

Article

Mixed-Reality Simulation to Support Practice Learning of Preservice Teachers

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Abstract: Before the COVID-19 pandemic, providing high-quality practice learning experiences for preservice teachers was already taxing due to the heavy reliance on school practicum, which is often besieged with challenges. Given these challenges, there is a growing urgency to explore alternative avenues for offering practice learning experiences to preservice teachers in addition to school practicum. With this backdrop, a qualitative study was conducted, employing observation and interviews as data collection methods to explore the potential of mixed-reality simulation (MRS) to strengthen the practice learning experiences of preservice teachers. The core teaching practice of questioning was chosen to explore the affordances of MRS for improving preservice teachers' understanding of and proficiency in utilizing questioning. This study found that MRS provides a low-risk learning environment that preservice teachers perceive as authentic. For these reasons, this environment is conducive to improvement, and it enables deliberate practice, which is vital for nurturing metacognition and adaptive expertise. The findings also highlight the importance of coaching for maximizing MRS advantages. The absence of coaching will most likely limit the affordances of MRS as an approximation of teaching practice. While our findings are promising, the resource-intensive nature of MRS implementation means that scalability requires further investigation.

Keywords: mixed-reality simulation; MRS; practice learning; preservice teachers



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1. Context of the Research

Before the COVID-19 pandemic, providing high-quality practice learning experiences for preservice teachers in South Africa was already a significant challenge. This challenge primarily arose from the heavy reliance on school practicum, also known as school experience, teaching practice, or practice teaching, as the primary method for facilitating these essential experiences. However, the emergence of COVID-19, which severely restricted the placement of preservice teachers in schools, heightened the urgency of exploring alternative ways to offer practice learning experiences to teachers. Here, the term “practice learning experiences” refers to experiences for preservice teachers to learn in practice (mostly through placements in schools) and learn from practice, which includes the study and analysis of practice, employing, for example, case studies, videos, and lesson observations with a view to inquire into and theorize practice. In our view, the use of MRS to create simulated classroom experiences, which is the focus of the research discussed in this article, enables learning both in and from practice simultaneously.

Teaching practice in schools is widely recognized as an essential component of preservice teacher education [1–3]. Graduates of teacher education programs often consider the school practicum as the most valuable part of their teacher education [4–6]. The school practicum is also seen as a form of workplace learning—a crucial component to enable preservice teachers to comprehend the nature of teaching and of being a teacher [7]. When well-designed and effectively utilized, the practicum can serve as a “learningplace” [8] for bridging the theory–practice gap [9]. It is where coursework learning can be practically

applied, tested, and reinforced through active exploration, practice, experimentation, trials, and demonstrations of the concepts and teaching practices encountered by preservice teachers during their coursework [10]. From a sociocultural perspective, the practicum is conceptualized as “guided practice within a professional community” [11] (p. x), implying that preservice teachers learn “with and from peers, expert practitioners, and the students they teach” [11] (p. xi).

However, the structure and ways of implementation of teaching practice are also contested in the teacher education literature [6,12,13]. White and Forgasz highlight [6] that “Practicum problems appear (across the international literature) to be long standing and almost universal. These obstacles continue to trouble stakeholders although different terms and descriptions are sometimes attributed to them” (p. 236). For example, learning during the practicum may remain superficial, limited to teaching activities and classroom routines. Resch and Schrittmesser [14] pointed out that the benefits of practice depend on whether reflection and analysis are integral to the learning process. The impact of mere practice differs significantly from deliberate practice, with the latter encouraging the active involvement of preservice teachers to enhance their skills through analysis and reflection.

The questions and dilemmas surrounding the practicum also include its purpose, timing, duration, sequence within the teacher education program, student teachers’ responsibilities, procedures employed to assess preservice teachers’ progress, and suitable contexts, mainly schools [15]. Bacevich et al. [12] emphasize that the exact purpose of the practicum often remains unclear in teacher preparation programs, highlighting the need for more well-defined and effective learning experiences for preservice teachers. Debates also persist regarding the ideal school settings for the practicum. Some advocate for placements in innovative and well-functioning schools [16], while others argue for exposure to a variety of school environments, including those in low socioeconomic areas [6]. We agree that exposing preservice teachers to a range of schools, especially those facing resource constraints or situated in impoverished communities, as is common in South Africa, would be beneficial to prepare preservice teachers for teaching in such schools. However, the dilemma remains that preservice teachers often encounter the same type of teaching in these schools as they experienced as learners, and they are not sufficiently challenged to question prevailing practices in these schools. Thus, the practicum often serves primarily to socialize student teachers into the existing status quo, potentially perpetuating traditional habits and norms, some of which may be undesirable [17].

