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Collaborative learning with avatars in virtual reality for kindergarten teacher education

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ABSTRACT

This study investigates the possibilities of using virtual reality (VR) for collaborative online learning activities in a kindergarten teacher education program. It is the first study exploring social VR in this educational context. The study focused on how the social learning climate is affected when applying VR as a tool for collaborative online learning. The study applied a design-based approach where six pre-service kindergarten teachers explored the uses of VR in six workshops (WS). The data consisted of recordings from the WS, both in-person and in VR, and five participant interviews. Transcripts of the WS and the interviews were analysed thematically, and the VR recordings were subject to structured observation. Three themes were identified, namely, perceived realism, togetherness, and challenges, and the findings reveal that VR may enhance the social aspects of online learning. The participants reported a feeling of being together in contrast, in particular, to experiences with video conferencing. The results are linked to the way gestures and apparent eye contact give the other attendees signals of attention, potentially leading to a stronger connection and thus improving the social environment and learning situation. The discussion indicates that the process of exploring a new technology might also contribute to some elements of kindergarten teachers' professional digital competence.

1. Introduction

Learning is fundamentally social, as communication and social interactions with others shape how learners think, reason, and develop competence [1, p. 5]. New technologies have led to increased opportunities for formal education and remote learning [2]. However, online environments can also restrict sociality [3–5], for example, by dampening social presence, constraining interactional cues, and weakening the sense of togetherness.

One of the emerging technologies used to simulate learning environments is virtual reality (VR). Previous research has highlighted how VR can be useful in showing students how to handle complex scenarios in a safe environment [6–8]. Given VR's immersive properties, it can also make scenarios seem more real than traditional (paper-based) learning methods [9,10]. The VR approach can help students understand and bridge the gap between real-life scenarios and the theory surrounding them, including conceptual understandings, classroom dilemmas, and conflict management [11–13]. Previous research has also reported how students evaluated VR simulations as positively impacting their specific course content learning and as a valuable tool to enhance their learning experience [6,14]. VR encompasses technologies with different levels of immersion [8], namely, the virtual worlds accessed by desktop computers and the more immersive types accessed using head-mounted displays (VR headsets). While its immersive properties are exploited to create realistic simulations, VR also has the potential to enable social interaction with others through avatars [15,16]. Research into the social aspects of VR has found benefits such as a sense of community [17,18], connecting with others [19,20], and enabling eye gaze and eye contact [21,22].

Billingsley et al. [6] pointed out that research into the use of VR in teacher education is lacking. While there seems to be a growing interest in this field [7,14,23–25], the focus appears to be primarily on simulations, with few studies concerned with social VR (e.g., [17]). Among several reviews of VR in teacher education [6,14,24,25], only one study [26] has emerged from kindergarten teacher education.

The use of digital technology in a teacher education programme both supports students' academic development and prepares them for their future work as teachers. Hence, this study also connects to scholarly discussions around the concept of professional digital competence for teachers (PDC). Norhagen et al. [27, p. 5] have defined PDC as 'the

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comprehensive ability for teachers to effectively and responsibly use digital technologies in education (…)'. Writing specifically about kindergarten teachers, Undheim and Ploog [28, p. 2] state that digitally competent teachers must be able to 'evaluate technology's didactic and pedagogical relevance'. A related element that has recently attracted attention is agency, with several researchers exploring ways to incorporate it into the conceptualisation of PDC [29,30].

The concept of PDC has primarily developed with a focus on the compulsory school levels, and the kindergarten field has, until recently, been under-represented [31]. Kindergarten teacher education is not just the context of the present study; it is, in its own right, an important area for investigation of the use of digital technology and PDC. While digitalisation is making an impact on children's lives globally, the kindergarten and early childhood field is grappling with how to adapt without compromising its distinct pedagogy, which is characterised by play, child-centredness, exploration, and collaboration (see [32–34]). These characteristics make kindergarten teacher education a particularly interesting context for exploring new technologies such as VR.

Collaborative learning (CL) is described as a way of organising learning processes with an emphasis on shared learning tasks, a combination of expertise, knowledge, and skills, and building or consolidating a learning community [35]. Following technological developments, the principles of CL have been applied to online learning environments. Bernard and Rubalcava [35, p. 265] proposed the following design issues for collaborative online learning (COL): 1) preparing for collaboration, 2) creating a social climate and a community of learners, 3) encouraging true collaboration, 4) applying learning approaches, and 5) using technology effectively. In this study, the notion of COL is placed in relation to the more general challenges of online education and social presence described above. Hence, our focus is mainly on design point 2, and we understand the social climate and a community of learners as students experiencing a positive connection to each other in a digital learning environment. For readability, we condense this into a *social learning climate*, which we use to refer to design point 2. Although here derived and most explicitly linked to COL, this construct and its importance is also closely related to other traditions exploring the significance of the social aspects in online learning, such as social presence theory [36] and the Community of Inquiry framework [37].

Researchers have also conducted studies combining CL and VR [20,38,39]. Drey et al. [38] investigated pair-learning in VR in a design that compared pairs in which both participants used a VR headset (symmetric system) with pairs in which one participant used a tablet (asymmetric system). The authors found that the symmetric VR system had higher presence, immersion, and player experience and a lower intrinsic cognitive load than the tablet. The symmetric and asymmetric systems performed equally in terms of learning outcomes. Prasolova-Førland et al. [20] reported on collaborative teamwork, where students in cross-disciplinary groups had regular meetings in VR to collaborate with other groups located on a distant campus. The study investigated the VR-based tool as a means of CL over two years and highlighted challenges with audio-communication, socialising, VR interactions, and efficiency. Prasolova-Førland et al. [20] reported that VR as a CL tool was perceived as particularly useful within distance learning, which is similar to the findings of several other studies [8,25,39,40].

