



Teachers and Students Envisioning Mixed Reality Remote Learning: A Qualitative Exploration on Fostering Academic Engagement

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Abstract

Mixed reality (MR) provides new opportunities and affordances for fostering student engagement in remote learning. The current qualitative case study set out to (1) explore teachers' perspective of academic engagement in traditional classrooms, (2) explore how teachers' and students' envision engaging lessons using MR for remote learning, and (3) extrapolate limitations and affordances for the further development of MR for remote learning. Eight students and four teachers from a primary school in Namibia participated. Each participant wore the HoloLens 2, interacting with others who were live streamed from another room. Group interviews with the teachers revealed core practices and strategies focused on the centrality of students, student-teacher relationships, rewards and evaluations, and the physical environment for creating engagement in traditional classrooms. Teachers and students participated in role-plays centered around fostering emotional, behavioral, and agentic engagement in imagined lessons that used MR for live streaming from different locations. The role-playing teachers mainly used verbal practices and strategies for fostering closeness, as well as giving feedback and evaluations. However, many strategies previously named or found in the literature were not enacted and symbolic MR boundaries were crossed. Based on our results, we derived affordances and future directions for the further design and development of MR for remote learning.

Keywords Educational technology · HoloLens · Mixed reality · Augmented reality · Academic engagement · Instructional practices · School · Qualitative

1 Introduction

Over the past two decades there has been an increased interest in students' academic engagement, as it has been linked with academic achievement and subjective well-being (Wong et al., 2024). Much research has been dedicated to exploring and developing effective instructional practices for fostering student engagement in traditional classrooms (Martins et al., 2022). During the Covid-19 pandemic most schools moved to remote

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learning, which resulted in a need to review and examine students engagement and the fostering thereof (Bozan et al., 2024). Although effective instructional practices from traditional classrooms were applied to remote learning, a set of limitations and challenges arose (Kurt et al., 2022). It is thus important to consider how to adapt instructional practices and design new technologies to allow engagement to be fostered in remote learning (Bozan et al., 2024). We maintain that the use of mixed reality (MR) technology could provide new opportunities and affordances for fostering student engagement in remote learning.

New affordances provided by MR have shown to increase student's engagement (Bodzin et al., 2020), and sustain motivation beyond the novelty effect (Huang et al., 2021). However, more studies are needed in educational contexts to design and develop thus far unexplored features in MR for remote learning. The rapid development of MR technologies, with an early push to market and a risk of discontinuation, leaves the educational sector in a continuous pursuit of tool discoveries and post-hoc adaptation. It is necessary to consider current educational theories and evidence-based practices (Hew et al., 2019), as well as including teachers and students early on in educational technology design (Woodward et al., 2022), to appropriately guide development priorities and possible use cases for remote learning.

In line with these considerations, our qualitative case study set out to (1) explore teachers' perspective of fostering academic engagement in traditional classrooms, (2) explore how teachers' and students' envision engaging lessons using MR technology for remote learning, and (3) extrapolate affordances and challenges for the further development of MR technology for remote learning. We aim to delineate technical features of MR headsets necessary for fostering engagement, and note how perceived limitations and challenges of remote learning could be circumvented.

2 Theoretical and Empirical Background

2.1 Academic Engagement

Engagement is a multifaceted construct, referring to "the quality of a student's connection or involvement with the endeavor of schooling and hence with the people, activities, goals, values, and place that compose it" (Skinner, Kindermann, & Furrer, 2009, p. 494). Multiple types of engagement exist, including behavioral, emotional, and agentic engagement (Reeve et al., 2020). *Behavioral engagement* has been defined as the enactment of positive classroom behaviors (e.g., adhering to rules), the absence of disruptive classroom behaviors, and the involvement in learning activities, including persistence, concentration, attention, contributing to class discussions and asking questions (Reeve et al., 2020; Skinner et al., 2009). *Emotional engagement* refers to students' affective states or reactions in the classroom, such as happiness, interest, boredom, and anxiety (Skinner et al., 2009). *Agentic engagement* is defined as students' proactive and constructive contribution towards the conditions and content of learning activities and instruction (e.g., expressing preferences, communicating needs) (Reeve et al., 2020).

Skinner et al. (2008) developed the Self-System Model of Motivational Development, which frames how personal and contextual factors foster or undermine students' engagement, i.e., the process by which an engaging climate is created and maintained within the classroom. The model proposes that the context (i.e., teachers' construction of the learning environment and social interactions), contribute to students' self-system processes (i.e.,

self perceptions organized around the basic need for autonomy, competence, and relatedness), which influence students' engagement (or disengagement) in activities (Skinner et al., 2008). Previous investigations have shown the significance of engagement for students' outcomes, revealing it to be a positive predictor of academic achievement well-being (Wong et al., 2024), and reducing school dropout (Archambault et al., 2022).

Similarly, multiple investigations have examined the contextual factors that foster engagement within traditional classrooms. In addition to task characteristics and classroom structure, prominent factors that have been found to be beneficial for enhancing engagement include positive student-teacher relationships, academic and social-emotional support from teachers, as well as autonomy support (Fredricks et al., 2004; Martins et al., 2022; Quin, 2017; Tao et al., 2022). Furthermore, teachers utilize various instructional practices to enhance engagement (Martins et al., 2022), including extrinsic motivators, such as incentives and rewards (Petrasek et al., 2022). Although not often considered, but relevant for the current study, the physical learning space (e.g., classroom equipment, cleanliness, spaciousness) can also have an impact on students' engagement (Kariippanon et al., 2019; Oliveras-Ortiz et al., 2021; Yusof et al., 2018).

