim}$ = 22), 28.6%, were completing a master's degree program in teacher education ($N_{VR\text{-}Sim}$ = 20, $N_{real\ Sim}$ = 2), and one person (1.3%) was completing a master's degree in educational science ($N_{real\ Sim}$ = 1). On average, pre-service teachers were in their sixth semester of teacher education (M = 6.3, SD = 3.5). Regarding teaching experience, most participants reported 1–10 independently taught hours (42.9%), followed by no teaching experience (23.4%), over 30 independently taught hours (19.5%), and 11–30 independently taught hours (14.3%).

Intervention Design

Using a mixed-method quasi-experimental design, we investigated whether the quality and perceived comprehensibility and usefulness of peer feedback differed depending on whether the microteaching was conducted in the real world or in a VR classroom (Figure 1).

The study involved three groups of pre-service teachers, all of whom had completed the university course *My Virtual Reality Teaching Partner* (My VRTP). In this course, participants (feedback providers) acquired competencies in professional classroom observation and in delivering high-quality, teaching-related feedback. After completing the course, they were assigned the task of applying these competencies in practice by independently organizing microteaching sessions for other pre-service teachers (feedback receivers), observing their teaching performance, and providing structured peer feedback.

Group 1 and Group 2 (intervention groups, VR condition; Figure 2) organized VR-based microteaching sessions. The division into Group 1 and Group 2 within the VR condition resulted solely from the course's organizational structure (separate cohorts) and did not reflect any difference in intervention procedure. Group 3 (control group, real-world condition; Figure 3) organized real-world microteaching sessions.

In all sessions, the feedback receivers – pre-service teachers with no specific preparatory training – received the same standardized lesson plan and presentation slides (on the topic of note-taking) in advance and conducted the same lesson using these materials. To ensure a high degree of standardization across conditions, the virtual students in the VR classroom behaved according to a predefined script, and in the real-world microteaching sessions, trained actors portrayed the students, following the exact same script as programmed for the virtual students. Both microteaching sessions lasted approximately 10 minutes. This ensured not only within-condition consistency but also comparability between the VR and real-world conditions.

During each teaching simulation, the feedback providers observed the lessons with the specific task of identifying relevant aspects of classroom management, instructional delivery, and student engagement, as practiced in the course. After the simulation, they conducted a structured, teaching-related feedback conversation with the feedback receivers, following the principles and guidelines emphasized in the My VRTP course. All feedback conversations were audio-recorded for subsequent analysis. Finally, the

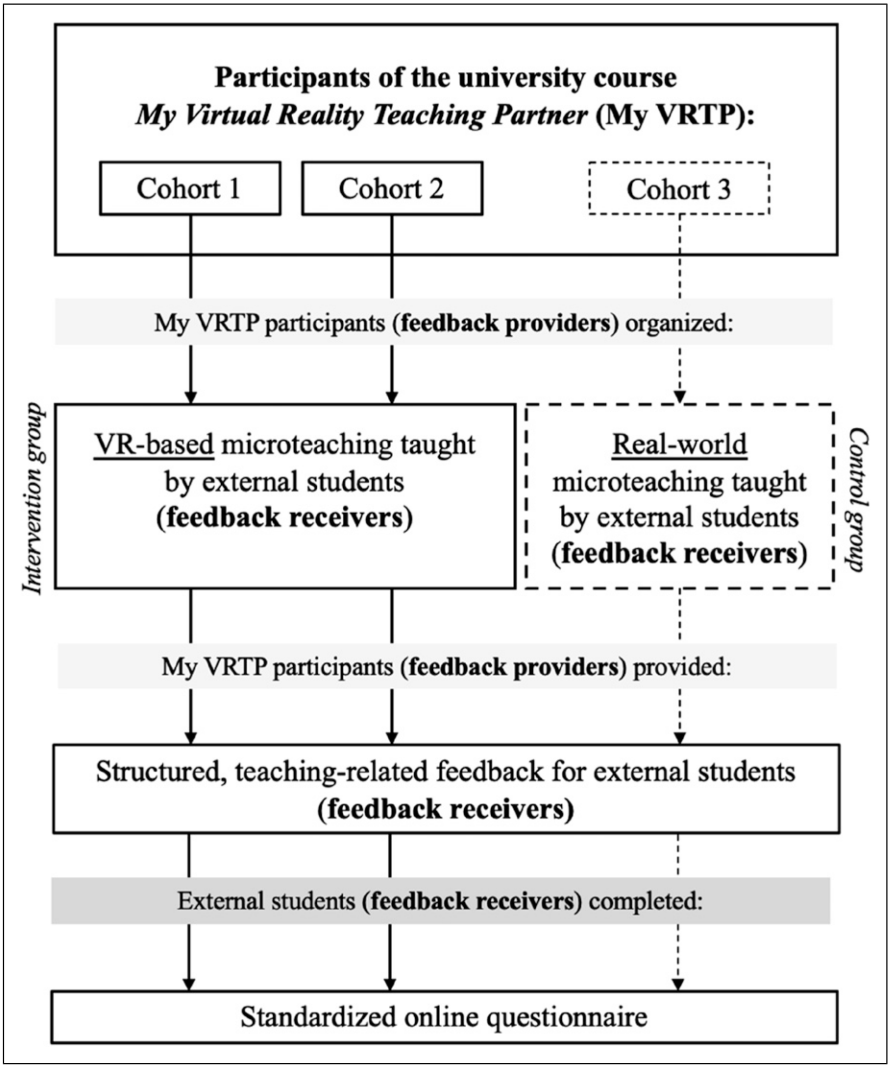

Figure 1. Overview of Study Design. Feedback Providers (My VRTP Participants) Organized Microteaching Sessions for Feedback Receivers. Cohorts 1 and 2 (VR Condition) Offered VR-Based Sessions; Cohort 3 (Real-World Condition) Offered Real-World Sessions. In all Groups, Feedback Providers Observed Lessons, Conducted Structured Feedback, and Feedback Receivers Completed a Post-Session Questionnaire. All Simulations Used Identical Lesson Plans and Scripted Student Behaviors to Ensure Comparability

Figure 2. VR-Based Microteaching

feedback receivers completed a standardized online questionnaire with closed-ended items assessing their perception of the feedback they had received.

Design of the Virtual Reality Classroom

Our study utilized a VR classroom designed to replicate an upper secondary school setting in Germany. The virtual environment was arranged with a classroom layout consisting of three columns and five rows of desks and chairs, each occupied by a student agent (Figure 4). These agents exhibited diverse physical attributes such as skin color, hairstyle, and clothing and were identifiable by name tags on their desks. Engaging in behaviors typical of a classroom, the agents performed tasks ranging from productive actions, like writing in notebooks, to disruptive ones, such as throwing paper balls. They maintained natural, seated postures with neutral facial expressions and reacted to participants' movements by occasionally shifting their gaze or adjusting their body position. This spectrum of behaviors, including detailed off-task activities, was derived from established patterns of classroom disruptions documented in educational research and has been shown to serve as salient focal points for feedback in prior research (Borko, 2016; Prilop et al., 2020; Wolff et al., 2016), ensuring all actions were precisely scripted for experimental consistency. The VR system facilitated interaction

Figure 3. Real-World Microteaching

by allowing users to move and look around freely, thereby enhancing the immersive experience (Huang et al., 2023c).

The technical infrastructure supporting the VR classroom included an HTC Vive Pro Eye system: a headset, two controllers, and two base stations for room-scale tracking.

Figure 4. Close-up View From a Student in the VR Environment

The headset has a resolution of 1440 × 1600 pixels per eye (2880 × 1600 combined resolution) with a 110° field of view. This headset was connected to an Alienware laptop equipped with a 2.2 GHz Intel Core i7-8750H processor, 16 GB of RAM, and an NVIDIA GeForce RTX 2060 graphics card with 6 GB of VRAM. This setup allowed the participants to physically navigate while engaging in a multisensory and immersive experience within the VR environment. Previous research has validated the authenticity and immersive quality of the VR setup, which contributed significantly to its realism (Wiepke et al., 2019, 2021).