The local context of the current study is the kindergarten teacher education at XX University. Among the aims of a new model for decentralised education combining physical gatherings, self-study, and online meetings was to explore whether the use of VR could provide opportunities other than those offered by existing solutions. Offering decentralised study programmes implies a need for good online solutions. Hence, there is a connection between the local context and the overarching research status outlined above.

1.1. Objectives and contributions

The challenge of diminished social presence in online learning environments described in the introduction forms the background for this study. Based on both existing research and the local contextual needs, the objective is to investigate how the use of VR might contribute to a social learning climate as described by Bernard and Rubalcava [35]. However, the study is exploratory and does not aim to examine measurable learning outcomes or to make quantitative comparisons between different communication solutions.

In Fig. 1 we outline the framework of this study. One objective was to build virtual social features that included avatar mediation to increase collaborative online learning (COL). Another objective was to design the COL successfully, including social space, small groups, and assigning tasks, all to make it relevant to students in a kindergarten teacher education programme. An important element, and part of the novelty in this study, was to provide the VR activity that enabled students to design and participate in a joint, social, and teamworking online learning environment. To ensure contextual relevance and account for students' experience (with no prior familiarity with VR), this study framework focused on examining and understanding perceived realism, togetherness, and collaborative interactions.

The concepts can appear similar and overlapping. To distinguish, our understanding of perceived realism is based on Weber et al. [41] and Newman et al. [42] who emphasise the importance of realism in VR. The focus is the individual and subjective perception of immersion resulting from the software's depicted environment. Our understanding of togetherness is connected to this perceived realism but the emphasis is more explicitly relational and social, linked to the interactions with others [43,44].

This article contributes to theory by connecting established COL principles to recent developments in the social features of VR technology. In the outcome, we suggest that students' takeaways from an exploration of VR technology can be both proximal and direct towards the social learning climate, as well as more distal in the development of PDC for teachers. Furthermore, the study makes practical contributions by showing how immersive workshops might be designed. It also offers methodological innovations in design-based research and in the use of spatial VR recordings as a qualitative data source.

To clarify our contributions, they are as follows:

1.1.1. Theoretical contributions

- Connecting established COL principles to new social features of VR
- Increased understanding of perceived realism and togetherness in VR in general, and specifically in the context of kindergarten teacher education

1.1.2. Practical contributions

- Showing how immersive COL workshops can be designed for this context
- Outlining virtual social features aimed at enhancing collaborative online learning.

1.1.3. Methodological contributions

- Using an exploratory, design based qualitative approach aligned with local contextual needs and students' lack of prior VR experience.
- Demonstrating the use of spatial VR recordings as a qualitative data source.

The research question investigated in this article is:

RQ1: How do students in a kindergarten teacher education programme perceive the social learning climate when applying virtual

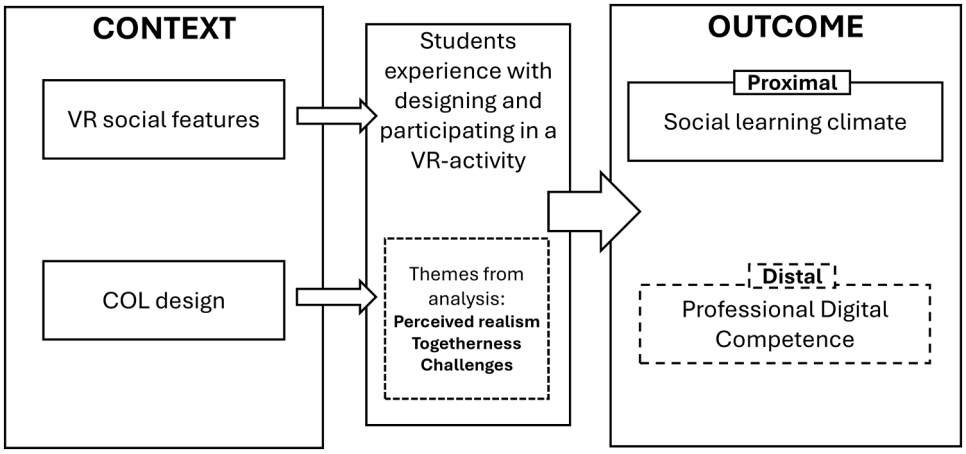

Fig. 1. Study framework.

reality as a tool for collaborative online learning?

1.2. Methods

1.2.1. Methodology

This is a qualitative study inspired by design research [45–47] and focused on COL by exploring existing VR technology solutions for kindergarten teacher education. The equipment used in the study was the VR headset Meta Quest 1, and the software used for meetings was ENGAGE VR. This software provides recordings of meetings that enable researchers to re-enter during playback, move around in the recording, and observe from different angles and perspectives. Since the study is exploratory and non-comparative it does not include a control group.