The challenges associated with the school practicum in South Africa have been well documented. Robinson [18] shed light on various issues faced by schools hosting preservice teachers, including time constraints, increased workloads, and overcrowded classrooms. Gravett and Jiyane’s study [15] further revealed that teachers were often reluctant to mentor preservice teachers, leaving them to fend for themselves. Thus, in South Africa, as is the case internationally, not all school practice opportunities are created equal [16].

Given these challenges, there is a growing urgency to explore alternative avenues for enriching the practice learning experiences of preservice teachers, moving beyond traditional school placements and conventional microteaching. While microteaching is a common practice in preservice teacher education [19,20], it frequently falls short of delivering the intended benefits [21] due to its often contrived nature, especially when fellow preservice teachers participate as learners.

The onset of the pandemic, which severely restricted the placement of preservice teachers in schools, has underscored the need for innovative solutions to enhance the practice learning experiences of preservice teachers. One promising solution is the incorporation of mixed-reality simulation (MRS) as a component of teacher education programs.

With this backdrop, a group of teacher educators at the University of Johannesburg embarked on an exploration of the potential benefits of purposefully using mixed-reality simulation (MRS) to create simulated classroom experiences in order to enhance the practice learning experiences of preservice teachers. The broad aim of this small-scale research was to explore whether MRS could effectively complement traditional school practicum experi-

ences. To achieve this, the research team decided to focus on a core teaching practice during the MRS intervention. Here, we define core teaching practices, following Grossman [22], as identifiable components essential to teaching, grounded in disciplinary goals, which teachers employ to support learning. These practices encompass strategies, routines, and moves that can be deconstructed and learned by teachers.

In the four-year preservice teacher education program involved in this research, we emphasize a dialogic approach to teaching [23]. One of the core teaching practices associated with dialogic teaching is the skillful and meaningful use of questions. Consequently, we chose to concentrate on the aspect of questioning within the MRS intervention.

2. Framing of the Research

Our research is framed by the body of knowledge on the development of expertise [24–28]. We drew on key ideas from this body of knowledge to design the MRS intervention and to inform our research on it.

We argue that practice learning experiences for preservice teachers should not neglect the fostering of routine expertise, which will enable teachers to effectively and confidently apply teaching practices, techniques, and routines [27]. Nevertheless, we agree with Hammerness et al. [29] that, due to the intricate nature of teaching, adaptive expertise should be pursued as the “appropriate gold standard” in teacher education.

Carbonell et al. [26] identified three key facets of adaptive expertise that we believe are important for teacher education and our research. First, adaptive expertise encompasses the foundational elements of routine expertise. Second, it involves heightened metacognitive skills compared with routine expertise. Third, adaptive expertise is characterized by attributes such as flexibility, innovation, commitment to continuous learning, a penchant for tackling challenges, and creativity.

Within the realm of adaptive expertise, metacognitive monitoring plays a pivotal role [30]. Metacognition is closely intertwined with adaptive expertise because it underlies the ability to assess, adapt, and refine one’s thinking and problem-solving skills. The development of metacognitive skills can empower teachers to become more flexible, resourceful, and effective when dealing with intricate and unfamiliar situations—attributes that are fundamental to adaptive experts. In turn, teachers who possess adaptive expertise demonstrate a heightened level of metacognitive awareness. This heightened awareness enables them to continually evaluate their own performance and make necessary adjustments to their assumptions and actions. They engage in metacognitive monitoring as a means to determine when and under what circumstances specific approaches are appropriate, as well as when and why it may be necessary to develop new and innovative approaches [27].

Therefore, we advocate for intentionally structuring practice learning experiences to facilitate the development of both routine expertise and the foundational elements of adaptive expertise. We acknowledge that achieving fully adaptive expertise within the confines of a typical teacher-preparation program’s timeframe is not feasible. However, systematically prioritizing the cultivation of adaptive expertise in preservice teacher education programs can establish a strong foundation for its gradual development over time.

Deliberate practice is a crucial method for fostering adaptive expertise in teacher education [26,27,31]. At its core, deliberate practice involves purposefully engaging in goal-directed activities aimed at improving and consciously elevating current performance levels. This process unfolds within a supportive learning environment, allowing for gradual refinement through repeated rehearsal, complemented by feedback, analysis, and reflection [32,33].