Instruments

Feedback Quality. My VRTP participants (feedback providers) were asked to give feedback to their trainees (feedback receiver) after the real-world or VR-based microteaching on the quality of the teaching. Feedback was supposed to focus on classroom management, organizational structures, methods, and the learning environment. The feedback sessions were recorded using OBS Studio and then transcribed digitally. Feedback was analyzed using quantitative content-structuring analysis. To assess the quality of the feedback sessions, we adapted a coding scheme from Prilop et al. (2019) to the feedback situation. Feedback quality was examined using three main categories and nine subcategories: *concreteness* (i.e., appropriateness, specificity, explanation, presence of suggestions for improvement, and explanation of suggestions), *empathy* (i.e., direction, style, and interaction), and *engagement* (i.e., presence of thought-provoking questions). For each subcategory, we added three more subcategories (learning environment, teacher, and students; henceforth referred to as sub-subcategories) so we were able to code which aspects of the microteaching session the feedback focused on. Each subcategory was rated as good (2), moderate (1), or poor (0) and, if applicable, assigned to one of the sub-subcategories and thus could be quantitatively interpreted in further analysis. Two student assistants were trained in coding the feedback quality. The training involved the random selection of ten feedback sessions as samples for practice. The research team addressed any differences in the ratings made by the coders before double coding 20% of the total sample (Zottmann et al., 2013). To establish interrater reliability, Cohen's kappa (κ) was calculated based on the double-coded sample. Intercoder reliability ranged from 0.72 to 1.00 (see Table 1), indicating substantial reliability (Fleiss & Cohen, 1973). The student assistants then coded all the transcribed feedback sessions using MAXQDA.

Feedback Perceptions of the Trainees (Feedback Receivers). After receiving the peer feedback, we asked the trainees (feedback receivers) how they perceived the feedback by using an adapted version of the Feedback Perceptions Questionnaire (FPQ) by Strijbos et al. (2021). The questionnaire includes a total of 18 items, of which we adopted 10 and modified another 2 to fit our study design. It measures pre-service teachers' perceptions of peer feedback in terms of *fairness* (e.g., "I consider this feedback fair"; $\alpha = 0.77$), *usefulness* (e.g., "I consider this feedback useful"; $\alpha = 0.86$), *acceptance* (e.g., "I accept this feedback"; $\alpha = 0.62$) and *willingness to improve* (e.g., "I

Table 1. Content Analysis of Feedback Quality: Subcategories, Examples, and Intercoder Reliability (Cohen's Kappa)

Subcategory	Good feedback definition	Code	Average feedback definition	Code	Suboptimal feedback definition	Code	κ	Good feedback example
Appropriateness	Aspects of classroom management and/or lesson delivery are discussed using classroom management terminology	2	Aspects of classroom management and/or lesson implementation are discussed without using terminology	1	Aspects of classroom management and/or other technical aspects of teaching are not addressed	0	1.00	"So perhaps an alternative option would be to point out certain rules and agreements right at the beginning of the lesson in order to avoid them later in class." (GUBEUN11, pos. 20)
Specificity	A specific situation is described	2	A situation that takes a longer period of time (phase) is partially described	1	No specific situation is described	0	0.90	"For example, moritz ate an apple at the beginning of the lesson, and you said directly that he should put it away and referred to the class rules again." (CHBENE06, pos. 6)
Explanation	Why the sequence is optimal/suboptimal is explained in detail	2	Why the sequence is optimal/suboptimal is briefly explained	1	No explanation is given as to why the sequence is optimal/suboptimal	0	0.73	"And I thought it was really cool that you still had a bit of aplomb in the situation where the two of them were chatting at the back, that you then walked across the room and then really stood at the back and just sort of stood between these disturbances." (DIBENA10, pos. 30)

(continued)

Table 1. (continued)

Subcategory	Good feedback definition	Code	Average feedback definition	Code	Suboptimal feedback definition	Code	κ	Good feedback example
Presence of suggestions for improvement	Alternatives are presented with explanations	2	Alternatives are presented without explanation	1	No alternatives are presented/hinted at	0	0.73	"Also simply go to the back and stand with your back to the wall and then have the pupils and the blackboard in view." (ANHANE06, pos. 10)
Explanation of suggestions	Alternatives are explained in detail	2	Alternatives are briefly explained	1	Alternatives are not explained	0	0.72	"I can imagine it would have come up again if you had just moved in its direction. Or, as I said, if you had simply radiated more presence by moving around the room." (ANBRJE07, pos. 6)
Direction	Equilibrium of positive and negative feedback	2	Mainly positive feedback	1	Mainly negative feedback	0	1.00	The "direction" category was evaluated in relation to the entire feedback session
Style	Formulated in first person throughout feedback	2	Occasionally formulated in first person	1	Not formulated in first person	0	0.85	"I will now go into this in more detail. Um, I also noticed that you…" (CHBENE06, pos. 6)

(continued)

Table 1. (continued)

Subcategory	Good feedback definition	Code	Average feedback definition	Code	Suboptimal feedback definition	Code	κ	Good feedback example
Interaction	Feedback provider consistently refers to the statements of the feedback recipient	2	Feedback provider only partially refers to the comments of the feedback recipient	1	Feedback provider makes no reference to the comments of the feedback recipient	0	0.85	"Um, I agree with your assessment at the beginning that you responded very well to some of the disturbances, for example this verbal question from a pupil." (BIBEIT12, pos. 22)
Presence of thought-provoking questions	An activating question (reflection) is asked	2	A question is posed to clarify the details	1	No questions are asked	0	0.78	"If you think about this again, how could the teaching sequence be carried out alternatively?" (ANHATT10, pos. 10)

am willing to improve my performance because of the feedback"; α = 0.79). For this study, a rather active wording of the items was chosen, slightly deviating from the wording of the original items (e.g., "I would be satisfied with this feedback."). Questionnaire items were rated from 1 = fully disagree to 11 = fully agree. Negatively phrased items were re-coded.

Methods of Analyses

We adopted a mixed-methods approach to enable a holistic view and greater depth of analysis. The statistical analyses provide general insights into the overall quality of the feedback sessions and the subsequent feedback perceptions of the pre-service teachers. However, it is the qualitative analysis of the feedback sessions that provide the detailed understanding necessary to fully grasp the underlying dynamics. With this dual approach, we aim to facilitate a comprehensive understanding of VR as a tool for pre-service teachers in feedback sessions. The research team processed the data material through independent efforts. One of the authors employed a quantitative methodology, utilizing a coding manual for analysis. Concurrently, the first author conducted a qualitative content analysis. This distinct methodological division enabled a nuanced examination of the data, allowing for a rich, in-depth analysis that leveraged the strengths of both quantitative and qualitative research paradigms.

Quantitative Analyses. Prior to the quantitative analyses, we cleaned the data to address inconsistencies in code assignment across different parts of the datasets. This process led to a reduction from 77 to 73 datasets for the quantitative analyses, thereby enhancing the reliability and accuracy of our analyses. The Shapiro-Wilk and Levenes' tests were employed, and the Z-score method was applied. The data regarding feedback perception and that regarding feedback quality and focus were analyzed by applying one-way analyses of variance (ANOVA). All statistical calculations were performed using SPSS 29, and we set the significance level at $p < 0.05$ for all tests.

Qualitative Analysis. Regarding the qualitative analysis, Schreier (2014) emphasizes the importance of identifying, conceptualizing, and systematically describing selected content aspects within the material. In light of this and given the goal of examining the promises and pitfalls of VR-based microteaching for fostering high-quality feedback sessions in large amounts of qualitative data (77 transcribed feedback discussions, 39,272 words in total), we opted for Kuckartz's (2016) method of a content-structuring qualitative content analysis; as it is systematic and rule-based, its results are intersubjectively comprehensible. This method comprises various approaches, which are all characterized by a rigidly structured methodology while allowing for a flexible strategy in category formation, making it the most appropriate choice for this context (Kuckartz, 2016). Figure 5 provides a visual depiction of the methodology employed.