2.2 Academic Engagement in Remote Learning

During the Covid-19 pandemic most schools made an emergency switch to remote learning. This resulted in a set of studies examining students' and teachers' perceptions of engagement in K-12 education, and specific strategies teachers used to promote student engagement in remote learning (Kurt et al., 2022; Yang et al., 2021). Based on known engagement strategies, teachers focused on creating explicit learning objectives and tasks, using interactive teaching techniques, and providing students with feedback (Kurt et al., 2022; Yang et al., 2021). An extended use of monitoring (e.g., attendance, completion of assignments) and rewards (e.g., certificates of appreciation) was also found to foster students' engagement in remote learning, as well as increased emotional support (e.g., motivational talks, asking students how they feel, showing concern, and lightening the mood with humor) (Kurt et al., 2022; Roman et al., 2022; Ewing & Cooper, 2021; Ong & Quek, 2023; Yang et al., 2021). Teachers highlighted that the continued adaptation of in-person engagement strategies is essential for effective remote learning (Roman et al., 2022). Yet despite adapting strategies, both primary and secondary school teachers still described difficulties keeping the students engaged, specifically noting challenges with surveying students' activities, giving appropriate feedback, and creating meaningful connections (Karaferye, 2022; Code et al., 2020; Roman et al., 2022; Ewing & Cooper, 2021; Bray et al., 2021). We propose that MR could be an alternative to conventionally used technology for remote learning, with the potential to overcome the challenges previously described and enable student engagement.

2.3 Mixed Reality in School Settings

MR describes a broad continuum between the unaltered real environment and a fully virtual environment, which entails (or is considered synonymous) with augmented reality (AR) but not virtual reality (VR) (Milgram & Kishino, 1994; Speicher et al., 2019). The Microsoft HoloLens is most often associated with MR (Speicher et al., 2019), being a headset that shows virtual additions, i.e., holograms of objects or people, in context to the real viewed environment. Although the application of MR has been examined within

tertiary education settings, research conducted within primary and secondary school settings is more scarce (Law & Heintz, 2021; Masmuzidin et al., 2022). Nonetheless, studies have shown that the use of holograms can positively effect students' achievement (Yu et al., 2022), and that the usage of MR can improve motivation, engagement, and interest in taught subjects (Abdullah et al., 2022; Sánchez-Obando & Duque-Méndez, 2023; Ustun et al., 2022; Leonard & Fitzgerald, 2018; Lindgren et al., 2016). Exploring pre-service teachers perceptions of AR tools, Sat et al. (2023) found that perceived advantages included increases to students' motivation, enjoyment, and interest (see also (Perifanou et al., 2022)). Conducting a design-based research study with the HoloLens in a secondary school, Leonard and Fitzgerald (2018) found that teachers and students tended to adapt the technology to established teaching and learning approaches. However, various technical and pedagogical implementation issues arose. A review by Korte and Väättäjä (2022) suggests that the HoloLens stimulates engagement through collaborative and interactive learning. This coincides with teachers' appeals for AR to support different forms of interactions, such as group work, as well as different presentation forms, such as teachers communicating with entire class versus with individual students (Heintz et al., 2021). Similarly, students who tried out the HoloLens indicated that they require more group work and collaboration, as well as visibility of each others work in order to have an engaging atmosphere (John et al., 2022). However, research on the HoloLens has mainly focused on students interacting with digital augmented objects (Lauer et al., 2021; Munsinger et al., 2019), with only a few studies exploring the creation and support of social interactions amongst students and teachers (Quin et al., 2021; Rötönen et al., 2021; Enyedy et al., 2017).

3 Current Case Study

3.1 Broader Project Context

The current case study is part of a larger research project, with the agenda to design and develop MR technology for remote learning together with students and teachers in school contexts. (see Pope et al., 2022; Mendes et al., 2023; Goagoses, Winschiers-Theophilus et al., 2024). We recognize new opportunities for remote learning, in which students and teachers from different places can be part of shared engaging learning experiences; utilizing MR, students and teachers from different parts of the world could convene for various learning actives and knowledge exchange. Central to our project are enabled social interactions amongst students and teachers, as well as strong theoretical foundations and delineations from established best-practices. In our project we explore the use HoloLens headsets to project 3D volumetric live stream videos of students and teachers into each



Fig. 1 HoloLens Usage in Remote Learning for Live Streaming of Teachers and Students

others physical space (see Figure 1), aiming to create immersive and engaging student-teacher interactions within remote learning. As an emerging technology, the HoloLens still faces numerous technical challenges and unexplored practical usages in school settings, we thus aim to define development priorities that align with end users visions for practical implementations. The project constitutes of an interdisciplinary team, with expertise in educational psychology, education technology, child-computer interaction, co-design, and software engineering; all members are continuously involved in the planning and conducting of the case studies, and critically reflecting and discussing the findings thereof.