Furthermore, deliberate practice encompasses guidance and feedback from experts who employ effective coaching techniques to assist novices in enhancing their knowledge and skills. In this way, novices can surpass their existing performance thresholds, progressively developing expertise over time [34].

The principles elucidated by Deans for Impact [32] are useful for guiding the implementation of deliberate practice in teacher education. The principles involve introducing

challenges that push preservice teachers slightly beyond their comfort zones; setting clear and specific goals aligned with desired outcomes; focusing practice activities on improving specific aspects of teaching rather than aiming for broad improvement; concentrating on practice activities using, for example, decompositions and approximations of teaching; providing high-quality feedback to novices and requiring them to adjust in response to that feedback; and developing a mental model of expertise related to specific aspects of teaching.

3. MRS in Teacher Education

MRS in teacher education, such as the TeachLivE™ platform that we used, leverages a blend of artificial intelligence and live actors to replicate the dynamics of a real classroom [34,35]. Preservice teachers access these simulations through video platforms like Zoom, enabling them to interact with avatars representing learners in real time. Live actors, referred to as “SIM specialists” or puppeteers, manipulate the behavior of the learner avatars. SIM specialists meticulously prepare for the simulation by acquainting themselves with the diverse personalities of the learner avatars, which reflect the varied personalities and behaviors typically encountered in classrooms [36]. The avatars emulate genuine responses from real children, and they respond to the preservice teachers in real time, adjusting their actions based on the predetermined teaching scenarios provided to them by the teacher educators [34,36–38]. This authenticity enhances the overall experience for preservice teachers [34,37].

MRS provides preservice teachers with opportunities to rehearse core teaching practices and classroom management skills in a controlled environment without any harm to actual learners. Traditional rehearsal methods, such as role playing or microteaching with other preservice teachers or a small group of learners, often lack the capacity for repeated practice until competency is achieved. Moreover, these methods are challenging to implement in an online environment. MRS overcomes these limitations and enables the tracking of preservice teachers’ progress by teacher educators and the preservice teachers themselves through video recordings of sessions. Using MRS in teacher education in this manner allows for authentic experiential learning, enabling preservice teachers to build a repertoire of pedagogical skills before they step into actual classrooms [38,39].

Ersozlu et al. [40] reported that MRS has been extensively utilized in preservice teacher training, spanning over 80 institutions across the USA, Europe, United Arab Emirates (UAE), Malaysia, and Australia. Dede et al. [41] noted the positive impact of MRS on teacher education, highlighting its potential to enhance teaching practices.

Research conducted by the University of Central Florida between 2014 and 2016 demonstrated that MRS effectively improved teaching practices in both mathematics and science [42]. Additionally, Straub et al. [43] found that just four 10 min sessions with MRS significantly enhanced mathematics teachers’ instructional skills and positively influenced science teachers’ professional development. Aguilar and Flores [44] conducted a study that compared preservice teachers exposed to MRS with a control group in a mathematics method course. The treatment group exhibited a 55% increase in the use of productive mathematical talk moves, demonstrating the potential of MRS to enhance instructional skill.

In a time series design study, Dawson and Lingnugaris-Kraft [45] observed that MRS effectively taught preservice teachers classroom management practices, leading to improvements in their delivery of praise and error correction, two crucial aspects for fostering a positive classroom climate.

Dieker et al. [46] conducted a large-scale study in the US focusing on the impact of MRS on high-leverage practices (HLPs) among teachers. This pre–post quasi-experimental study involved over 135 teachers divided into experimental and control groups, and the results indicate that just four 10 min sessions with the mixed-reality simulator increased the use of HLPs, with these skills being effectively applied in real classroom settings. In addition, teachers assigned to the simulator asked a higher percentage of higher-order

thinking questions in their real classrooms compared with those who did not receive the simulator treatment.

In Sweden, Samuelsson et al. [47] conducted a two-year comparative study on different training experiences for preservice teachers, including training with virtual characters, peers, and actual school pupils. The results show that three hours of MRS training was as effective in developing preservice teachers' self-efficacy beliefs in teaching mathematics as three weeks of training with real learners. The effects of virtual intervention also surpassed the development achieved when training with peers.

Small-scale case studies have been conducted in the South African context on MRS in teacher education [48,49]. These case studies have shown the potential of using MRS to support preservice teachers' practice learning.

Feedback after MRS sessions has been identified as a crucial factor in its effectiveness. Reinking and Martin [50] and Cohen et al. [51] reported that real-time feedback and coaching significantly improved teaching skills and preservice teachers' perceptions of learner behavior, as well as their ideas about how to address such behavior.