1.2.2. Participants

The participants in this study were students from a kindergarten teacher education programme at XX University. They were recruited in the autumn semester of 2022 from a cohort in the third and final year of their education. The students were enrolled in a specialised course on PDC for teachers; hence, they had some exposure to lectures and activities related to digital technologies in education, but none had previous experience with VR. Due to the Covid-19 pandemic restrictions, the students were receiving more online teaching than originally planned. In total, six students were recruited from the PDC class and participated in the study. The six recruited students had the option to participate in six different workshops (WSs), and most participated in all six. Table 1 presents the participants' identity (ID), sex, and age and lists the WSs in which they participated. Six participants were considered sufficient due to the narrow and contextual focus, combined with rich data from several sources, also in line with the information power principle [48].

Table 1
Participants.

Participant ID	Sex	Age	Previous VR experience	WS participation
ID1	F	≈ 40	No	WS1, WS2, WS3, WS4, WS5, WS6 debrief / evaluation, interview
ID2	F	43	No	WS1, WS2, WS3, WS4, WS5, WS6 debrief / evaluation, interview
ID3	F	39	No	WS1, WS2, WS3, WS4, interview
ID4	F	≈ 50	No	WS1, WS2, WS4, WS5, WS6, debrief / evaluation
ID5	F	≈ 40	No	WS1, WS2, WS3, WS4, WS5, WS6, debrief / evaluation, interview
ID6	F	43	No	WS1, WS2, WS3, WS4, WS5, WS6, debrief / evaluation, interview

Ethical approval of the study was received from the Norwegian Agency for Shared Services in Education and Research (Approval No 525313), covering the participants' legal rights, a plan for processing personal data, and the information given to the participants about the project, voluntary participation, withdrawal at any time, and informed consent.

1.3. Procedure

As shown in Fig. 2, the iterative design process included different elements for each of the six WSs. For a more detailed account, see Appendix G. In WS1, the technology was introduced, and accounts were set up, followed by testing and playing. The participants then took their VR headsets home for individual exploration. WS2 was in-person, and the session included sharing experiences, brainstorming ideas, and developing a plan for a test activity. This plan was carried out in WS3, where the students joined a VR meeting in ENGAGE from home. In WS4, we met in person again for an evaluation of WS3 and to plan for WS5 and WS6 in the spring semester.

WS5 was a general discussion on a topic in an environment that resembled a meeting room. After this, the students were given the option of taking the next session, discussing a text, through video conference instead of ENGAGE. The students chose ENGAGE; hence, WS6 was also carried out in VR but in a different environment. In this case, there was a projector on the wall and screens in front of each participant where they could view content from a computer. The debrief was also in VR and in the same environment as WS5. Five individual interviews were conducted and recorded through Zoom at the end of the spring semester 2023, one was postponed to the autumn, and one student was not interviewed. A condensed procedural summary for the VR sessions is found in Table 2. The average duration of VR sessions was 17 min.

1.4. Data material

Across the WSs, various methods were used to provide different types of data for the study (Table 3). Data from the whole process consist of field notes, both journal and condensed accounts [49] written in OneNote, VR recordings, written WS material, and sound recordings of WSs and interviews. The multiple data sources made it possible to compare and expand the participants' statements in interviews with observations and more indirect statements from the VR sessions and evaluation. Transcriptions of the audio from group conversations in WS4 and the debrief were treated as focus group interviews and analysed together with the individual interviews.

Using the VR recordings responds to the need for research into what

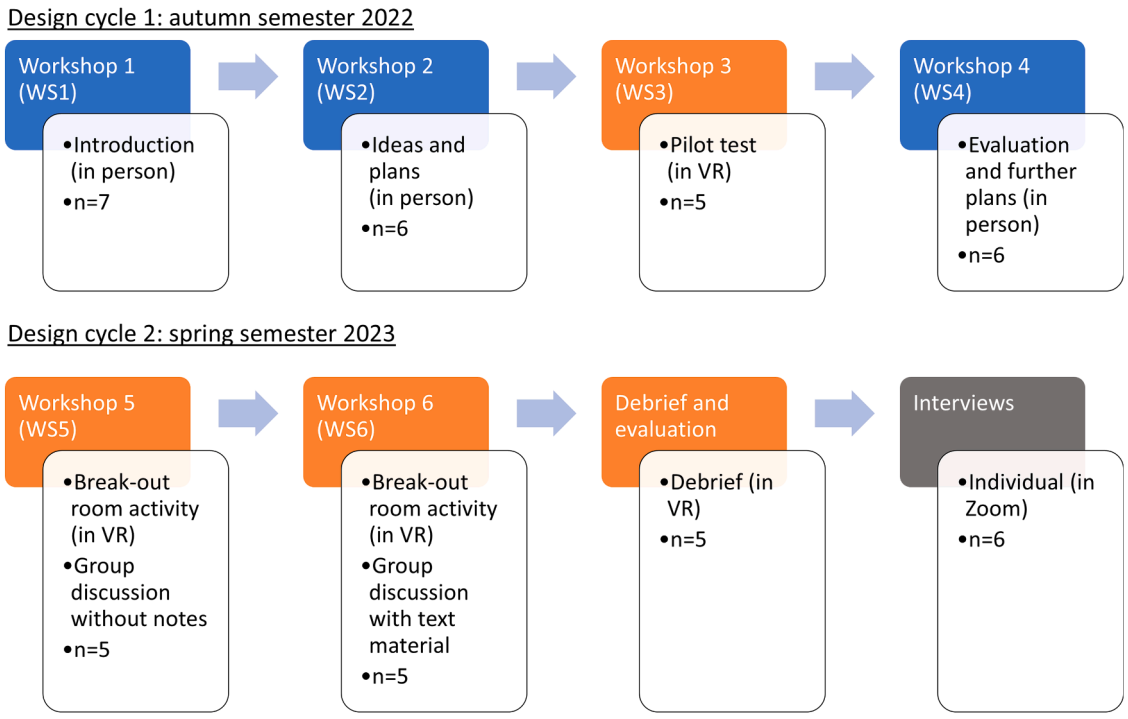

Fig. 2. Design process cycle 1 and 2.