The initial stage of our qualitative study involved textual analysis of feedback transcripts, requiring multiple readings, the identification of key passages, and the recording of preliminary insights. The subsequent stage concentrated on establishing a

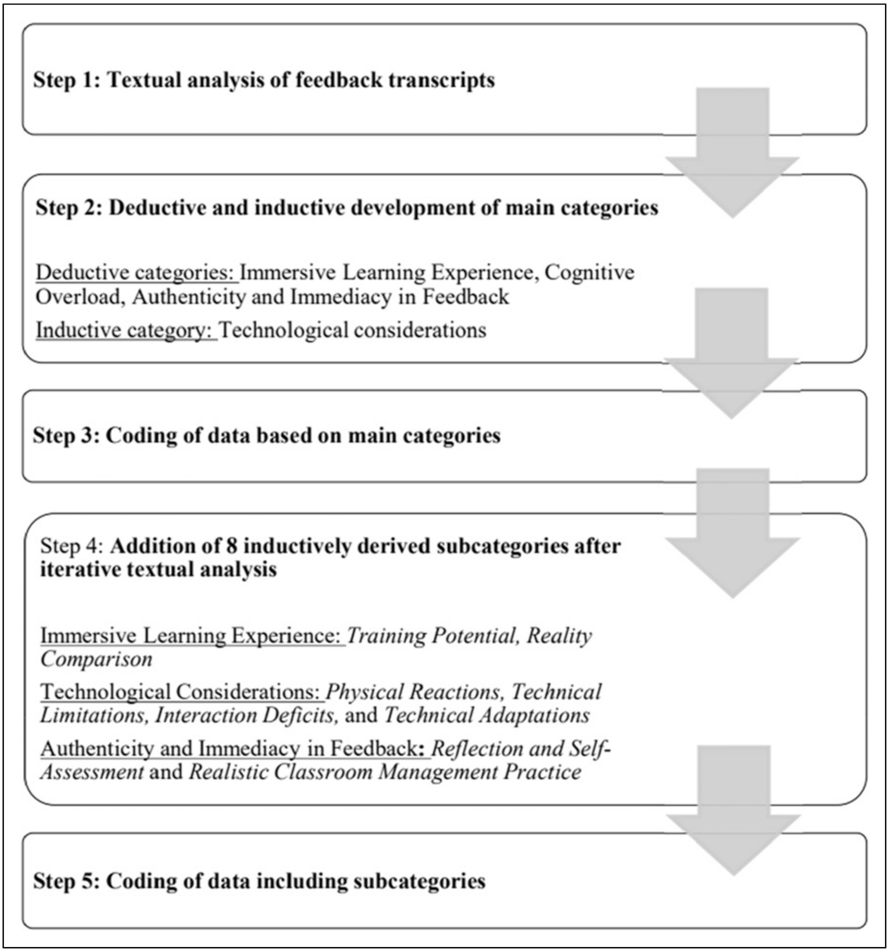

Figure 5. Overview of the Content-Structuring Content Analysis

categorization scheme for the analysis. Kuckartz (2016) posits that categorization may be approached deductively from theoretical frameworks and research questions, inductively from the data, or via a hybrid method. This study adopted the third strategy, deducing three primary categories from the literature (Immersive Learning Experience, Cognitive Overload, Authenticity and Immediacy in Feedback) and inducing one primary category (Technological Considerations). In the fourth stage, iterative textual analysis led to the addition of eight inductively derived subcategories. This was followed by a second round of coding and detailed data analysis using MAXQDA 2022, a specialized QDA tool that supports a digital and transparent data examination process. The coding procedure was followed by the analysis phase and, ultimately, the writing of the results section.

Results

Feedback Quality

The Shapiro-Wilk test, known for its higher precision with smaller sample sizes, was used to evaluate deviations from normality. The results indicated statistically significant deviations from normality in both groups ($p < .001$), indicating a violation of the normality assumption. Due to the asymmetry of the data, Levene's test based on the median was used to assess the equality of variances. The results of Levene's test indicated homogeneity of variances across all groups ($p > .05$). During data analysis, two outliers were identified within the VR group using the Z-score method (±3 SD). After review, the outliers were kept, as they reflected plausible variation within the study population. Therefore, to address our first research question, a one-way ANOVA was conducted to examine the effect of VR-based microteaching on the quality of pre-service teachers' peer feedback compared to real-world microteaching. To evaluate the stability of the results with and without the outliers, a sensitivity analysis was performed.

The analysis (see Table 2) showed no significant group differences for any peer-feedback subcategory except *specificity*. For *specificity*, the real-world microteaching group scored higher than the VR-based group, F (1, 71) = 5.04, $p = .028$, $\eta^2 = .066$ (95 % CI [0, .197]), representing a medium effect (Cohen, 1988). This indicates that the microteaching modality accounted for a meaningful amount of variance in the *specificity* of peer feedback. In other words, significantly more events were described in greater detail within the real-world microteaching group. All remaining subcategories did not differ significantly between groups (all $p > .05$).

Table 2. Descriptive Statistics and ANOVA Results for Feedback Quality (VR-Based vs. Real-World Microteaching)

Category	Subcategory	VR-based M (SD)	Real-world M (SD)	F	p	η^2
Concreteness	Appropriateness	1.47 (0.58)	1.38 (0.58)	0.428	.515	.006
	Specificity	1.36 (0.67)	1.72 (0.55)	5.043	**.028**	.066
	Explanation	1.09 (0.72)	0.99 (0.72)	0.263	.610	.004
	Suggestions for improvement	1.38 (0.78)	1.40 (0.70)	0.015	.904	.000
	Explanation of suggestions	0.80 (0.70)	0.80 (0.70)	0.001	.976	.000
Empathy	Direction	1.16 (0.51)	1.21 (0.66)	0.103	.750	.001
	Style	1.86 (0.35)	1.79 (0.41)	0.492	.485	.007
Engagement	Interaction	1.41 (0.70)	1.54 (0.51)	0.684	.411	.010
	Thought-provoking questions	1.62 (0.48)	1.70 (0.32)	0.617	.435	.009

Note. Items coded 0 = poor, 1 = moderate, 2 = good; F- and p-values refer to the ANOVA comparing the two groups. η^2 = Eta-squared effect size.

Since the initial ANOVA revealed a significant group difference for *specificity*, we conducted a follow-up ANOVA for the sub-subcategories *learning environment*, *teacher*, and *students* (for a brief description of the sub-subcategories please see the Instruments section). These analyses revealed that attention to the roles of both the *teacher* and the *students* was significantly higher in the real-world condition. *Teacher*: $F(1, 71) = 12.35, p < .001$, 95% CI [0.028, 0.296]; *students*: $F(1, 71) = 7.18, p < .01$, 95% CI [0.006, 0.231]. Overall, the feedback following the microteaching session in the real-world scenario described more events, particularly with regard to the actions of both the teacher and the students.

Feedback Perceptions

The Shapiro-Wilk test yielded statistically significant p-values ($p < .05$), indicating a significant departure from normality for most of the dependent variables. Despite this violation of normality, the median-based Levene test showed no significant violation of homoscedasticity for any of the variables ($p > .05$). During data analysis, potential outliers were identified using the Z-score method, with values greater than ±3 standard deviations considered outliers. A total of three outliers were identified in the data set. After careful review, two outliers from the VR group were retained in the analysis as these data points appeared to reflect plausible variation within the study population. One outlier from the VR group with a standard deviation of −6.36 was excluded from the data set. Finally, to investigate the influence of VR-based microteaching versus real-world microteaching on pre-service teachers' perceptions of peer feedback, a one-way ANOVA was conducted. A sensitivity analysis was performed to assess the robustness of the results in the presence and absence of outliers.

The analysis revealed no significant differences in the constructs of *fairness*, *usefulness*, *acceptance*, and *willingness to improve* (all $p > .05$). On an 11-point scale, mean ratings for feedback perceptions in both groups ranged from 9.77 to 10.69. These results indicate that participants generally rated the feedback positively in both conditions. For details see Table 3.

Table 3. Descriptive Statistics and ANOVA Results for Feedback Perception (VR-Based vs. Real-World Microteaching)

Measure	VR-based M (SD)	Real-world M (SD)	F	p	η^2
Fairness	10.48 (0.77)	10.43 (0.63)	0.077	.782	.001
Usefulness	9.79 (1.43)	9.77 (1.19)	0.004	.948	.000
Acceptance	10.61 (1.11)	10.69 (0.51)	0.131	.718	.002
Willingness to improve	9.87 (1.42)	10.33 (1.01)	2.118	.150	.027

Note. Items ranged from 1 = fully disagree to 11 = fully agree. F- and p-values refer to the ANOVA comparing the two groups. η^2 = Eta-squared effect size.