Bautista and Boone [38] also emphasized the value of feedback with their study showing a substantial increase in efficacy beliefs among preservice teachers. Peer observations and reflections, as highlighted by Bautista and Boone [38] and Samuelsson et al. [46], played a significant role in developing new instructional strategies and classroom management techniques.

Collectively, this body of research underscores the increasing interest in MRS in teacher education and its capacity to enhance preservice teacher education and development across diverse countries. The studies conducted suggest that MRS has evolved into a valuable tool in teacher education, providing preservice teachers with authentic, risk-free teaching experiences in controlled environments.

4. Methods

A qualitative research approach was employed in this study, consistent with the principles for qualitative research outlined by Ravitch and Carl [52]. We wanted to gain insight into how participants construct meaning within a particular context. Specifically, we sought to comprehend how preservice teachers made meaning of their involvement in MRS, which focused on questioning as a core teaching practice, accompanied by coaching sessions, within the context of a preservice teacher education program. The research question that guided the research was as follows: What affordances does the utilization of MRS hold for improving preservice teachers' understanding of and proficiency in utilizing questioning as a core teaching practice?

To address this research question, the researchers selected a sample of 14 final-year preservice teachers at random within the 2022 student cohort who were pursuing a four-year Bachelor of Education degree ($N = 224$). The MRS intervention took place from April to October 2022 and involved preservice teachers delivering planned segments of lessons to learner avatars in the simulator over five cycles. Each cycle comprised two sessions focusing on specific aspects of questioning, such as using questions to elicit and expand upon prior knowledge during the lesson introduction phase. In the first MRS session, each preservice teacher conducted a 5 min lesson segment centered on the cycle's designated focus. During the session, each preservice teacher interacted with the learner avatars who were displayed on a big screen. Each preservice teacher would, for example, begin by greeting the avatars, who would respond like actual learners. Then, the preservice teachers would ask the avatars questions in line with the session's focus. The interactions between the preservice teachers and the learner avatars simulated a real classroom discussion.

While these teaching sessions were ongoing, a teacher educator, acting as the coach, and other preservice teachers serving as observers documented strengths and areas for improvement related to the specific skill being practiced. A brief reflection session was held directly after the MRS session during which the teacher educator (coach) and preservice teachers provided feedback on each student's lesson, which was observed by the rest,

emphasizing strengths and areas for improvement regarding the questioning skill being honed. These sessions allowed for immediate reflection on action. This was followed a week later by a 30 min online coaching session aimed at addressing areas requiring improvement. Preservice teachers then revised the lesson segments and presented them again during the subsequent cycle of MRS sessions, which were always accompanied by coaching. Thus, each lesson segment was presented twice.

Data collection involved various methods, including focus group interviews, stimulated-recall interviews, observations, and video analysis. Interviews were chosen as a means to uncover the lived experiences of the participants in relation to their MRS involvement and the significance they attributed to these experiences [53]. For example, focus group interviews were employed to gain insight into the preservice teachers' perspectives and experiences during the MRS sessions, coupled with coaching, and how these sessions, combined, contributed to the enhancement of their understanding of questions as a core teaching practice and of their questioning skills. In addition, stimulated-recall interviews [54] were conducted with seven participants (using the video recordings of the lesson segments that they taught) at three points during the intervention to understand the reasoning behind the decisions they made while engaging in the MRS sessions. To closely monitor the preservice teachers' performance in employing questioning as a core teaching practice, an observation protocol was used during the MRS sessions, and participants' MRS lessons were recorded on video for subsequent more in-depth analysis using the observation protocol.

Table 1 contains a summary of the data collection methods used, their rationale, collection timeframes, and the participants involved in each.

Table 1. Data collection methods.

Data Source	Rationale	Timeline	Participants
Focus group interviews	Understanding preservice teachers' views and experiences of the MRS sessions, coupled with the coaching sessions, in relation to questioning as a teaching practice	<ul style="list-style-type: none"> • August 2022 (1) • November 2022 (2) • November 2022 (3) 	All participants (n = 14)
Stimulated-recall interviews	Understanding the rationale behind the decisions the preservice teachers made when teaching in the MRS sessions	<ul style="list-style-type: none"> • July 2022 (1) • October 2022 (2) • November 2022 (3) 	Seven participants (n = 7)
Observations Video recordings	Monitoring preservice teachers' progress in using questioning as a teaching practice	<ul style="list-style-type: none"> • April—October 2022 	All participants (n = 14)

To ensure ethical research, the following measures were taken: Ethics approval was obtained from the faculty where the study was conducted (ethics clearance number: 1-2022-041). A clear explanation of the ethics procedure was provided to participants before collecting data, and participants were required to provide informed consent to participate in the research.