3.2 Case Study Aims

The current qualitative case study is the first in the project, with the objective of having students and teachers try out the HoloLens in its current form, and gaining new insights and design ideas that may promote academic engagement in remote learning. The one-week long study included multiple activities; for the current manuscript, we draw upon a group interview held with teachers, and role-play scenarios enacted by students and teachers. The first aim was to explore teachers' perspectives of fostering academic engagement in traditional classrooms, with a specific focus on utilized practices and strategies. The second aim was to explore how teachers' and students' envision engaging lessons using MR for live streaming of teachers and students from different physical locations. Based on former, the third aim was to extrapolate limitations and affordances for the further development of MR for remote learning. Specifically, we strived to delineate technical features of MR headsets necessary for fostering engagement based on the insights gained from exploring teachers' and students' perspective of engagement in traditional classrooms and visions for MR in remote learning.

3.3 Strengths and Addressed Research Gaps

The current case study possesses several strengths and effectively addresses key research gaps. Firstly, the study has a solid foundation in educational theories, current constructs, and empirical findings, which guided the design and data analysis, as well as the delineations of the results for further recommendations. This is in contrast to many previous studies in the field of educational technology, which often do not make reference to any theories or only do so superficially (Hew et al., 2019). Secondly, we draw upon a unique sample of primary school teachers and students from Namibia to provide insights for the fostering of engagement with MR in remote learning. Literature reviews indicate there is a need to increase research attention to K-12 education, as well as including the perspectives of teachers and students from African countries, when focusing on academic engagement, remote learning, and MR (Yang et al., 2023; Goagoses, Suovuo, et al., 2024). Thirdly, we involved the targeted end-users of the technology, i.e., teachers and students, involving them early on so that their envisioned ideas and practices can guide the design and development. Educational stakeholder needs and desires are often lacking in the development of emerging technologies, yet their involvement in early stage technology design can have a profound impact on suitable implementations Van Mechelen et al. (2023); De Lima et al. (2022). Woodward et al. (2022) established that children's perceptions and expectations of AR differ from adults' conceptualisations, and therefore we included both students and teachers in our case study. They both provide expertise in the adaptation of technology to established teaching and learning approaches Leonard and Fitzgerald (2018). Lastly, a

novelty of our research is the focus on live streaming students and/or teachers as holograms in the context of remote learning. Thus far the vast majority of research implementing MR in school settings has focused on holographic objects for learning (Yu et al., 2022), despite continuous calls from teachers and students to expand on the possibilities for varying social interactions as is typical in traditional classrooms (Heintz et al., 2021; John et al., 2022).

4 Method

4.1 Participants

Both students and teachers were recruited at an urban public primary school in Namibia, which has a longstanding collaboration with researchers from the local university. The researchers offer weekly extra-curricular educational technology design and evaluation lessons to approximately twenty learners from Grade 6 and 7. From these, eleven children (three boys and eight girls) expressed interest in participating in the current study. In an attempt to create a gender balance all three boys were selected. Five girls were selected based on their active engagement in the sessions and demonstrated commitment. The information technology teacher, who is involved in the extra-curricular lessons, recruited three other teachers from the school on a voluntary-response basis. The teachers (two males and two females) taught a variety of subjects, including physical education, design and technology, information and communication technology, English, mathematics, natural sciences, and social studies. The time that they had taught at the school ranged from a few months to seven years. The language of instruction at the school is English.

The research project received ethical clearance from the local university, written approval from the Ministry of Education, Arts and Culture and the principal of the school. Students and teachers participated on a voluntary bases, and could stop participating at any time point without any consequences. For each participating student we received a signed informed consent from a parent or legal guardian, and the students also provided their consent. Participating teachers also signed an informed consent. Both students and teachers were informed about the activities, and provided consent of photo and video recordings during the study, and that these may be used in scientific publications.

4.2 Experience Wearing Hololens 2

At the start of the one-week case study, all students and teachers had the opportunity to wear the Microsoft Hololens 2, a MR/AR headset (see Figure 2). This was the first time both teachers and students wore MR headsets, having not previously used this technology in their classes. A pair of Intel Realsense LiDAR cameras were arranged and calibrated in one room and the Hololens was located in a neighbouring room with an ethernet cable link between the rooms. The cameras provide a 3D position for each image pixel, and both camera viewpoints can be combined once a calibration process has been performed to identify the precise relative position of each camera. The colour image and 3D data is encoded and streamed as video to a rendering machine in the other room which provides the image to the Hololens. In both rooms, a laptop with an Nvidia GPU was sufficient to capture, stream and render the holograms. Some of the participants were asked to stand in front of the cameras whilst the others were able to view their holograms and walk around them. It was a one way experience, those in front of the cameras were not aware of the Hololens user



Fig. 2 Teacher wearing the Microsoft HoloLens 2 and students positioned in front of LiDAR Cameras

looking at them, nor could they hear anything. The overall quality of the experience was poor due to reflections and sunlight in the rooms increasing the noise and distortion of the LiDAR data, resulting in considerable gaps in the hologram image. There were also challenges in positioning the holograms correctly in the room. Despite this, all of the students and teachers were excited to see the holograms and the activity was sufficient to inspire them for the remainder of the workshop. None of the participants referred to the quality issues whilst using the HoloLens, however, it was necessary to prompt them to move around to find the best position to see the hologram since with only two cameras the holograms were not complete on all sides.