Qualitative Content Analysis

A combined deductive and inductive content-structuring analysis (Kuckartz, 2016) of the transcribed feedback sessions revealed four primary categories (written in **bold** below) and eight subcategories (written in *italic* below) that reflect pre-service teachers' experiences with VR-based microteaching.

The first primary category, **Immersive Learning Experience**, emphasizes the optimization of learning and training through the distinctive properties of presence and agency afforded by VR, essential for immersive educational experiences (e.g., Jensen & Konradsen, 2018; Makransky & Petersen, 2021; Slater, 2018). This category is further divided into two subcategories: *Training Potential* and *Reality Comparison*. The *Training Potential* category encompasses positive assessments of the potential of VR-based microteaching for preparing and training certain skills. Participants reported that the practice of disruption management, enhancement of spatial awareness, and optimization of space utilization in the classroom were particularly beneficial: *"I definitely think it's a useful tool for training so that you're more likely to notice something like that (classroom disruption)."* The feedback providers pointed out effective strategies: *"You were often on the move anyway, and at the beginning of the lesson you walked to the left and to the right, you moved around and always had a good look around the classroom."* This illustrates the capacity of VR to enhance physical engagement and awareness in a simulated setting. Furthermore, the discussions highlighted the pre-service teachers' proficiency in establishing rules and fostering connections and motivation among students amidst distractions. This showcases the VR-based microteaching's capability in cultivating a conducive learning environment. In terms of the *Reality Comparison* subcategory, pre-service teachers saw VR-based microteaching as a preparation tool for real-world professional challenges, providing a unique opportunity to practice responses to situations that are difficult to simulate or arrange in real life: *"Yes, I think that there's a certain added value, because I don't think you can implement a microteaching like this in real life. I can't use my own school class for it because I can't control it like that."* The subcategory highlights how VR allows for safe exploration of teaching strategies that might be impractical or disruptive in a real classroom: *"But I'll be happy to take the hint in school practice, in real school practice, and also reflect on the contrast I create between my admonitions and my normal teaching language."* The subcategory underscores VR's role as a bridge between theoretical knowledge and real-world application.

The second primary category, **Cognitive Overload**, was formed deductively and was intended to include passages highlighting a paradox Makransky and Lilleholt (2018) found, where students felt more present yet learned less in immersive VR environments, with a higher cognitive load verified by electroencephalography (EEG) studies. Interestingly, we did find that some pre-service teachers struggled to balance multiple tasks, such as managing student engagement, delivering content, dealing with disruptions, and managing technical aspects, which stretched their cognitive resources and could be indicative of cognitive overload: "*Although I had a good overview and was walking around, I have to say that I lacked orientation at times (...) That means* *technically or generally and my concentration (...) was still more focused on presentation this time, which is why I couldn't concentrate on the students as well..."* In addition, some participants reported initial surprise or adjustment challenges within the VR environment, suggesting that adapting to the virtual classroom while managing instructional tasks increased their cognitive load.

The third primary category, **Technological Considerations**, includes statements about the relationship between VR technology and its effectiveness in promoting high-quality feedback discussions and the overall implementation of the simulation. It includes the subcategories *Physical Reactions, Technical Limitations, Interaction Deficits,* and *Technical Adaptations*. The first subcategory *Physical Reactions* includes statements pertaining to all forms of physical reactions to the VR environment. This covers symptoms such as nausea, discomfort, and adjustment difficulties, which are commonly observed in the context of VR experiences (Heo & Yoon, 2020; Widyanti & Hafizhah, 2022). However, there is a paucity of data on the participants themselves. They appeared to acclimate successfully following the first simulation phase. Despite generally positive perceptions of the VR-based microteaching, *Technical Limitations* were noted. These limitations stemmed from the current limitations of VR technology that affect natural movement: *"because (in real life) I can't teleport"* and limited communication with virtual students: *"What really irritated me was that you couldn't address them (the students), because I think that's how a classroom discussion works."* Communication with the virtual students as a limiting factor leads directly to the subcategory of *Interaction Deficits*. Such interaction deficits, especially in verbal communication and eye contact, underscore the perceived gap in authentic classroom interaction within the VR environment. Furthermore, discussions around classroom interventions (e.g., using non-verbal cues before verbal ones, moving around the room more) highlight perceived interaction deficits within VR-based microteaching. Despite some technical limitations, there was *Technical Adaptation* as well. Participants' feedback suggests an adaptive learning process in engaging with VR technology, with further practice and acclimatization potentially reducing initial technical difficulties and discomfort. Although some reported initial challenges with the VR controls: *"I had to get to grips with the technique of moving around the room"*, rapid adaptation was commonly observed: *"I was pleasantly surprised that I was able to do it after all"*.

The last primary category, **Authenticity and Immediacy in Feedback,** highlights VR's efficacy in providing cost-effective, repeatable, and uniform training that has the potential to yield instant and realistic feedback (Dieker et al., 2014; Pottle, 2019). This category is further divided into *Reflection and Self-Assessment* and *Realistic Classroom Management Practice*. Statements from pre-service teachers regarding the subcategory *Reflection and Self-Assessment* emphasized how they actively participated in self-reflection and critically reflected on their VR-based microteaching experiences, identifying personal strengths and improvement areas: "What I would change would be to choose a better position in the room or adapt it to the situation." Additionally, statements regarding *Realistic Classroom Management Practice* show that feedback conversations frequently addressed strategies for managing classroom disruptions and maintaining lesson progression: *"You also noticed 3 out of 6 disruptions and then you* *ran up to the students and admonished them.",* demonstrating VR's role in offering a true-to-life setting for mastering classroom management techniques and enabling engagement in high-quality feedback sessions.

In conclusion, four primary categories emerged from the analysis of pre-service teachers' feedback sessions following their VR-based microteaching experiences. First, the **Immersive Learning Experience** highlighted the value of VR in improving teaching skills, such as managing interruptions and spatial awareness. Second, although **Cognitive Overload** was not directly reported, participants faced challenges in multitasking within the VR environment, particularly in teaching-related activities. Third, the **Technological Considerations** revealed both *limitations* and *adaptations* to VR technology over time. Finally, the **Authenticity and Immediacy in Feedback** highlighted the role of VR in providing realistic feedback and enhancing classroom management.

Discussion

This study examined the differences in quality and perception of peer feedback among pre-service teachers following VR-based versus real-world microteaching. Additionally, it investigated the extent to which pre-service teachers perceive VR as an effective tool for facilitating feedback sessions. This study shows that VR-based microteaching produces feedback processes and perceptions that are largely similar to those in real-world settings. However, real-world microteaching elicits more specific peer feedback.

Feedback Quality

Regarding the first research question, the quantitative analysis showed no significant differences for the quality of any categories of the pre-service teachers' feedback, except for *specificity. Specificity* refers to the extent to which concrete situations from the teaching session are described during the feedback discussions. The results indicate that participants in the real-world condition provided more detailed descriptions of specific events in their feedback than those in the VR-based condition. Further analysis revealed that, when describing such events, discussions following real-world microteaching paid significantly greater attention to both the teacher's and students' roles. Pre-service teachers' increased focus on the teacher's and students' role within real-world microteaching may stem from an emphasis on teacher–student interaction within real simulation environments, highlighting the immersive and contextually rich nature of analog settings. In most cases, such environments still provide a richer sensory experience, which is why multisensory cues in VR training improve user experience and later task performance in real-world scenarios (Cooper et al., 2021).

The lack of significant differences aligns with previous findings (Huang et al., 2023b; Seufert et al., 2022) and should be viewed as a positive outcome, especially given the limited opportunities for pre-service teachers to practice in real classroom settings. Although the study design shares some features with traditional media comparison research, the primary focus of this study is on the feedback process rather than the medium itself. Quasi-experimental studies of this kind are essential for establishing an evidence base to inform future design-based research in teacher education. As Petersen et al. (2022) emphasize, "VR should not replace traditional ways of teaching (…) Rather, it can be a complement to traditional teaching that can increase accessibility."