For data analysis, we employed the constant comparative method of analysis [55,56]. The process involved the following steps: (1) transcription of interviews, followed by a thorough reading of each transcript to identify provisional categories; (2) coding of transcripts by identifying individual "units of meaning" [56] (p. 28) and assigning a code that encapsulated the essence of each unit; (3) grouping similar units of meaning together within the provisionally identified categories, following the "look/feel-alike" criteria outlined by Maykut and Morehouse [55] (p. 137); (4) creation of new categories when existing provisional categories did not match the semantic units of meaning, which led to the merging of some initial categories while others were discarded; and (5) continuous refinement of categories by establishing inclusion rules, which determined whether to include or exclude codes in the identified categories.

For the analysis of video recordings, an observation protocol was employed, which included specific criteria for each session. We used a rating scale from 1 to 3 to assess

participants' progress in using questioning, providing comments and evidence for each criterion. This allowed us to generate categories that captured the preservice teachers' development in using questioning as a fundamental teaching practice.

After completing the analysis of each dataset, we compared the categories that we had uncovered during the data analysis process to identify similarities and differences. This process enabled us to consolidate the categories and derive the final categories for the study, which are presented in the subsequent section.

Figure 1 provides an overview of the data analysis process.

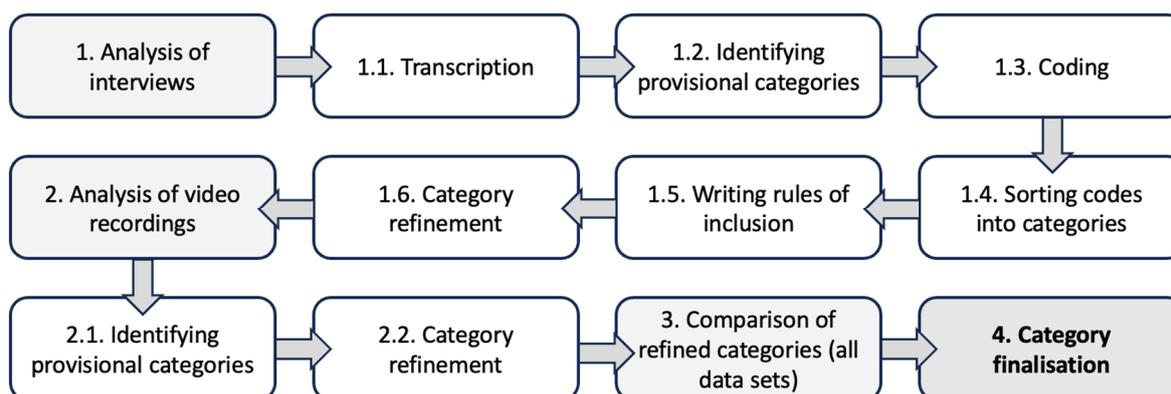


Figure 1. Data analysis process.

5. Results

The data analysis process generated four categories that encapsulate the findings of the study. Though the data excerpts that are presented as evidence for each category draw mainly on interview data, the categories also capture the researchers' observations of the MRS reflection and coaching sessions.

5.1. MRS Created a Beneficial Setting for Preservice Teachers to Purposefully Practice and Refine Specific Questioning Techniques

As previously noted, the MRS intervention aimed to provide preservice teachers with the opportunity to teach lesson segments where they deliberately practiced using questions as a core teaching practice. The data indicate that the MRS intervention was successful in achieving this goal by creating a constructive environment for preservice teachers to purposefully practice and hone questioning techniques. The following excerpts from interviews illustrate this finding:

MRS allowed me to experiment with different questioning techniques, leading to a boost in my confidence as a teacher.

(Focus Group interview 3).

My experience with being involved in the sessions was that I got to realize how we were able to use the theory that we had learned, like how to elicit prior knowledge and to find a way to read a text and make meaning of it and to engage with learners' personal experiences.

(Focus Group interview 1).

Through MRS, I gained confidence in my ability to ask thought-provoking questions to my learners which stimulated their thinking and participation.

(Stimulated Recall interview 3).

The immediate feedback during the simulations helped me see the effectiveness of my questions, which built my confidence in using them to guide my learners in the classroom.

(Focus Group interview 3).

By practicing questioning in MRS, I developed the confidence to create an interactive and engaging learning environment for my future learners.