4.3 Group Interview with Teachers

A semi-structured interview guide was created based previous studies which explored engagement from teachers' perspectives both in traditional classrooms and remote learning (Dolezal et al., 2003; Harris et al., 2022; Harris, 2011), as well as previously identified predictors for engagement (Fredricks et al., 2004; Skinner et al., 2009). The teachers were told that the aim of the interview was to understand how they engage students, to get ideas and insights that can be incorporated in the development of new technology. The interview was structured according to thematic blocks, to address (1) the teachers' understanding, definition, and identification of engagement, (2) explore their previous successes, (3) identify perceived factors driving engagement, (4) identify employed strategies and practices that promote engagement, and (5) identify employed strategies and practices that counteract disengagement. Additionally, the teachers' were asked about (6) the impact of student-teacher relationships on engagement and strategies used to develop these, (7) the usage of rewards for engagement, and (8) what aspects of the physical learning environment contributes to students' engagement.¹ The interview was conducted in the school library and was approximately 30 min.

¹ Questions concerning autonomy support and the use of technology were also created, yet due to time constraints were not asked in the interview.

4.4 Teacher and Student Role Plays

Based on literature about the different types of engagement (Fredricks et al., 2004; Skinner et al., 2009; Reeve et al., 2020), we created three role play scenarios for emotional, behavioral, and agentic engagement. The role plays were enacted separately by three of the teachers, and the students were split into two groups of four. One participant in each group was given the role of being a teacher and the other three students (see Figure 3); the participants rotated in their assigned roles in the three scenarios. The teachers and students were given 10 min to prepare, and the role play lasted 10 min. After each role play a short reflection discussion was conducted, with some prompting questions, such as how the role play went, how they came up with their ideas, and how it compares to normal lessons. To simulate the holographic nature under which they would be interacting (i.e., not being in the same physical space, but rather being holograms), the teacher and students were separated by a plexi-glass. The role plays were conducted in the school library and classrooms.

Emotional Engagement Role Play. The role-playing teacher received the instructions to pretend that they were giving a lesson, and could draw upon a topic they recently taught or learned in class. They were told that they will notice the students getting bored, and need to try to adapt the lesson to make it more interesting and fun. The role-playing students were instructed to act bored at the beginning of the lesson. They were told that the teacher will try to make the class more fun and interesting. If they felt that the teacher was doing a good job in fostering emotional engagement, they could change how they were acting (i.e., showing that they are having fun). Yet if they felt like the lesson was still boring, they could keep acting bored.

Behavioral Engagement Role Play. Again the role-playing teacher received the instructions to pretend that they were giving a lesson. They were told that they will notice that the students are not paying attention and avoiding work, and that they will need to adapt the lesson to get the students listening and working hard. The role-playing students were instructed to act like they are not paying attention and avoiding work. They were told that the teacher will try to make them pay attention and give them a push to try harder. If they thought the teacher was doing a good job in fostering behavioral engagement, they could change how they were acting. Alternatively they could continue acting how they were.

Agentic Engagement Role Play. To simulate an interaction that allows for agentic engagement, the role-playing teacher was instructed to inform the students that there would be a free choice lesson next week, and that they could together with the teacher decide/plan



Fig. 3 Teachers and Students during Role Play

the lesson (with the note that the students should still learn something). The teacher was told to support the students and make sure that the planned lesson includes the students' ideas and interests, as well as what and how they want to learn. The role-playing students were also given this information, and told that the goal is to plan a lesson which includes their interests, ideas, and suggestions.

4.5 Data Analyses

The transcribed interviews were analysed with the MAXQDA software, following a thematic content analysis (Braun & Clarke, 2006), and drawing upon the analysis and results of studies that have similarly examined students' and teachers' perspectives of academic engagement (Yusof et al., 2018; Harris, 2011; Fredricks et al., 2019). To begin with, the interview transcript was read to provide a holistic review of encompassed content. Thereafter initial themes were generated, and the teachers' responses systematically coded according to the themes, based on previously extracted examples and coding rules. The themes mainly encompassed teachers' beliefs and practical strategies for fostering students' engagement. One researcher summarized the teachers responses under the themes, and a second researcher checked the summaries against the interviews to ensure no vital information was overlooked or misinterpreted. Thereafter a list of essential conditions for creating an engaging lesson was extracted, to adequately inform design affordances for MR in remote learning. Hence, a deductive-inductive category building, in which the initial categories arise from the interview guide and theories as a starting point for preliminary categorization, followed by an inductive building of subcategories (Kuckartz & Rädiker, 2022).

For the analysis of the video recorded role-plays, we created a checklist of practices and strategies teachers utilize to engage students, based (1) on the previously extrapolated list of essential conditions for fostering engagement from the teacher interviews, (2) the strategies utilized by K-12 teachers to promote student engagement in remote learning, as identified from qualitative interviews by Kurt et al. (2022), and (3) the practices used by primary school teachers to motivate academic engagement in traditional classrooms, as identified from qualitative interviews by Dolezal et al. (2003). The later two established multiple strategies and practices, from which we selected those that were deemed relevant and feasible in the current role-plays. One researcher watched the recorded role-plays, indicating for each whether the strategy or practice was observed (yes, no, unclear). This provides an indication of which instructional practices or strategies are drawn upon within scenarios mimicking lessons as expected when utilizing the HoloLens. Furthermore, the researcher carefully noted which objects the teachers and students used or interacted with during the role play, and for what purpose. Lastly, the researcher noted the instances in which the plexi-glass boundaries were ignored. This provides further information for technical features that need to be implemented to support future lessons that utilize the HoloLens.