Feedback Perceptions

Regarding the second research question, the findings for feedback perceptions indicate that pre-service teachers rated the feedback they received highly in both VR-based and real-world conditions, with no statistically significant group differences in perceptions of fairness, usefulness, acceptance, or willingness to improve. These results suggest that participants considered the feedback process as both credible and beneficial, regardless of modality.

The high ratings of feedback perception across both modalities may reflect the strong standardization of feedback protocols and the preparatory training provided to all feedback providers. Previous research suggests that such standardization can minimize variation in perceived credibility and utility of feedback (Wisniewski et al., 2020). Furthermore, it is possible that pre-service teachers' generally positive attitudes towards receiving any feedback, regardless of modality, are a function of limited prior feedback experiences or social desirability in structured settings (Altstaedter & Doolittle, 2014; Tsui & Ng, 2000). The finding that VR-based feedback was not perceived as inferior suggests that immersive digital environments can provide credible and accepted feedback experiences, supporting the integration of VR in practice-based teacher education.

Qualitative Analysis of VR-Based Microteaching Experiences

Regarding the third research question, the qualitative analysis supports the assumptions drawn from the quantitative comparisons. In particular, the distinction between real-world and VR-based microteaching modalities was a frequent topic of discussion in the feedback sessions, as reflected in the subcategories of *Reality Comparison*, *Technological Limitations*, and *Interaction Deficits*. These findings suggest that current VR technology does not fully capture the intricacies of real-world microteaching, particularly in terms of spontaneous teacher-student interactions and nonverbal cues. This limitation likely contributed to the observed differences in feedback quality between the two groups. While some improvements to the VR system are needed, the qualitative content analysis indicates that VR-based microteaching provides an immersive environment that supports preservice teachers' reflection on key teaching competencies such as situational awareness and classroom management (e.g., *Training Potential*, *Realistic Classroom Management Practice*). This aligns with research that supports VR's capacity to replicate complex real-world scenarios for professional development (Pottle, 2019). Moreover, feedback sessions with pre-service teachers indicated that the immersive VR experience facilitates engaging peer feedback (see **Authenticity and**

Immediacy in Feedback) and contributes to the development of professional competencies (see **Immersive Learning Experience**). The results are in accordance with and supplement those reported by Richter et al. (2022), who demonstrated that recordings of VR-based microteaching and recordings of real-world teaching triggered similar reflective activities in pre-service teachers. This finding broadens the implications to microteaching, thereby refining our understanding of feedback quality and perception. This highlights the potential of VR as an effective tool for pre-service teacher education. It can be successfully applied to promote feedback processes, thus significantly narrowing the research gap outlined by Snelson and Hsu (2020).

Despite the anticipated cognitive challenges associated with immersive learning environments (Makransky & Lilleholt, 2018), there were no explicit reports of cognitive overload from the participants in our study. The initial difficulties encountered by the participants in adapting to the VR environment were quickly overcome (see *Technical Adaptation*). However, the requisite multitasking – managing student behavior, adhering to the lesson plan, and responding to unpredictable student actions – hints at a substantial cognitive demand. While the qualitative analysis revealed the necessity to mitigate the *Interaction Deficit* in VR-based microteaching, the cognitive demands of multitasking may also prepare pre-service teachers more effectively for the subsequent real-world classroom setting. Those cognitive demands may enable pre-service teachers to efficiently manage their cognitive load. This ability is crucial for novice teachers facing the task of juggling multiple demands with limited cognitive resources, as discussed by Feldon (2007) and Moos and Pitton (2014). It may therefore be possible to train this ability in VR-based pre-service teacher education.

Overall, the results of the ANOVAs and in-depth analysis of the 77 feedback discussions indicate that, although current technology still lacks the capacity for complex student-teacher interaction, VR-based microteaching holds significant potential for teacher education. This is particularly true given that it provides a secure environment for practice and reflection. The qualitative analysis suggests that VR-based microteaching, when complemented by subsequent feedback sessions, can facilitate profound self-reflection and professional development.

Implications for Teacher Education

VR offers a novel avenue for teacher education, providing a realistic yet controlled environment for the cultivation of teaching competencies. In contrast to conventional video-based training, which predominantly develops observational and analytical abilities (e.g., Gaudin & Chaliès, 2015; Nückles, 2021), VR facilitates active skill acquisition through immersive, hands-on experience.

This study extends prior research (e.g., Huang et al., 2023b; Seufert et al., 2022) by providing empirical evidence that VR-based microteaching enables immersive feedback experiences that are comparable to real-world microteaching, albeit with less specificity in the feedback. While previous studies have explored VR's role in teacher training (for reviews see Snelson & Hsu, 2020; Huang et al., 2023a), there has been limited research on its effectiveness in fostering high-quality peer feedback. Our findings bridge this gap by demonstrating that VR-based feedback sessions can achieve levels of specificity and engagement equivalent to real-world settings. This study contributes to the ongoing debate on the effectiveness of VR in teacher education and highlights its potential to improve reflective practice and feedback literacy in pre-service teachers.

This study demonstrates how VR technology can be used to integrate immersive simulations with immediate feedback, thereby supporting learners at all stages of teacher education. Immediate feedback is of paramount importance in fostering reflective practice among pre-service teachers, with the capacity of VR experiences to enhance self-assessment abilities being directly linked to this factor.

Furthermore, VR has the potential to significantly enhance traditional pedagogical approaches, such as real-world microteaching, by providing pre-service teachers with the opportunity to experiment with diverse teaching techniques in a secure setting, receiving constructive feedback along the way. These findings of this study indicate that integrating VR-based training at an early stage of Bachelor's programs could prove highly advantageous.

The quantitative data from this study indicate no significant differences in perceptions of peer feedback or feedback quality, except in the category of specificity. Furthermore, an analysis of the qualitative data, specifically the subcategories *Reality Comparison* and *Training Potential*, suggests that teacher education programs should integrate VR simulations designed to address high-pressure teaching scenarios. This integration would better prepare pre-service teachers for the challenges they will encounter in the classroom, enhancing their adaptability and responsiveness. In particular, such pressure testing is rarely possible in real-world settings, and thus, VR can serve as a valuable complement to traditional teaching methods, increasing accessibility to specific training scenarios (Petersen et al., 2022).

Integrating VR-based microteaching in pre-service teacher education provides structured opportunities for deliberate practice and feedback provision. Given that feedback quality in teacher education is often variable, VR simulations could serve as a controlled environment for pre-service teachers to develop and refine their feedback skills before engaging in real-world teaching contexts. The ability to repeatedly engage in standardized simulations ensures that pre-service teachers receive equitable training opportunities, ultimately leading to more consistent and higher-quality feedback exchanges.

The incorporation of VR into teacher education can effectively bridge the gap between theoretical knowledge and practical application. Furthermore, VR-based microteaching, which is both scalable and cognitively demanding, has the potential to prepare pre-service teachers for real-world classroom interactions more effectively than traditional methods.

Future Research

The results of the present study suggest several avenues for future research. First, the promising results of our quasi-experimental study highlight the need for longitudinal studies to assess the effects of repeated VR-based microteaching sessions on teaching competence or design-based studies to explore different VR-learning environment iterations. Such studies could shed light on the sustainability and long-term benefits of VR in teacher education.

Second, the qualitative analysis revealed technical limitations that warrant the development and rigorous testing of new VR features aimed at improving user interaction with agents and facilitating more intuitive movement within the VR environment. Improvements in AI and machine learning could be used to develop more responsive and realistic virtual students, thereby enhancing the interactive quality of VR training. This could significantly enhance the immersive experience and, by extension, the ability to promote constructive feedback and positive learning outcomes. Expanding VR capabilities is more than just a technology update. It drives educational innovation by creating immersive, interactive environments that encourage deeper engagement with feedback and provide unique teaching experiences beyond traditional methods.

Third, future research could investigate how VR-based microteaching affects teachers' emotional and cognitive load compared to traditional teaching methods. We found no explicit mention of cognitive load in all 77 peer feedback sessions. What we did find was implicit talk of high cognitive load, but not in relation to the VR environment, but in relation to the teaching itself. Makransky and Lilleholt (2018), on the other hand, confirmed higher cognitive load in VR environments and hypothesized that students learn less in a VR environment because of the higher cognitive load they observed. We hypothesize that these contradictory results are due to the fact that the cognitive overload we implicitly found in relation to classroom management is not caused by VR, but by the complex act of teaching itself. This could be explored in future studies that examine how pre-service and in-service teachers manage stress and mental effort in VR environments, and how VR experiences can be optimized to enhance learning without overwhelming users.