(Focus Group interview 3).

You learn from what you did, and you always want to improve based on how the lesson goes.

(Focus Group interview 1).

The student teachers learned to use questions to ensure all learners were engaged in the lesson.

(Observation Notes).

5.2. Using MRS Created a Low-Risk, Low-Stress Learning Environment That Was Conducive to Improvement

Interacting with avatars meant that the preservice teachers did not have to worry about causing harm to real children's learning, though it was clear that they soon interacted with the avatar learners as if they were real learners. The data showed evidence that this safe and low-stakes environment, which was simultaneously experienced as authentic, minimized the fear of judgement or making mistakes, which fostered an environment conducive to improvement.

The advantages of practicing without the fear of impacting "real learners" were noted as follows:

When you teach in the MRS sessions, yes, teaching is important, but you can make many mistakes as opposed to doing this with real children. It is only practice. When you make many mistakes with real learners, there's a bigger impact than with the avatars.

(Focus Group interview 1).

I could experiment with different teaching strategies without the fear of making mistakes in front of real learners.

(Stimulated Recall interview 3).

Having a space where you can practice, in a sense, a safe space because technically any mistakes that you could make here are not directly affecting learners.

(Focus Group interview 2).

MRS provided a safe space for me to practice and refine my teaching skills. It made it easy for me to try new approaches without the fear of judgement.

(Focus Group interview 3).

The participants also commented on the authenticity of the MRS in relation to the low-risk environment.

The mixed-reality simulations felt incredibly real, and it allowed me to practice teaching in a safe and controlled environment.

(Stimulated Recall interview 3).

One of the preservice teachers reflected on the learner avatars as follows (Stimulated Recall interview 2):

I think Maria is a very good example of a student who knows a lot but doesn't say a lot. . . she's a very knowledgeable student.

She also reflected on CJ: . . . you never know what to expect when it comes to CJ basically, I also don't know if CJ was put on a different setting because I think I was expecting her to be antagonistic and then she wasn't at all. So that kind of threw me for a loop in a good way. But yeah, that was also unexpected.

She also made a comment on Ed: The reason why I chose Ed is because he's also kind of one of the quieter learners from the class.

5.3. Combining MRS with Coaching Sessions Allowed Preservice Teachers to Pinpoint Areas Where They Lacked Comprehension and Proficiency in Utilizing Questioning as a Core Teaching Practice

The data showed that holding the MRS sessions in conjunction with coaching sessions enabled the preservice teachers to identify gaps in their understanding and application of questioning.

The reflective discussions helped me uncover the strengths and weaknesses of my questioning techniques and provided guidance on how to refine them.

(Focus Group interview 3).

This in turn allowed them to adapt their questioning approach in subsequent sessions, as evidenced by the following quotes:

I feel like in the first session, there were open-ended questions but majority of the questions were closed, but then when we got to the second session, I was able to come up with questions that were more open-ended using the feedback that we got.

(Focus Group interview 1).

The coaching sessions really helped. We realized what we did in the first session did not work. We need to change or adapt and be more structured almost.

(Focus Group interview 1).

The nature of the feedback—positive, encouraging—had a bearing on the value of these sessions and promoted deep reflection:

I think they were very good, in a sense that we got to see the things that we did correctly and wrong. [The coach] did not only focus on the negatives, which could really be discouraging.

(Focus Group interview 2).

The post-MRS reflection sessions encouraged me to think deeply about how I can refine my questions to better support my learners in the classroom.

(Focus Group interview 3).

The coaching is effective. They're encouraging you in new weaknesses and reinforcing your strengths.

(Focus group interview 1).

Evidence for the benefits of the coaching session was observed in the following transcribed exchange between a teacher educator (coach) and preservice teachers:

Teacher Educator: What are one or two things that you would like to specifically focus on this week?

Pre-service teacher 1: I would like to do what I did last week, improve it slightly and try a different strategy. What I did last week was to try to get them to engage in terms of having a discussion. I would like to implement that, but I would like to try something maybe different, maybe a game or something that would also elicit metacognition.

Pre-service teacher 2: One thing that I would like to improve on is the wait time, as you previously articulated, so I would give the learners wait time and give the learners the whole 10 s as I had indicated and also try to probe [learners] further.

Pre-service teacher 3: I think I would like to take other strategies I've seen implemented well by my colleagues and put those into practice, such as reducing the number of questions that I pose and having one or two focal questions, and also try to practice having learners form their own questions.