Table 2
Procedural summary VR sessions.

VR session	Date / duration	Technical information / setup
WS3 Pilot	26.10.2022/ 23:51 min	**Device**: Meta Quest 1**Software**: Engage**VR environment**: Basic meeting room, rectangular table, 20 seats (see Fig. 3)**Settings**: • Spatial sound on • Avatar name tag on • Avatar customisation no restrictions • Head and hand tracking on
WS5 Breakout-room discussion	15.02.2023 / 13:34 min	**Devices**: Meta Quest 1 + PC (ID5) **Software**: Engage**VR environment**: Basic meeting room**Settings**: • Spatial sound on • Avatar name tag on • Avatar customisation no restrictions • Head and hand tracking on
WS6 Breakout-room group discussion	15.02.2023 / 17:56 min	**Devices**: Meta Quest 1 + PC (ID5) **Software**: Engage**VR environment**: Advanced meeting room with virtual screens, rectangular table, 14 seats, each with a virtual screen on the table (see Fig. 6)**Settings**: • Spatial sound on • Avatar name tag on • Avatar customisation no restrictions • Head and hand tracking on • Screen sharing of content on
Debrief and evaluation	15.02.2023 / 12:51 min	**Devices**: Meta Quest 1 + PC (ID5) **Software**: Engage**VR environment**: Basic meeting room**Settings**: • Spatial sound on • Avatar name tag on • Avatar customisation no restrictions • Head and hand tracking on

happens within VR, as pointed out by Paulsen et al. [8]. The debrief and evaluation session was not originally planned to be part of the data; however, since the session was also recorded in VR, it supplements the material from the other sessions. ID3 did not take part in WS5, but as they had experienced the other WSs, it was still relevant to interview them.

Table 3
Data material overview.

Origin	Recorded material	Written material	Images
WS1	None	Field notes (journal account)	
WS2	None	Brainstorm results Field notes (journal account)	Photo of brainstorm results
WS3	VR- recording	Field notes (journal account)	Screenshots
WS4	Audio recording	Field notes (journal account) Transcription of audio	
WS5	VR recording	Field notes	
WS6	VR recording	Field notes (journal account)	
Debrief and evaluation	VR recording Extracted audio	Transcription of extracted audio	Screenshots
Individual interviews	Audio recording	Transcription of audio	
VR observation	Audio recording (sound log)	Field notes (condensed account) Transcription	'Virtual photos' (screenshots)

1.5. Data analysis

The interviews were analysed by practical thematic analysis [50] in three steps: reading, coding, and theming (see Appendix A, B, C and D). The material was transcribed using automatic transcription in Microsoft Word. The analysis began with a thorough reading and manual revision of the transcripts. The software NVivo was used to manually code the

data, but this process was combined with sorting and categorising the material in printed form (see Appendix E). To ensure increased transparency, supervisors and research groups provided feedback during the process. While the text material was subject to initial theming, this process was not finished until the observation was completed.

VR recordings from WS5 and the debrief were subject to observation (see Appendix F). While the observers used a VR headset, a portable voice recorder was used to make an audio note of comments, which were transcribed using the translation service https://klartekst.uit.no/. The observer was positioned centrally in the meeting room, at the end of the table. This position was complemented by occasionally taking the seat and perspective of participants. The observation did not follow a structured protocol, but a more emergent exploration approach. Some still images were taken for documentation. A written note was also made directly after each playback. These results were then merged with the thematic analysis when the main themes were identified. The themes were consistent across both the individual interviews and the data from earlier group sessions. When also observations aligned and confirmed the themes, we considered it sufficient.

2. Results

In this section we address RQ1 – how students in a kindergarten teacher education programme perceive the social learning climate when applying virtual reality as a tool for collaborative online learning. Seven subthemes and three main themes were identified through the thematic analysis and observations: 1. perceived realism, 2. togetherness, and 3. challenges (see Table 4):

In the context of COL [35], themes 1 and 2 are principally related to the issue of creating a good social learning climate, while theme 3 primarily relates to the issue of using technology effectively. The quotes presented here are translated from Norwegian. During the analysis, elements that were closely connected were split. Hence, the themes are more intertwined than they appear. A more detailed overview of themes and codes is found in Appendix A and D.

2.1. Perceived realism

In WS5, the participants left their online class for a breakout room discussion. The subject of the class was how to design research for a bachelor's thesis, and the purpose of the discussion was to share and listen to preliminary ideas about each other's research projects (see Fig. 3).

Descriptions of an experience of realism recurred in the material, a finding that aligns with existing literature on VR (see [8,9,20]). All the participants described a feeling of being there, using phrases such as how it 'felt real', 'realistic', 'like being physically present', and 'forgetting that they were in a virtual room'. One participant even emphasised the realistic experience by putting it like this:

"I thought it was absolutely crazy to enter!" (ID2)

Table 4
Summary theme table.