Finally, comparing feedback from VR-based microteaching with that from actual classroom observations could provide insights into the authenticity and effectiveness of VR-based teacher training. This comparison could reveal areas where VR-based simulations excel and where they fall short, guiding future refinements.

Limitations

The present study has some limitations. First, the research was limited to pre-service teachers from bachelor's and master's programs at a single university. This specificity limits the generalizability of our findings to broader educational contexts.

Second, although all feedback providers received the same standardized training, differences in their prior experience with teaching and feedback may have influenced how they observed teaching, formulated feedback, and interacted during feedback sessions. For instance, prior exposure to structured feedback either as a teacher or a learner may shape their understanding of feedback (e.g., To et al., 2023). Future research should explore the potential impact of prior teaching and feedback experience in more detail.

Thirdly, the research indicated the presence of a ceiling effect in the analysis of feedback perceptions. This suggests that the measurement scale may lack sufficient sensitivity to accurately capture subtle variations in feedback quality between the groups. This phenomenon may be attributed to the fact that pre-service teachers who are still developing their professional identity tend to evaluate feedback in a positive manner. This is because they generally receive a paucity of feedback, or because they wish to avoid the perception of negativity, particularly in environments where feedback is structured. As a result, this phenomenon may have obscured finer distinctions in how pre-service teachers perceive feedback. Future studies could investigate alternative or more nuanced scales with a broader response range or employ qualitative methods to gain deeper insights into these subtle differences.

Finally, the VR technology implemented did not fully replicate the intricate characteristics of real-world microteaching. However, this limitation reflects the current state of the technology and highlights the need for continued research in this area. It also indicates the significant potential of VR in educational settings, as substantial feedback discussions were possible with the existing technology.

Conclusion

In conclusion, this study contributes to the emerging field of VR's applicability in pre-service teacher education. It highlights its strengths in simulating safe teaching environments where pre-service teachers can practice their skills and engage in high-quality feedback sessions. Despite its limitations, pre-service teachers expressed interest in using VR for microteaching and appreciated the opportunity to experiment in a risk-free environment. The ratings of feedback quality, feedback perceptions, and the qualitative analysis of the content of feedback sessions suggest that VR is a valuable tool for facilitating high-quality feedback discussions in teacher education. The use of VR-based, customizable, safe microteaching environments for experiential learning and feedback sessions provides immersive approximations of practice. Therefore, VR-based microteaching has the potential to enhance current approaches to teacher education.

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Ethical Considerations

In Germany, the criteria set forth by the German Research Foundation (DFG) stipulate that a study must obtain ethical clearance if it subjects participants to significant emotional or physical stress, doesn't fully disclose the study's purpose, involves patients, or includes procedures like functional magnetic resonance imaging or transcranial magnetic stimulation. Our research did not meet any of these conditions, so it was not necessary for us to seek ethical approval. The pre-service teachers as well as the experts provided the feedback voluntarily. Moreover, all participants were informed about the study's purpose and confidentiality as well as data protection information.

Author Contributions

Lucas Jasper Jacobsen: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Kira Elena Weber**: Conceptualization, Methodology, Formal analysis, Resources, Writing - Review & Editing. **Christopher Neil Prilop**: Methodology, Resources, Writing - Review & Editing. **Yizhen Huang**: Software, Investigation, Writing - Review & Editing. **Anna Geske**: Investigation, Writing - Review & Editing. **Eric Richter**: Conceptualization, Investigation, Writing - Review & Editing, Project administration. The authors declare that each author has made a substantial contribution to this article, has approved the submitted version of this article and has agreed to be personally accountable for the author's own contributions.

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Data Availability Statement

All data generated or analyzed during this study are either included in this published article or can be made available by the authors upon request.

Declaration of Generative AI in Scientific Writing

During the preparation of this work, the authors used ChatGPT (https://www.chat.openai.com/; GPT-3.5 and GPT-4) as well as DeepL (https://www.deepl.com/) and Grammarly. (https://www.grammarly.com/) in order to improve the readability and language of single sentences. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

Albus, P., Vogt, A., & Seufert, T. (2021). Signaling in virtual reality influences learning outcome and cognitive load. *Computers & Education*, *166*(11), Article 104154. https://doi.org/10.1016/j.compedu.2021.104154

Alqassab, M. (2017). Peer feedback provision and mathematical proofs: Role of domain knowledge, beliefs, perceptions, epistemic emotions, and peer feedback content. *LMU*

München Institutional Repository. [Doctoral dissertation, LMU München Fakultät für Psychologie und Pädagogik].

Altstaedter, L. L., & Doolittle, P. (2014). Students' perceptions of peer feedback. *Argentinian Journal of Applied Linguistics*, *2*(2), 60–76.

Benton-Kupper, J. (2001). The microteaching experience: Student perspectives. *Education*, *2*(5), 1043–1053. https://doi.org/10.4304/jltr.2.5.1043-1051

Blomberg, G., Sherin, M. G., Renkl, A., Glogger, I., & Seidel, T. (2014). Understanding video as a tool for teacher education: Investigating instructional strategies to promote reflection. *Instructional Science*, *42*(3), 443–463. https://doi.org/10.1007/s11251-013-9281-6

Borko, H. (2016). Methodological contributions to video-based studies of classroom teaching and learning: A commentary. *ZDM Mathematics Education*, *48*(1-2), 213–218. https://doi.org/10.1007/s11858-016-0776-x

Calonge, D., Mark, K., Chiu, P., Thadani, D., & Pun, C. (2013). Extreme-Teaching-2 (XT 2): Evaluation of an innovative semester-long intensive GTA training program based on microteaching. *The International Journal of Teaching and Learning in Higher Education*, *25*(1), 129–143.

Cavanaugh, S. (2022). Microteaching: Theoretical origins and practice. *Educational Practice and Theory*, *44*(1), 23–40. https://doi.org/10.7459/ept/44.1.03

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum.

Cooper, N., Millela, F., Cant, I., White, M., & Meyer, G. (2021). Transfer of training—Virtual reality training with augmented multisensory cues improves user experience during training and task performance in the real world. *PLoS One*, *16*(3), e0248225. https://doi.org/10.1371/journal.pone.0248225

Dayanindhi, V., & Hegde, S. (2018). Effectiveness of microteaching as a method of developing teaching competence among in-service medical teachers. *Journal of Advances in Medical Education & Professionalism*, *6*(4), 155–161.

Deale, D., & Pastore, R. (2014). Evaluation of simschool: An instructional simulation for pre-service teachers. *Computers in the Schools*, *31*(3), 197–219. https://doi.org/10.1080/07380569.2014.932650

Dieker, L. A., Rodriguez, J. A., Lignugaris/Kraft, B., Hynes, M. C., & Hughes, C. E. (2014). The potential of simulated environments in teacher education: Current and future possibilities. *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, *37*(1), 21–33. https://doi.org/10.1177/0888406413512683

Donia, M. B. L., Mach, M., O'Neill, T. A., & Brutus, S. (2021). Student satisfaction with use of an online peer feedback system. *Assessment & Evaluation in Higher Education*, *47*(2), 269–283. https://doi.org/10.1080/02602938.2021.1912286

Fan, Y., & Xu, J. (2020). Exploring student engagement with peer feedback on L2 writing. *Journal of Second Language Writing*, *50*, Article 100775. https://doi.org/10.1016/j.jslw.2020.100775

Feldon, D. (2007). Cognitive load and classroom teaching: The double-edged sword of automaticity. *Educational Psychologist*, *42*(3), 123–137. https://doi.org/10.1080/00461520701416173

Fleiss, J. L., & Cohen, J. (1973). The equivalence of weighted kappa and the intraclass correlation coefficient as measures of reliability. *Educational and Psychological Measurement*, *33*(3), 613–619. https://doi.org/10.1177/001316447303300309