5.4. Using Coaching Sessions Alongside MRS Sessions Stimulated Both Individual and Collaborative (Group) Reflection with Peers, Leading to Incremental Improvement

It was evident from the data that the preservice teachers felt that though the MRS sessions were valued for the opportunity they afforded them to practice questioning

techniques and reflect in the moment, much of their positive developmental trajectory resulted from purposefully reflecting on their use of questioning in the MRS sessions. This happened mainly during the brief reflection sessions following the teaching sessions and the coaching sessions, with the latter invoking reflection on action and reflection for action intentionally. Evidence for this finding can be seen in the following quotes from the data:

The reflection sessions after each MRS session made me analyze my questioning techniques and think critically about how to improve them.

(Stimulated Recall interview 3).

Engaging in group discussions with fellow student-teachers after the MRS sessions provided a supportive and collaborative learning environment.

(Stimulated Recall interview 3).

Discussing our MRS experiences with peers helped me feel supported and motivated to continually improve my questioning skills.

(Focus Group interview 1).

Sharing our experiences and exchanging ideas with peers helped me gain different perspectives on effective questioning practices.

(Stimulated Recall interview 3).

The collaborative learning environment fostered by MRS allowed us to learn from each other's experiences and support one another.

(Focus Group interview 3).

I never realized how much I could learn from self-reflection and coaching. It transformed how I approach questioning.

(Focus Group Interview 3).

6. Discussion of Findings and Implications for Practice Learning

As previously mentioned, the broad aim of the research was to investigate the potential of MRS to strengthen the practice learning experiences of preservice teachers and consequently to determine whether MRS could effectively complement traditional school practicum experiences.

To achieve this, we focused on the core teaching practice of questioning, and we explored the affordances of utilizing MRS for improving preservice teachers' understanding of and proficiency in utilizing questioning as a core teaching practice. This decision aligned with a principle of deliberate practice, which emphasizes improving a particular aspect of teaching rather than pursuing broad, general enhancement.

The ensuing discussion addresses the benefits that our research revealed regarding the use of MRS in enhancing participants' comprehension of and proficiency in employing questioning as a core teaching practice. We use this discussion as a basis for commenting on the potential of MRS for strengthening the practice learning experiences of preservice teachers in general.

Like the international studies mentioned earlier, our research demonstrated the effectiveness of MRS in providing preservice teachers with a powerful platform to experiment, learn from their mistakes, regroup, and enhance their teaching skills. We aimed to help preservice teachers grasp the significance of asking appropriate questions at various stages of a lesson and to execute these questions purposefully. Both our research team who observed the MRS and coaching sessions and the preservice teachers themselves acknowledged the significant progress that the preservice teachers made through their MRS engagements. Particularly notable was the progress made in areas of metacognitive awareness and monitoring of how they utilized questions, as well as in their improved execution when they taught the avatar learners. Furthermore, our research affirmed the crucial role of feedback and coaching to maximize the benefits of MRS.

The two findings related specifically to MRS underscore its value for facilitating effective practice learning. MRS was shown to offer a low-risk and low-stress environment for preservice teachers to intentionally practice a specific teaching practice, in this case, questioning.

Using MRS in the way that we described above allowed for both decomposing of the practice of teaching and the approximation of teaching practice, which Grossman et al. [56] identified as important ways in which professionals can learn through experimentation and reflection within the controlled environment of the university. In our case, we decomposed practice by focusing on the core teaching practice of questioning.

We utilized MRS as an approximation of teaching practice by affording preservice teachers the opportunity to design and present various components of lessons to learner avatars, closely resembling the activities involved in teaching within an actual school setting. Grossman et al.'s [57] metaphor of "learning to kayak on calm waters" aptly describes the benefits of our MRS usage. It allowed the preservice teachers to navigate challenges related to why and how to use questions during teaching in a controlled environment. It allowed them to experiment, make mistakes, regroup, and reflect, in collaboration with other preservice teachers who observed guidance from a coach. They received support and feedback as they honed their understanding of meaningful questioning and improved their questioning techniques.

Our observations aligned with those reported by Dieker et al. [36], indicating that the immersive nature of the MRS environment led participants to suspend their disbelief, making them feel as if they were interacting in a real-life scenario. Consequently, preservice teachers began to engage with the avatars as if they were genuine learners. The participants in our research noted that the MRS felt "incredibly real", and some preservice teachers spoke about the different personalities of the avatars in relation to classroom learners. One participant even referred to the avatars as "my learners". Therefore, we argue that MRS provides a significantly more authentic and potent approximation of teaching practice compared with other methods, such as analyzing case studies, reviewing video recordings, engaging in role play, or traditional microteaching.