5 Results

5.1 Fostering Engagement in Traditional Classrooms

During the interview, the teachers described an engaged student as one who follows instructions, does their work on their own instead of being told what to do, and believes in

themselves despite their current abilities. Based on the teachers interview responses, a list of essential conditions for creating an engaging lesson was extracted (see Table 1).

Past Successes. Three teachers described a previous lesson in which their students were engaged. The first teacher described an interactive lesson, in which the students spoke about everyday games and researched the rules of the games (i.e., on Google). The teacher noted how the students were having fun and how quickly time went. The second teacher described a social studies lesson, in which the students learned about the weather. The teacher distributed small paper notes amongst the students, which contained information about what is being measured, with what instrument it is measured, and in what units (e.g., rain, rain gauge, millimeters). The students ran around the class with the task of grouping themselves according to their notes. The students enjoyed running about and grouping themselves. The third teacher described a science lesson, in which students got to experiment about the properties of different substances. The students were tasked with bringing substances to the lesson (e.g., sugar, salt), which were then placed in test tubes with water. The students had to shake them, observe color changes, explore textures and temperature, and also tasted the mixtures. The teacher noted that the students were very keen to complete the actions, and that they could tell the lesson was engaging because the whole classroom was a mess afterwards.

Table 1 List of Conditions for Engagement

To create an engaging lesson, students should be able to...

- ... Talk with each other.
 - ... Talk with the teacher.
 - ... Do their own research on the internet.
 - ... Run around the classroom.
 - ... Partake in experiments with multiple actions and senses.
 - ... Quickly talk to multiple classmates.
 - ... Form their own groups.
 - ... Help each other.
-

To create an engaging lesson, teachers should be able to...

- ... Know their students' names.
 - ... Use the students names when calling upon them.
 - ... Pay attention to students' emotions and moods.
 - ... Give advice to students.
 - ... Incorporate ice-breakers.
 - ... Observe/evaluate good classroom behavior.
 - ... Observe/evaluate whether students are doing well.
 - ... Offer outdoor activities and field trips.
 - ... Offer snacks.
 - ... Provide students with verbal praise.
 - ... Display a ranking list of students' grades.
-

To engage students, classrooms should...

- ... Include computers.
 - ... Have decorations.
-

Centrality of Students. The teachers voiced their perspectives that learner-centered teaching is important for engaging students. They noted that teachers should not spend the whole lesson giving frontal instruction, but rather that the majority of time should be filled with students talking or doing something. The teachers noted that “constructive noise” should be allowed in the lessons, especially when students are helping each other. One teacher also noted that choosing topics that interest students is important.

Student-Teacher Relationships. The teachers noted that “a good relationship with the learners is something that is valuable”, as it results in students wanting to come to class, wanting to learn, wanting to pass, as well as participating more in class, being open to ideas, and following instructions. One teacher noted that because of his height students are often afraid, but that developing a good relationship gives them the courage to talk more in his class. To foster good relationships, one teacher described the importance of knowing the students’ names and using their names when calling upon students. Another mentioned the importance of considering their developmental stage (i.e., adolescence), and to pay close attention to their emotions; the teacher noted that “when I notice a certain mood or a certain atmosphere then, that is going to hinder the learning process, then I start to, tackle that and talk about it give some advices here and just to give them an ice-breaker”. This sentiment was picked up by another teacher, who noted the importance of listening to students (recognizing that they are going through things), to create a warm and open yet professional relationship. Supporting students with tasks, letting them know they can freely try things out, was also mentioned.

Rewards and Evaluations. The teachers noted that they give rewards to students for performing well (e.g., passing a test), answering questions correctly, and for good behavior. In addition to verbal praise, the teachers mentioned giving students sweets, as well as promising outdoor activities at the school (e.g., playing sports on the field, having a braai [barbeque] at the end of the semester) and field trips (e.g., to the swimming pool). One teacher noted that giving verbal praise for performing well would also motivate other students to do well, and another noted that creating a list of students who scored the best on a test was also motivating.

Physical Environment. At the school the teachers have their own classroom, but also rotate (i.e., use different classrooms). Asked in which room they think the students are most engaged, the teachers responded the computer lab. One teacher noted that having posters on the wall (i.e., not having blank walls) offers a conducive learning environment, as the students can look at and read these when they are done with their work. A second teacher chimed in, noting that all classrooms should have thematically and grade-level suited posters.

5.2 Fostering Engagement for Mixed Reality Remote Learning

We observed and coded the frequency with which the previously identified practices and strategies to enhance engagement were incorporated by the nine role-playing teachers (see Table 2). The most commonly observed strategies were related to fostering closeness, with the teachers asking students to recite their names and referring to students by their name, as well as attending to students’ emotions/moods and behaviors, and treating students with kindness (e.g., the teacher says thank you to the students for standing up to great her). Furthermore, engagement strategies also focused on feedback and evaluation, with teachers checking and correcting students’ work, as well as academic support and management,