Gaudin, C., & Chaliès, S. (2015). Video viewing in teacher education and professional development: A literature review. *Educational Research Review*, *16*, 41–67. https://doi.org/10.1016/j.edurev.2015.06.001

Gielen, M., & De Wever, B. (2015). Structuring peer assessment: Comparing the impact of the degree of structure on peer feedback content. *Computers in Human Behavior*, *52*, 315–325. https://doi.org/10.1016/j.chb.2015.06.019

Gielen, S., Peeters, E., Dochy, F., Onghena, P., & Struyven, K. (2010). Improving the effectiveness of peer feedback for learning. *Learning and Instruction*, *20*(4), 304–315. https://doi.org/10.1016/j.learninstruc.2009.08.007

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching*, *15*(2), 273–289. https://doi.org/10.1080/13540600902875340

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Heo, J., & Yoon, G. (2020). EEG studies on physical discomforts induced by virtual reality gaming. *Journal of Electrical Engineering & Technology*, *15*(3), 1323–1329. https://doi.org/10.1007/s42835-020-00373-1

Hsia, L.-H., Huang, I., & Hwang, G.-J. (2016). Effects of different online peer-feedback approaches on students' performance skills, motivation and self-efficacy in a dance course. *Computers & Education*, *96*, 55–71. https://doi.org/10.1016/j.compedu.2016.02.004

Huang, Y., Richter, E., Kleickmann, T., & Richter, D. (2022). Class size affects preservice teachers' physiological and psychological stress reactions: An experiment in a virtual reality classroom. *Computers & Education*, *184*, Article 104503. https://doi.org/10.1016/j.compedu.2022.104503

Huang, Y., Richter, E., Kleickmann, T., & Richter, D. (2023a). Virtual reality in teacher education from 2010 to 2020. In K. Scheiter & I. Gogolin (Eds.), *Edition ZfE. Bildung für eine digitale Zukunft* (pp. 399–441). Springer. https://doi.org/10.1007/978-3-658-37895-0_16

Huang, Y., Richter, E., Kleickmann, T., & Richter, D. (2023b). Comparing video and virtual reality as tools for fostering interest and self-efficacy in classroom management: Results of a pre-registered experiment. *British Journal of Educational Technology*, *54*(2), 467–488. https://doi.org/10.1111/bjet.13254

Huang, Y., Richter, E., Kleickmann, T., Scheiter, K., & Richter, D. (2023c). Body in motion, attention in focus: A virtual reality study on teachers' movement patterns and noticing. *Computers & Education*, *206*, Article 104912. https://doi.org/10.1016/j.compedu.2023.104912

Huisman, B., Saab, N., Van Driel, J., & Van Den Broek, P. (2018). Peer feedback on academic writing: Undergraduate students' peer feedback role, peer feedback perceptions and essay performance. *Assessment & Evaluation in Higher Education*, *43*(6), 955–968. https://doi.org/10.1080/02602938.2018.1424318

Ilgen, D. R., Fisher, C. D., & Taylor, M. S. (1979). Consequences of individual feedback on behavior in organizations. *Journal of Applied Psychology*, *64*(4), 349–371. https://doi.org/10.1037/0021-9010.64.4.349

Jacobsen, L. J., & Weber, K. E. (2025). The promises and pitfalls of large language models as feedback providers: A study of prompt engineering and the quality of AI-Driven feedback. *AI*, *6*(2), 35. https://doi.org/10.3390/ai6020035

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, *23*(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0

Karlström, M., & Hamza, K. (2019). Preservice science teachers' opportunities for learning through reflection when planning a microteaching unit. *Journal of Science Teacher Education*, *30*(1), 44–62. https://doi.org/10.1080/1046560X.2018.1531345

Kaufman, D., & Ireland, A. (2016). Enhancing teacher education with simulations. *TechTrends*, *60*(3), 260–267. https://doi.org/10.1007/s11528-016-0049-0

Kavanagh, S. S., & Rainey, E. C. (2017). Learning to support adolescent literacy: Teacher educator pedagogy and novice teacher take up in secondary English language arts teacher preparation. *American Educational Research Journal*, *54*(5), 904–937. https://doi.org/10.3102/0002831217710423

Kerman, N. T., Noroozi, O., Banihashem, S. K., Karami, M., & Biemans, H. J. A. (2024). Online peer feedback patterns of success and failure in argumentative essay writing. *Interactive Learning Environments*, *32*(2), 614–626. https://doi.org/10.1080/10494820.2022.2093914

Klinzing, H. G. (2002). Wie effektiv ist Microteaching? Ein Überblick über fünfunddreißig Jahre Forschung [How effective is microteaching? An overview of thirty-five years of research]. *Zeitschrift für Padagogik*, *48*(2), 194–214. https://doi.org/10.25656/01:3829

Kramer, C., König, J., Kaiser, G., Ligtvoet, R., & Blömeke, S. (2017). Der Einsatz von Unterrichtsvideos in der universitären Ausbildung: Zur Wirksamkeit video-und transkriptgestützter Seminare zur Klassenführung auf pädagogisches Wissen und situationsspezifische Fähigkeiten angehender Lehrkräfte [The implementation of instructional videos in higher education: Evaluating the effectiveness of video- and transcript-supported seminars on classroom management regarding pedagogical knowledge and context-specific competencies of pre-service teachers]. *Zeitschrift für Erziehungswissenschaft*, *20*(1), 137–164. https://doi.org/10.1007/s11618-017-0732-8

Kuckartz, U. (Ed.), (2016). *Qualitative inhaltsanalyse. Methoden, praxis, computerunterstützung [qualitative content analysis: Methods, application, and computer-assisted support]*. Beltz Verlagsgruppe.

Lugrin, J.-L., Latoschik, M. E., Habel, M., Roth, D., Seufert, C., & Grafe, S. (2016). Breaking bad behaviors: A new tool for learning classroom management using virtual reality. *Frontiers in ICT*, *3*, Article 26. https://doi.org/10.3389/fict.2016.00026

Lynch, R., McNamara, P. M., & Seery, N. (2012). Promoting deep learning in a teacher education programme through self-and peer-assessment and feedback. *European Journal of Teacher Education*, *35*(2), 179–197. https://doi.org/10.1080/02619768.2011.643396

Makransky, G., & Lilleholt, L. (2018). A structural equation modeling investigation of the emotional value of immersive virtual reality in education. *Educational Technology Research & Development*, *66*(5), 1141–1164. https://doi.org/10.1007/S11423-018-9581-2

Makransky, G., & Petersen, G. B. (2021). The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. *Educational Psychology Review*, *33*(3), 937–958. https://doi.org/10.1007/s10648-020-09586-2

McDonald, B. (2020). *Improving teaching and learning through experiential learning*. Cambridge Scholars Publishing.

McDonald, M., Kazemi, E., & Kavanagh, S. S. (2013). Core practices and pedagogies of teacher education: A call for a common language and collective activity. *Journal of Teacher Education*, *64*(5), 378–386. https://doi.org/10.1177/0022487113493807

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers and Education*, *56*(3), 769–780. https://doi.org/10.1016/j.compedu.2010.10.020

Moore, J. W., & Fletcher, P. C. (2012). Sense of agency in health and disease: A review of cue integration approaches. *Consciousness and Cognition*, *21*(1), 59–68. https://doi.org/10.1016/j.concog.2011.08.010

Moos, D., & Pitton, D. (2014). Student teacher challenges: Using the cognitive load theory as an explanatory lens. *Teaching Education*, *25*(2), 127–141. https://doi.org/10.1080/10476210.2012.754869

Narciss, S. (2013). Designing and evaluating tutoring feedback strategies for digital learning environments on the basis of the interactive feedback model. *Digital Education Review*, *23*(1), 7–26.