Themes	Theme definition	Subthemes
1. Perceived realism	• Participants' perception of the virtual environment as realistic	• Feels like being physically present • Sense of space
2. Togetherness	• Participants' experience of a feeling of being together with the other students in the virtual environment	• Conversation • Apparent eye contact • Feeling of being together
3. Challenges	• Participants' experience of different challenges, both technical and physical	• Physical consequences and discomfort • Technical challenges

Fig. 3. VR environment with participants.

One feature in VR that contributes to such feelings is being seen and seeing others as avatars. The participants commented several times that they became used to seeing the avatars and knowing there were people behind them and that the use of avatars was more natural than they had anticipated. However, the experience with avatars was not related only to how they perceived the others; rather, it concerned their embodying and being an avatar themselves:

"Even though the avatar didn't look like us, it kind of became us." (ID2)

Other research has found similar results regarding how users construct and experience themselves when using social VR platforms [51]. While the choice of avatar was not the principal consideration of this study, the participants did spend some time choosing and adjusting their avatar. The identification with the avatar was also evident in the way both the participants and the researcher referred to themselves and the avatars as 'I' or 'me' when talking about events in VR. Gamers talk similarly about the character they are (playing) in a computer game [52].

The signals that may be mediated through avatars vary across VR solutions. Researchers have looked at, for example, bio-signal visualisations [53] and facial expressions [54]. The avatars in this study could mediate their head, arm, and body movements and thus also the direction of a participant's gaze and attention. The lips would move when an avatar was speaking but were not completely synchronised, and if the avatars showed facial expressions, they were relatively neutral and did not reflect the real expressions of the participants. Some of the effects of this selection of possible cues will be further elaborated in Section 3.2.

The three-dimensional room, another important and frequently mentioned factor, also relates to and contributes to the perceived realism. The participants described feeling as if they were in a room together, sitting around a table or on a sofa. The level of perceived realism depends on the software, as discussed by Paulsen et al. [8, p. 10], but one unexpected event in the project also highlighted the significance of hardware. ID5 had forgotten her VR headset for WS5 and had to take part from a desktop computer, which provided a comparison and insight that would otherwise have been lacking. During the meetings, the other participants commented that her avatar was largely sitting still. Likewise, she described a feeling of being more on the outside than when wearing the VR headset. This difference between the VR headset and the desktop version was also observed in the recordings (see Fig. 4).

ID5's avatar appeared more static and less 'alive' than the others. Her gaze had a more 'staring' quality than that of the others since the avatar's body and head were fixed in one position. This finding could indicate that the perceived realism of VR is experienced more strongly when VR headsets are used than with a desktop computer. Moreover, during the debrief and the individual interview, ID5 described and confirmed this difference, since she had also experienced the feeling of using a VR headset. These results are similar to those reported by Drey et al. [38], namely, that the symmetric system where both attendees used VR provided a stronger presence, immersion, and player

Fig. 4. Perceived realism: contrast between immersive VR and desktop VR.

experience.

2.2. Togetherness

The participants brought up the strong sense of being together they had experienced when describing the setting they were in, sitting around a table in a meeting room and seeing each other, as well as a feeling of intimacy. One participant put it like this:

> *"I hadn't imagined that it would feel so intimate in a way when you kind of enter VR, that when you then meet the others and sit and listen to them, it feels like they are sitting right next to you." (ID1)*

The participants also talked about another element that affects this togetherness, that is, how the conversation in the meetings flowed naturally. Through several statements, the participants described how they always knew who they were talking to while they were in the VR environment and that it was easy to speak up:

> *"Yes, one became more engaged. I felt that we were more in it, the conversation, and it was more natural to sort of take the floor, and we could see who was speaking, and yes, the gestures of these avatars, and it was kind of like you almost forgot that you were sitting in a virtual room." (ID3)*

The experience of seeing others has its counterpart in the experience of being seen by others, and the participants also referred to someone looking at them in the meetings. Eye contact is an important factor in human communication and one that is often reduced in online communication. Obviously, there is no real, direct eye contact in VR, yet the participants touched upon this phenomenon both implicitly and explicitly:

> *"It seemed like, yes, as ID2 says, we were actually in a meeting, and you sort of moved your head to look from one person to another, right? You felt like you made eye contact even though the person wasn't there." (ID5)*

These results support the significance of eye contact for communication, as described by Hietanen [55], but also extend this finding, since Hietanen's review did not comment on VR. These elements are further confirmed by the observation of VR recordings. When the interactions are observed from the participants' perspectives, the impressions are strikingly different from video conferencing platforms such as Zoom and Teams, where it is difficult to determine what the other attendees are looking at or focusing on (see Fig. 5).

The group had extensive experience with video conferencing, and while the participants were specifically asked about the comparison in the interviews, they also brought it up themselves on several occasions. They described VR as better and more realistic, easier to take part in, and, maybe obviously, considering our chosen activity, said that breakout rooms, in particular, worked a lot better in VR than in video conferencing. ID2 also highlighted the experience of feeling that the participants were more present than when black screens are used, that is, when people have their camera turned off during online lessons. ID5 even said during the interview, which was conducted in Zoom, that the interview situation could have been better in VR.