Table 2 Enactment of Strategies and Practices

	Engagement type				Total
	Emotional	Behavioral	Agentic		
Structure					
Expectations for students' social and learning behavior are clearly communicated. ^a	0	1	1	2	
Directions are given in a simple yet precise way and understanding thereof is checked. ^a	0	1	0	1	
Explanations and reasons behind activities and classroom rules are communicated. ^a	1	0	0	1	
The importance of students giving their best effort is communicated. ^a	0	0	0	0	
The importance of meticulously completing schoolwork is communicated. ^a	0	0	0	0	
Closeness					
Students are referred to by their names. ^c	1	2	2	5	
Students are asked to recite their names. ^c	2	1	1	4	
Students' emotions and/or moods are attended to. ^{b c}	2	2	0	4	
Verbal praise is given to complement/ encourage students' learning success, and social and learning behaviors. ^{a,c}	1	0	1	2	
Warmth, care, and concern are demonstrated towards students, accompanied by humor and modeled enthusiasm for learning. ^{a,b}	1	0	1	2	
Students are treated with kindness, and the teacher remains attentive to their personal lives, i.e., caring about them and wanting them to succeed. ^{a,b}	0	1	0	1	
Students are given advice and support. ^{b c}	0	0	0	0	
Autonomy Support					
Students are given opportunities to make choices about aspects relevant to their learning. ^a	1	0	1	2	
Students are entrusted to do things on their own, i.e., are encouraged to try by themselves before asking for help. ^a	1	0	0	1	
Students are given opportunities to form their own groups. ^c	0	0	0	0	
Rewards					
Immediate rewards are used for appropriate social and learning behaviors, as well as for learning success. ^{a c}	0	0	0	0	

Table 2 (continued)

	Engagement type			Total
	Emotional	Behavioral	Agentic	
Delayed rewards are used for appropriate social and learning behaviors, as well as for learning success. ^{a b c}	0	0	0	0
Feedback and Evaluation				
Students' behaviors are attended to. ^c	1	2	1	4
Students' work is checked and corrected. ^{b c}	1	3	0	4
Students receive constructive feedback; the feedback is specific and immediate. ^a	0	0	0	0
Students' grades or results are ranked or displayed. ^c	0	0	0	0
Peer Interactions				
Cooperation between students is emphasized. ^{a c}	0	0	0	0
Cooperative learning strategies are utilized, including group work. ^a	0	0	0	0
Task Characteristics				
Opportunities for hands-on learning are given, including the use of materials or experiments. ^a	1	1	0	2
Games and playful activities are used to reinforce learning and make it more enjoyable. ^{a b}	0	0	0	0
Opportunities for conducting own research are given. ^c	0	0	0	0
Activities entail gross-motor (e.g., running around) to make tasks more enjoyable. ^c	0	0	0	0
Academic Support and Management				
Students' understanding is monitored with questions; answers are probed, time for thinking is given, and self-correction is encouraged. ^{a b}	1	2	1	4
Students are told that they can accomplish challenging activities. ^a	1	0	0	1
Understanding of material is constantly assessed, and learning behavior is monitored and directed. ^{a b}	1	0	0	1
Ice-breakers are incorporated into the start of the lesson. ^c	1	0	0	1
Positive management techniques are employed, i.e., behavior is quickly and discreetly corrected, without disrupting other students. ^a	0	0	0	0
Students receive assistance when struggling to understand or learn new material. ^a	0	0	0	0

Table 2 (continued)

	Engagement type			Total
	Emotional	Behavioral	Agentic	
The value of education is communicated, including overcoming adversities and working hard for one's dreams. ^a	0	0	0	0

Note Strategies and practices described by ^a Dolezal et al. (2003), ^b Kurt et al. (2022), ^c Teachers in the interview (Table 1)

with teachers posing questions and encouraging students during challenging activities (e.g., teacher the teacher tells the students "You can do this").

From the role plays the utilized objects and uses were also extracted, as well as instances in which the plexi-glass boundary was ignored. Within the role-plays the teachers utilized (1) textbooks, looking at the content and having students read from these, (2) pens/pencils, for pointing a students, banging on table, marking papers, and handing them to students for tasks, (3) papers, handed to students for tasks and collected for marking, and (4) chalk, to write on the chalkboard. The role-playing teachers ignored the plexi-glass boundaries in order (1) to hand over and collect books/papers, (2) to hand over and collect experiment material, pens/pencils, (3) to point at objects held by students, and (4) to threaten with punishment.

6 Discussion

The focus of the current study are the instructional practices utilized to engage students, by exploring how teachers foster engagement in traditional classrooms (i.e., their repertoire of strategies), and how teachers and students imagine the fostering of engagement in remote learning, as could be created with the HoloLens (i.e., what strategies they apply, and which were not enacted). From these we aimed to extrapolate new affordances and challenges for the technology, as well as delineating ideas for future research and technology development processes. Expanding on previous AR research, which has involved school students in the design augmented objects (Alhumaidan et al., 2018; Cassidy et al., 2015), experiences (Sim et al., 2018), and hardware (Woodward et al., 2022), the current study involves teachers and students to explore instructional practices to enhance academic engagement in social interactions and teaching situations.