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, *31*(2), 199–218. https://doi.org/10.1080/03075070600572090

Nückles, M. (2021). Investigating visual perception in teaching and learning with advanced eye-tracking methodologies: Rewards and challenges of an innovative research paradigm. *Educational Psychology Review*, *33*, 149–167. https://doi.org/10.1007/s10648-020-09567-5

Petersen, G. B., Klingenberg, S., & Makransky, G. (2022). Pipetting in virtual reality can predict real-life pipetting performance. *Technology, Mind, and Behavior*, *3*(3). https://doi.org/10.1037/tmb0000076

Pottle, J. (2019). Virtual reality and the transformation of medical education. *Future Hospital Journal*, *6*(3), 181–185. https://doi.org/10.7861/fhj.2019-0036

Poupard, M., Larrue, F., Sauzéon, H., & Tricot, A. (2024). A systematic review of immersive technologies for education: Learning performance, cognitive load and intrinsic motivation. *British Journal of Educational Technology*, *56*(1), Article 13503. https://doi.org/10.1111/bjet.13503

Prilop, C. N., Weber, K., & Kleinknecht, M. (2019). Entwicklung eines video-und textbasierten Instruments zur Messung kollegialer Feedbackkompetenz von Lehrkräften [Development of a Video- and Text-Based Instrument for Measuring Teachers' Collegial Feedback Competence]. In T. Ehmke, P. Kuhl, & M. Pietsch (Eds.), *Lehrer. Bildung. Gestalten: Beiträge zur empirischen Forschung in der Lehrerbildung [Shaping Teacher Education: Contributions to Empirical Research in Teacher Education]*: Beltz Juventa Verlag.

Prilop, C. N., & Weber, K. E. (2023). Digital video-based peer feedback training: The effect of expert feedback on pre-service teachers' peer feedback beliefs and peer feedback quality. *Teaching and Teacher Education*, *127*, Article 104099. https://doi.org/10.1016/j.tate.2023.104099

Prilop, C. N., Weber, K. E., & Kleinknecht, M. (2020). Effects of digital video-based feedback environments on pre-service teachers' feedback competence. *Computers in Human Behavior*, *102*, 120–131. https://doi.org/10.1016/j.chb.2019.08.011

Prilop, C. N., Weber, K. E., Prins, F., & Kleinknecht, M. (2021). Connecting feedback to self-efficacy: Receiving and providing peer feedback in teacher education. *Studies In Educational Evaluation*, *70*(2), Article 101062. https://doi.org/10.1016/j.stueduc.2021.101062

Prins, F., Sluijsmans, D., & Kirschner, P. A. (2006). Feedback for general practitioners in training: Quality, styles and preferences. *Advances in Health Sciences Education*, *11*(3), 289–303. https://doi.org/10.1007/s10459-005-3250-z

Remesh, A. (2013). Microteaching, an efficient technique for learning effective teaching. *Journal of Research in Medical Sciences*, *18*(2), 158–163. PMC3724377.

Richter, E., Hußner, I., Huang, Y., Richter, D., & Lazarides, R. (2022). Video-based reflection in teacher education: Comparing virtual reality and real classroom videos. *Computers & Education*, *24*(3), Article 104601. https://doi.org/10.1016/j.compedu.2022.104601

Schreier, M. (2014). Varianten qualitativer Inhaltsanalyse: Ein Wegweiser im Dickicht der Begrifflichkeiten [Variants of qualitative content analysis: A guide through the jungle of terminology]. *Forum: Qualitative Sozialforschung / Forum: Qualitative Social Research*, *15*(1), Article 18.

Seufert, C., Oberdörfer, S., Roth, A., Grafe, S., Lugrin, J.-L., & Latoschik, M. E. (2022). Classroom management competency enhancement for student teachers using a fully immersive virtual classroom. *Computers & Education*, *179*, Article 104410. https://doi.org/10.1016/j.compedu.2021.104410

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153–189. https://doi.org/10.3102/0034654307313795

Slater, M. (2018). Immersion and the illusion of presence in virtual reality. *British Journal of Psychology*, *109*(3), 431–433. https://doi.org/10.1111/bjop.12305

Sluijmans, D. (2003). Assessment and the development of reflection skills in teacher. *Journal of Higher Education*, *21*(4), 230–250.

Sluijsmans, D. M. A., Brand-Gruwel, S., & van Merriënboer, J. J. G. (2002). Peer assessment training in teacher education: Effects on performance and perceptions. *Assessment & Evaluation in Higher Education*, *27*(5), 443–454. https://doi.org/10.1080/0260293022000009311

Snelson, C., & Hsu, Y.-C. (2020). Educational 360-degree videos in virtual reality: A scoping review of the emerging research. *TechTrends*, *64*(3), 404–412. https://doi.org/10.1007/s11528-019-00474-3

Stavroulia, K. E., & Lanitis, A. (2019). Enhancing reflection and empathy skills via using a virtual reality based learning framework. *International Journal of Emerging Technologies in Learning (iJET)*, *14*(07), 18–36. https://doi.org/10.3991/ijet.v14i07.9946

Straub, R. (1997). Students' reactions to teacher comments: An exploratory study. *Research in the Teaching of English*, *31*(1), 91–119. https://doi.org/10.58680/rte19973873

Strijbos, J.-W., Pat-El, R., & Narciss, S. (2021). Structural validity and invariance of the feedback perceptions questionnaire. Studies In Educational Evaluation, 68, Article 100980. https://doi.org/10.1016/j.stueduc.2021.100980

Strijbos, J. W., Pat-El, R. J., & Narciss, S. (2010). Validation of a (peer) feedback perceptions questionnaire. In L. Dirckinck-Holmfeld, V. Hodgson, C. Jones, M. de Laat, D. McConnell, & T. Ryberg (Eds.), *Proceedings of the 7th International Conference on Networked Learning* (*7*, pp. 378–386). Aalborg University. https://doi.org/10.54337/nlc.v7.9203

To, J., Tan, K., & Lim, M. (2023). From error-focused to learner-centred feedback practices: Unpacking the development of teacher feedback literacy. *Teaching and Teacher Education*, *131*, Article 104185. https://doi.org/10.1016/j.tate.2023.104185

Tripp, T., & Rich, P. (2012). Using video to analyze one's own teaching. *British Journal of Educational Technology*, *43*(4), 678–704. https://doi.org/10.1111/j.1467-8535.2011.01234.x

Tsui, A. B. M., & Ng, M. (2000). Do secondary L2 writers benefit from peer comments? *Journal of Second Language Learning*, *9*(2), 147–170. https://doi.org/10.1016/S1060-3743(00)00022-9

Widyanti, A., & Hafizhah, H. N. (2022). The influence of personality, sound, and content difficulty on virtual reality sickness. *Virtual Reality*, *26*(2), 631–637. https://doi.org/10.1007/s10055-021-00525-2

Wiepke, A., Heinemann, B., Lucke, U., & Schroeder, U. (2021). Jenseits des eigenen Klassenzimmers: Perspektiven & Weiterentwicklungen des VR-Classrooms [Beyond the own classroom: perspectives & further developments of the VR classroom]. In L. Steinke, A. Kienle, A. Harrer, J. M. Haake, & A. Lingnau (Eds.), *Delfi 2021* (pp. 331–336). Gesellschaft für Informatik e.V.

Wiepke, A., Richter, E., Zender, R., & Richter, D. (2019). *Einsatz von Virtual Reality zum Aufbau von Klassenmanagement-Kompetenzen im Lehramtsstudium [Use of virtual reality to develop classroom management skills in teacher training programs]. DELFI 2019* (pp. 133–144). Gesellschaft für Informatik eV.

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: A meta-analysis of educational feedback research. *Frontiers in Psychology*, *10*, Article 3087. https://doi.org/10.3389/fpsyg.2019.03087

Wolff, C. E., Jarodzka, H., van den Bogert, N., & Boshuizen, H. P. A. (2016). Teacher vision: Expert and novice teachers' perception of problematic classroom management scenes. *Instructional Science*, *44*(3), 243–265. https://doi.org/10.1007/s11251-016-9367-z

Zhang, H., Song, W., Shen, S., & Huang, R. (2014). The effects of blog-mediated peer feedback on learners' motivation, collaboration, and course satisfaction in a second language writing course. *Australasian Journal of Educational Technology*, *30*(6), 670–685. https://doi.org/10.1007/s10753-013-9783-z

Zottmann, J. M., Stegmann, K., Strijbos, J.-W., Vogel, F., Wecker, C., & Fischer, F. (2013). Computer-supported collaborative learning with digital video cases in teacher education: The impact of teaching experience on knowledge convergence. *Computers in Human Behavior*, *29*(5), 2100–2108. https://doi.org/10.1016/j.chb.2013.04.014

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