Further details were noted in the observation regarding how interaction and communication between the avatars contributed to the participants' feeling of togetherness. Despite limitations compared to physical bodies, the avatars' movements, gestures, and direction of gaze still seemed to attract and signal attention. They sent cues that were easily interpreted by the others, for example, to give the floor to someone or to agree. These traits seemed especially characteristic of participants ID1, ID2, and ID6. These three frequently turned towards each other and showed small movements and signs to indicate where they were directing their attention, which is similar to the experience of being together physically. This behaviour created a more natural flow to the conversation between these participants than with ID4 and ID5. For ID5, this contrast was due to her use of the desktop version, but for ID4, it was likely technical challenges that limited the social interaction. This pattern was noted in both sessions, but the communication in WS6 was a little different because the participants were also reading on the screens. In this setting, the avatar postures indicated whether the person was reading (looking down) or ready to talk (looking up). This was not the case for ID5, since in the desktop version, it was possible to see the screen and the environment without changing position. Hence, when her avatar had been sitting still for a long time, the lack of signals made the other participants insecure, and they asked if she was actually there. These features are not only in contrast to what is available when black screens are used, which several of the participants mentioned, but also differ from watching others talk in video conferences, even when cameras are turned on. In a video conference, one must choose whether to look at the other meeting participants on the screen, which they will perceive as you looking the other way, or to look into the camera, which they will perceive as you looking at them, even if you are not. While VR does not (yet) provide realistic faces, the avatar's face, combined with a mediated direction of the participant's gaze that better corresponds to reality, seems to recreate the feeling of being seen in a more impactful way than the talking heads of conventional video conferences.

During the WSs, debrief, and one of the interviews, the participants

Fig. 5. Togetherness: observer perspective vs. participant perspective.

sometimes used the word 'safety' to describe how it feels to be in a VR meeting. The feeling was described as contrasting with the feelings experienced in both video conferences and physical meetings, and it is a contributing factor to the social learning climate required for COL:

"It feels almost a bit safer in here." (ID2)

Other researchers have also pointed out that VR affords a safe space for learning [6,7,25,56,51]. However, the safety described by the participants was more to do with the social experience than with practising a dangerous task; hence, it contributed to creating the social learning climate that is vital for COL.

2.3. Challenges

The participants were mostly positive, as visible in themes 1 and 2, but they also remarked on some challenges, primarily connected to technical or practical issues. Most of these challenges are well-known from other VR studies (see e.g., [57]), including network connectivity, accounts and login, fallouts, and sound problems, all of which can be problematic with any digital technology. More specific challenges to VR are the adjustment of the device on the head and eye settings, eye and neck strain, and cybersickness [57].

During the WSs, several of these issues were discussed, and we decided to use VR environments that let us sit still and spend limited time within VR. These decisions probably contributed to the fact that no physical or health-related problems were experienced during the project. In WS6, ID4 was struggling with the controllers and could not find a way to sit down; hence, her avatar appeared to emerge from the table with her arms in an unnatural position, as shown in Fig. 6. This posed a challenge to both her and the other participants' concentration.

A feature in ENGAGE for viewing content or notes inside VR also posed a challenge. While a regular educational setting with group discussions allows for notes or texts to be part of the activity, VR users cannot see their physical surroundings. Hence, they must either remember what to say on the spot, as was done in WS5, or use the content-viewing feature, as was done in WS6 (see Fig. 6). However, this feature did not work well. When viewed in the VR headset, the content on the screens flickered and was difficult to read, an issue that the participants reported and was also commented on during observation. ID5, on the other hand, reported that this problem did not occur in the desktop version, where all the text was easily readable. This finding showed that despite having some disadvantages related to perceived realism and togetherness, the desktop VR worked better for some purposes. ID5 also commented that it was easier to navigate the user interface in this version and that the possibility of joining a VR meeting even without access to specialised equipment is beneficial.

Another workaround for the lack of notes was explored when ID4 found a solution for reading physical handwritten notes by tilting the VR glasses up during WS5. According to her, this solution worked well, but the observation showed that it had a different effect inside the VR room from the perspective of the other participants. Her avatar froze in an unnatural position when the glasses were tilted up, and this seemed to interrupt the flow of the social interaction. This finding illustrates another point, namely, that the identified challenges are not merely examples to be communicated to developers for improvement. It is also possible to view the struggles and attempts to find solutions as opportunities for growth in areas of PDC. From that perspective, the process whereby ID4 found her own way to solve the problem she had encountered can serve as an example of digital agency [29,30]. Most of the challenges also turned out to be manageable by adapting activities according to experiences.

3. Discussion

Building on the specific themes that emerged from the analysis, certain overarching implications of the study stand out and are discussed in this section. These include social dynamics or demands, pedagogical implications, most notably, the potential PDC development for teacher students, and lastly, technological insights.

3.1. Social dynamics

The perceived realism and togetherness experienced by the participants indicate that VR meetings demand a strong commitment to the social situation. When ID4 puts her VR headset up on her head and the avatar freezes, the 'contract' is violated. A similar effect occurs when sounds are heard from the physical environment (dog barking, family speaking). The difference between using VR with a headset and using the same software on a desktop also highlights a similar phenomenon. Cues of attention (body movements mediated by the VR headsets) that the participants had started to expect from each other, were lacking from ID5's avatar. This resulted in confusion about whether she was paying attention or had mentally absented herself. Such cues are a natural part of physical meetings and social interactions but are often lost in digital environments.