6.1 Transferring Conditions for Engagement to Mixed Reality Remote Learning

In Table 3 we transfer engagement conditions from traditional classrooms into MR remote learning and derive necessary technical features for the realisation thereof. This list should be considered relevant in the development of technologies aimed at supporting student engagement with MR remote learning. While some of the technical necessities might be easier to realize than others, they nevertheless provide an indication for future research and development. As many of the conditions require oral communication between the teacher and students, the audio transmission quality of MR technologies needs to be excellent. Future research could investigate 3D Audio (Tashev, 2019), i.e., the necessity thereof for students and teachers when interacting in engaging lessons. Exact requirements for the portrayal of objects that are needed for certain activities (e.g., reviewing students work) and enhancement of the classroom environment (e.g., wall posters) need to be further explored with teachers and students.

6.2 Ideas to Enhance Mixed Reality Headsets for Engagement in Remote Learning

Based on the theoretical models for academic engagement, as well as the findings of the current study, we delineated a set of design and development ideas for AR headsets that could potentially enhance students emotional, behavioral, and agentic engagement, or provide teachers with necessary information and insights to foster these.

Table 3 Transferring Engagement Conditions to Mixed-Reality Learning Environments and Requires Technical Necessities

Students should be able to...	Application in mixed-reality	Technical necessities
... Talk with each other.	... Conduct a seamless conversation between present and remote students.	Audio features need to support omni-directional, broadcast and 3D sound options in AR headset.
... Talk with the teacher.	... Converse with remote or present teacher, selecting between one-on-one conversations and class conversations.	Audio features need to support omni-directional, broadcast and 3D sound options in AR headset.
... Do their own research on the internet.	... Utilize an individual tablet/platform.	Individual device which could be connected to the AR headset.
... Run around the classroom.	... Interact with physical and virtual space elements, while being displayed to remote students and teacher.	Continuous tracking and display of moving students and elements in the physical and virtual space.
... Partake in experiments with multiple actions and senses.	.. Interact with physical and virtual objects.	Track and provide feedback for actions (haptic or visual).
... Quickly talk to multiple classmates.	... Talk with present and remote classmates (equally).	High audio quality.
... Form their own groups.	... Move in the physical and virtual space to form groups.	Remote students need to be displayed in proximity of present students, while not exhausting their own physical space.
... Help each other	... See each other's interaction objects, such as textbooks (in addition to talking with others and moving around).	Display student's work to remote students and allow for remote interaction.
Teachers should be able to...		
... Know and use their students' names when calling them.	... See names displayed in the headset for present and remote students.	Requires recognition or position of present and remote students.
... Pay attention to students' emotions and moods.	... Have good visual on present and remote students to interpret signs indicating emotions and moods.	The video quality of remote streamed students needs to be high and the position of present students needs to be recorded to avoid obstruction by virtual objects.
... Give advice to students.	... Talk one on one with students, and see their work.	There needs to be directional sound, as well as visuals on the student's work (physical or shared virtual).

Table 3 (continued)

Teachers should be able to...	
... Incorporate ice-breakers.	... Talk, move, draw, etc.
... Observe/ evaluate good classroom behavior.	... Have a good visual and audio on individual students, as well as groups.
... Observe/ evaluate whether students are doing well.	.. Access the student's work and give feedback.
... Offer outdoor activities and field trips.	... Take the headsets outside, without these obstruct outdoor activities.
... Offer snacks.	NA
... Provide students with verbal praise.	... Talk directly to one or many present and remote students.
... Display a ranking list of students' grades.	... Display lists inside the headsets or on a separate device/shared space.
To engage students, classrooms should...	
... Include computers.	... Include different devices, in addition to the headsets and the cameras.
... Have decorations.	... Include physical or virtual decorations.

See above

Remote students need to be displayed in such a manner that the teacher can observe remote and present students simultaneously.

A visual display of the physical work in the headset, or a digital space which is either displayed inside the headset or on a separate device for the teacher to edit.

Students which are outdoors need to be captured by cameras and displayed on the headset for live streaming.

NA

Directional, broadcast, and 3D sound.

For display in the headset, the list needs to be retrieved from a connected device.

The devices need to be interconnected, and provide sharing and hiding options.

The display of remote decorations depends on the capturing by the camera, as well as considering the physical decoration as not to overlay the two realities.

In order for teachers to get an accurate read of students current emotional state, the integration of emotional annotations could present as useful. As an additional augmented object, students could place emotional markers or emojis to express their current emotions (e.g., enjoyment, boredom, anxiety). In a previous study, in which primary school students co-designed an online platform to work with and interact with other students from around the world, the idea of adding "feeling emojis" as an additional communication tool was developed (Rötkönen et al., 2022). Although other forms of emotion recognition could be integrated into the technology, such as facial expression and body movement recognition (Mehta et al., 2018), the use of emotional annotations provides students with more autonomy over which emotions they want to share with teachers and classmates. Previous studies have also shown that a positive classroom climate can enhance students emotional engagement (Krauss et al., 2022), yet creating a positive classroom climate with MR remote learning has thus far not been explored (Goagoses, Suovuo, et al., 2024). Drawing on the control-value theory of achievement emotions (Pekrun, 2018), additional features for students to regulate negatively-valenced emotions, such as anxiety before and during lessons or tests, could also be considered. Thus far, it has been shown that the use of AR can be as beneficial for students with learning anxiety (Yu et al., 2022) or as an addition to psychotherapy for anxiety disorders (Ma et al., 2021), yet proposed additional augmented features for reducing anxiety in classroom interactions have not yet been explored.