The increased immersion and perceived realism in social VR seem to

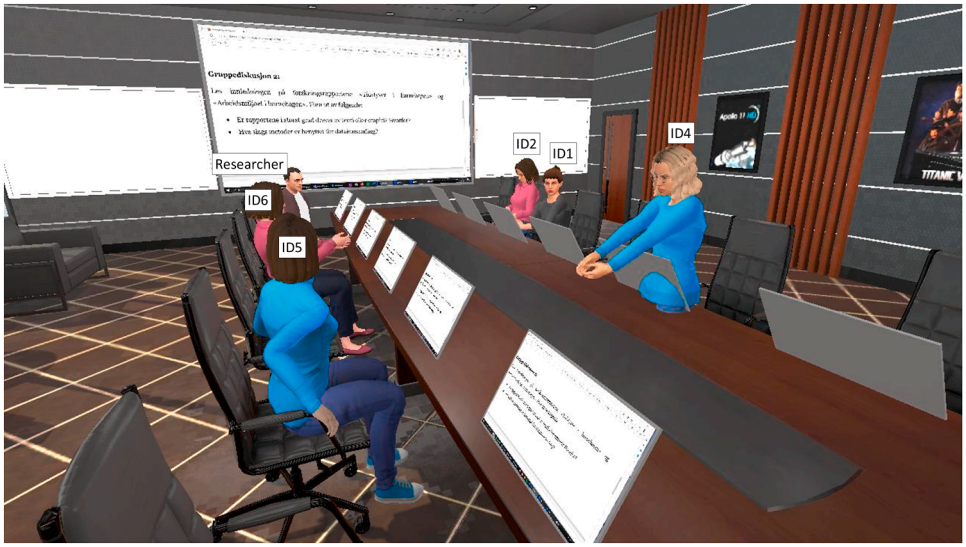

Fig. 6. Challenges: technical difficulties.

provide a more demanding experience, which is a positive outcome, as it has greater resemblance to the demands made on us by a real social situation. However, some limits regarding the social cues should also be noted. For example, our VR setup lacked eye tracking and could not mediate facial expressions.

3.2. Pedagogical implications

The participants in this study were students of kindergarten teacher education. While the main results of the study are relevant to a broader field of education, certain elements from the process and material are more specifically relevant to this context and to the development of professional digital competence (PDC). We did not measure PDC directly, so these implications are not evidenced, but rather inferred and based on interpretation of observations and dialogue with participants. However, they are relevant and should be investigated more explicitly in future studies. First, engaging with a new and unfamiliar technology could potentially affect the attitudinal element of PDC. The participants initially expressed scepticism towards the VR project. However, as they engaged with the technology, they reported increased confidence and enthusiasm. This shift highlights the potential importance of an explorative attitude, which resonates with the kindergarten context where digital tools are intended to facilitate exploration, play, learning, and creativity [58]. Further, the process of evaluating the usefulness of a digital tool in a certain context aligns with notions of PDC [28]. Finally, this evaluative skill, combined with an explorative and playful attitude, resonates with discussions about agency as part of PDC [29,30].

3.3. Practical implications

While VR has become recognised in certain areas, especially for simulation, there has been little take-up of its possibilities for social interaction. This study shows the potential in VR to strengthen the social elements for students in COL. However, due to, for example, the negative effects of extensive use, it should only be supplemental to other solutions. Further, organisations and corporations whose employees work remotely could also benefit from supplementing their online work environment with social VR.

The discussion of PDC suggests that a playful exploration could be considered effective in the learning of digital tools. Although more obvious in the field of kindergarten teacher education, such playfulness could inspire a stronger exchange across different contexts and education levels, as schools and higher education could more often look to the pedagogy of kindergartens, even in areas such as digital technology (see [59]).

3.4. Study strengths

This study has several strengths. First, we would like to highlight the novelty of our combination of a VR study with the kindergarten context. To our knowledge, this is one of the first studies on social VR in kindergarten teacher education. Furthermore, methodological rigour strengthens the study. Secondly, triangulation of different data sources (observation, interviews, and spatial recordings from the VR software) strengthens the robustness of the analysis and the findings. The methodological innovation of using replay of spatial VR recordings is also worth highlighting.

In general, one main strength of qualitative methods lies in the possibilities they offer of delving deeply into the meaning-making of participants [60], even if the participants are few in number. The participants' backgrounds, as adult female students of kindergarten teacher education without a particular experience of or interest in technology, can suggest that the results are at least more transferable to a broader audience than, for example, studies recruiting participants from IT education or similar.

Regarding methods, the iterative design approach is also a strength in that it leads to increased ecological validity, relevance and authenticity. This is both because the researcher can observe the participants over time, and that the activities take place in the natural settings of the students. Lastly, the particular strength of the analysis lies in the pedagogical insights that link playful exploration, which is normally associated with kindergarten, and the target context of teacher students with the development of PDC for teachers.

4. Limitations and future research

One limitation of this study is the number of included participants and the lack of a control condition or group. The sample was homogeneous (all six participants were women from a single cohort), which can limit diversity and transferability. Future studies should include more and more diverse participants and provide more robust findings on how VR can be used as a tool for COL in a kindergarten teacher education programme. There is also a limitation in the contextual specificity, as cross-cultural validation is not possible.