Behavioral engagement can be enhanced when tasks are designed with specific characteristics, such as allowing autonomy and peer collaboration (Fredricks et al., 2004), which also aligns with the self-determination theory (Ryan & Deci, 2024; Chiu, 2021). Having tasks that are specifically designed for behavioral engagement in learning scenarios with the the HoloLens, have already been shown to be effective (Richards, 2023), and teacher training for creating such tasks would be necessary. Similarly, gamification has been shown to foster behavioral engagement in remote learning (Kratochvil et al., 2023), and gamification elements for the HoloLens, such as achievement points and badges (Molero et al., 2021; Schez-Sobrinio et al., 2020), could be designed for specific classroom activities. In general, many tools and implementation ideas for MR are likely to positively impact behavioral engagement, such as collaborative learning projects (Ali et al., 2019; Han et al., 2022), interactive augmented objects (Baran et al., 2020; Weng et al., 2019) and environments (Hsiao et al., 2016; Harrington et al., 2021; Bekele et al., 2021).

Agentic engagement is fostered by autonomy support, with teachers providing multiple opportunities for students to act as agents in their own learning experience, by seeking out information, and learning tasks that reflect their personal interests (Reeve & Shin, 2020). For MR this could mean the introduction of choice-based learning activities, whereby students have multiple augmented objects or stations at which they can explore and learn. In remote learning, the adoption of other roles (e.g., students being the teacher) and control over the technology (e.g., permissions to demonstrate) allow students to experience agentic engagement (Harris et al., 2022). Furthermore, students should have a learning environment that allows them to share their experiences (AL-Sinani & Al Taher, 2023), and create their own content and present this to their teachers and classmates. Based on a design-based research approach, Sinfield and Cochrane (2020) describes the use of augmented reality for students to enhance physical posters displays when sharing their work with lectures and classmates. Alternatively, the HoloLens could project interactive white boards; students and teachers can write and draw on these, either with virtual pens or on tablets with interactive whiteboards.

6.3 Limitations

The current case study presents qualitative results, obtained from a small sample of teachers and students. We were limited to a convenience sample, and due to the explorative nature were not able to determine a sample size in advance, as only after data analysis can judgements about new meanings and interpretations emerge Braun et al. (2019). We do not claim that the utilized instructional practices, nor that the derived implications and suggestions are generalizable. Nevertheless, this sample allowed us to meet our research objectives, provide detailed descriptions of experiences, and generating new insights and perspectives that can inform future research studies and technology development. Although the current study provides insights, an evaluation of whether these instructional practices do actually result in students engagement within MR remote learning lies beyond the scope of the current study. Drljević et al. (2024) developed an observational tool to assess primary school students' emotional, behavioral, and cognitive engagement during augmented reality learning, which could be utilized in future studies that examine the effectiveness of instructional practices highlighted in the current study. Concerning the data analyses, we chose strategies that we deemed relevant from the literature (i.e., Table 2), yet this is not an exhaustive list of all possible strategies and practices. Furthermore, the non-use of strategies and practices in the engagement role-plays are difficult to interpret; it remains unclear whether these were not utilized because these are practices the teachers never use, they were not fitting in the scenario, or they did not deem them feasible in the envisioned MR setup. Thus, teachers might require training for giving engaging lessons with MR remote learning (Berg et al., 2023; Anton et al., 2023). Lastly, we note that although continuously pushing for the involvement of students and teachers in the development of educational technology, technical and implementation challenges do arise when focusing on emerging technologies that are still in early developmental phases. Lastly, we note the technical and implementation challenges that arise when focusing on emerging technologies that are still in early developmental phases, which may be especially difficult for teachers and students to grasp and work around (see also Leonard and Fitzgerald (2018)).

7 Conclusion

We explored teachers' perspectives of fostering academic engagement in traditional classrooms with a group interview. Their practices and strategies highlighted the centrality of students, student-teacher relationships, rewards and evaluations, and creating an engaging physical environment, which showed some overlaps with previous findings but also revealed unique approaches to engage students. Utilizing role-plays, we explored teachers and students visions for engaging lessons using MR for live streaming of teachers and students from different physical locations. We observed enacted practices and strategies for fostering emotional, behavioral, and agentic engagement. The role-playing teachers enacted mainly verbal practices and strategies that were previously mentioned in the interviews or in the literature. Role-playing teachers often utilized practices and strategies for fostering closeness, as well as feedback and evaluation. Practices and strategies that required physical objects or gross-motor activities were not enacted, nor was interaction between the students fostered. This indicates that both students and teachers make a quick selection and adaptation of known and feasible engagement strategies when envisioning

MR remote learning. Despite an aversion of strategies that require rethinking in MR remote learning, the physical boundary was still crossed for simple actions, such as handing over learning material. We conclude that in its current form the Microsoft Hololens is not yet a usable technology to support engaging interactions between students and teachers in remote learning. Based on our results, we derived affordances and future directions for the further design and development of MR for remote learning. These mainly highlight the need for high quality audio, correct positioning of holograms, and visibility of the students' work for feedback and sharing. We encourage researchers and technology developers to build upon our work, and highlight the importance of framing with educational theories and empirically established best-practices, including underrepresented populations, and collaborating with teachers and students in order to direct technical developments of MR remote learning.

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Data Availability The participants of this study did not give written consent for their data to be shared publicly, so the research supporting data is not available.

Declarations

Conflict of interest The authors have no relevant Conflict of interest to declare.

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