Another limitation concerns the role of the researcher. Being actively involved in every part of a design process involves several roles, as discussed by McKenney and Reeves [46, p. 180]. Preparation for the project required familiarisation with the technology, and the experiences gained in this process may have influenced interpretations. Additionally, the researcher is present in the data both through recorded statements from the WSs and as an avatar in the VR recordings. The researcher also taught a few lessons in the class from which the students were recruited. The triple role of teacher, facilitator, and researcher may have influenced the participants to act and respond out of kindness. However, it was emphasised, both in a formal written contract and verbally, that participation was voluntary and that the participants could withdraw from the project at any time. During the WSs and interviews, the participants were also encouraged to be honest. After the analysis, the participants had the opportunity to read and comment on the results. Presenting and discussing results with a supervisor, colleagues, research groups, and a co-author were also strategies to reduce bias.

Further, we were very aware of potential bias when undertaking the thematic analysis. Thematic analysis is widely recognised in qualitative research, especially for its flexibility and ability to provide an in-depth, detailed account of data [61]. However, there are also limitations (as with all methods) and mitigations that must be considered when conducting thematic analysis. The method's flexibility can be both an advantage and a major limitation, and researchers must maintain consistency and accuracy. Consistency is maintained in this study by including transparency and by showcasing examples of how the themes were derived (Appendix A-F). Accuracy is maintained by intra-observer and intra-analyst reliability, as the researcher analysed the material twice. Preliminary results were also discussed with a supervisor and the co-author. Another potential difficulty concerns the language translation. This study is based on the Norwegian language and culture, but when translated into English, some of the inherent meaning in the themes (as coded) might be lost. A replication of the study in a different cultural context would enable validation of the results.

A more general limitation of the study is the ability to design and implement a VR COL activity in a more dynamic process (before, during, and after), as within, for example, the suggested VR engagement model [62]. Further research should investigate the more regular implementation of VR for COL and group discussion in online study programmes. Such research would provide longitudinal data for more secure conclusions about the impact on PDC, also distinguishing possible novelty effects on participants' enthusiasm from sustained change. Another option would be to move the focus to the workplace and explore an equivalent VR collaboration among kindergarten teachers with limited professional communities. Additionally, future research could focus on the specifics of social interactions in VR, such as the impact of gaze and gestures, and could benefit from quantitative studies to

complement the qualitative insights gained here. The themes of togetherness and perceived realism that emerged through the qualitative analysis should be further investigated and quantified in a mixed-methods study where validated scales for social presence and immersion are applied.

The comparison of social VR with conventional video conferencing platforms was not a main point of investigation in this study. However, it was frequently brought up in WSs and interviews. We recommend more specific comparative studies of these technologies. Such studies might contribute not only to improving educational use but to furthering hardware and software development within both VR and video conferencing platforms. Considering the lack of studies exploring what happens within VR, as pointed out by Paulsen et al. [8], we particularly tried to make use of the possibilities of recording and observing. Although these features in ENGAGE, and probably in other available software, were exploited to some degree in the current study, they have greater potential for qualitative analysis that should be further explored in future research.

5. Conclusions

Returning to the study framework illustrated in Fig. 1, through results and discussion we suggest that this cohort of students experience with designing and participating in a VR-activity, bringing together COL design issues with the social features of VR, leads first to the proximal outcome of the social learning climate being affected. This was elaborated through the three themes: perceived realism, togetherness, and challenges. Secondly, through interpretation and discussion, we suggest that such experience distally also might influence the students' development of professional digital competence.

This study of students' use of social VR indicates that VR may have a potential to create a realistic feeling of connection and of being together, which is often lost in collaborative online learning environments. We suggest that VR could be a useful addition to the basic existing toolbox for online students of a PC and a web camera, especially to enhance the social learning climate that is suitable for discussions and social interaction. The study also indicates that the exploration of a new technology might contribute to some elements of kindergarten teachers' professional digital competence, especially in terms of attitudes and agency. Following from this, it is also suggested that the kindergarten pedagogical perspective on technology, distinguished by play, exploration, and creativity, might be a useful approach to technology learning beyond this context.

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CRediT authorship contribution statement

Nils Christian Tveiterås: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Thomas Bjørner:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.caeo.2026.100377.

Appendices

Appendix A: Translated example excerpts of coding and theming

Themes	Theme definition	Subthemes	Codes
Perceived realism	Participants' perception of the virtual environment as realistic	Feels like being physically present	Feels really like we are sitting in the same room Feels like sitting together in a classroom Felt like you were actually in a meeting room
		Sense of space	You who have VR goggles feel that you are sitting in the room Feels more like a room Feels like we are actually in a room Felt like we were sitting in a meeting Sat around the table, talking Sitting on the sofa Feels more realistic Feels real Feels so real Felt that you were in a meeting even though you were in a different place

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Themes	Theme definition	Subthemes	Codes
			Forgetting that it is a virtual room
			Forgot that you were in VR
			Absolutely crazy
Togetherness	Participants' experience of a feeling of being together with the other students in the virtual environment	Conversation	Good conversations
			Easy to talk
			Natural conversation
			Natural to sit and have a dialogue
			Natural to speak up
			See who is talking
		Eye contact	You felt that you had eye contact even though the person was not there
			Someone is looking at you
		Feeling of being together	Felt like you sat around the table together
			Feels almost like sitting physically together
			Feels like they are sitting right next to you
			When you exit, it feels like you have been together with someone
			Feels closer to people
			Feel connected
Challenges	Participants' experience of different challenges, both technical and physical	Physical consequences and discomfort	Headache might come
			Tired if used too long
			Need for breaks
		Technical challenges	Falling out and disappearing
			Adjustments to see clearly
			Choppy sound when talking at the same time
			Text on virtual screens is difficult to read

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