The other two findings suggest that relying solely on MRS as an approximation of practice is not optimal for creating effective practice learning experiences for preservice teachers. While MRS has its benefits as explained earlier, it was combining MRS with the reflection and coaching sessions that significantly enhanced the preservice teachers' learning and development. Similar findings were reported by Cohen et al. [51]. Their study, which employed MRS, showed that candidates who received coaching exhibited significant and substantial improvements in their skills relative to those who only reflected on their teaching. Their study suggested that preservice teachers can make significant teaching skill improvements with coaching, within the university environment, rather than mainly relying on school practicum.

In our study, the reflection and coaching sessions were pivotal in helping preservice teachers to pinpoint their weaknesses and to focus intentionally on improvement. The immediate reflection session following the completion of the MRS teaching, along with the coaching session one week later, proved indispensable. Furthermore, we cannot overemphasize the importance of guided self-reflection and collaborative reflection with peers during these sessions, as they played a crucial role in facilitating improvement.

We believe that the MRS intervention provided a "learningplace" for fostering the early stages of adaptive expertise development. This was primarily achieved through the implementation of deliberate practice. The deliberate practice process that we used entailed focusing on the specific goal of improving a single core teaching practice. Although the student teachers engaged with questioning in a way that built on their prior knowledge, they were pushed just beyond their comfort zones owing to the intentional emphasis on specific questioning techniques and types of questions, which necessitated thoughtful and skillful execution. Their "learning edges" [58] (p. 128) were invoked, which is conducive for stimulating learning and development. Furthermore, they received high-quality feedback

that required them to make adjustments in response, which is crucial for deliberate practice. The process followed also aimed to assist student teachers in constructing mental models or representations [58] of effective teaching, particularly related to questioning. These mental models improved their ability to think critically and logically about the act of questioning, enabling them to monitor and evaluate their own performance and adapt their assumptions and actions accordingly. Continuous learning is an important aspect of adaptive expertise, and students' willingness to seek and receive feedback was evident throughout the intervention.

Essentially, student teachers developed heightened metacognitive awareness. This is particularly evident from preservice teachers' comments on how the reflection and coaching sessions helped them to reflect on and monitor their progress. These comments suggested that apart from reflecting in action during the MRS sessions and making real-time adjustments based on the avatar learner responses, students also engaged in reflection on action [59] inspired by having observed their peers and the feedback provided during coaching sessions. Importantly, they also reflected for action [60], contemplating how they could adapt their teaching in the future. This last form of reflection involves anticipating potential challenges and planning for these. The reflection exhibited by the students is akin to metacognitive awareness and monitoring, which are crucial for the development of adaptive expertise.

The Learning Policy Institute and Turnaround for Children [61] argue that to cultivate adaptive experts capable of effectively applying their knowledge in diverse contexts, teacher preparation programs must teach not only the "how-tos" but also the "whys" and "whens" (p. 14). The MRS intervention did just that.

Our research has demonstrated that MRS as an approximation of teaching practice holds great promise for bolstering practice learning experiences for preservice teachers. MRS is particularly well-suited for the implementation of deliberate practice, and our study offers substantial evidence that the deliberate practice approach we employed yielded positive outcomes. The participants in our research were final-year students in a four-year Bachelor of Education program. Despite them having had a theoretical understanding of the importance of meaningful questioning in teaching and a basic grasp of its application as a core teaching practice, it became evident that they faced a common challenge known as the "enactment dilemma". This challenge manifested in their initial struggle to apply their knowledge of questioning effectively in teaching the avatar learners. However, it appears that combining MRS with coaching effectively addressed this dilemma in relation to questioning as a core teaching practice. Consequently, we can reasonably assert that the process we followed could be equally effective in improving the understanding and implementation of other core teaching practices, e.g., practicing classroom management, which often poses a persistent challenge for novice teachers.

Nonetheless, we realize that the full integration of MRS into preservice teacher education programs, along with coaching, would pose a significant demand in terms of time and resources. To make this feasible for a larger number of preservice teachers, it would be necessary to limit the practice opportunities for each core teaching practice and to distribute these opportunities over the first three years of study. (In the fourth year of study, the preservice teachers carry out the bulk of their school practicum.) However, we are uncertain whether limiting MRS involvement per teaching practice would still yield improvements substantial enough to justify the investment in time and resources. Further research is required to determine the optimal number of simulation sessions and the level of support needed to achieve long-term improvements. We plan to explore this in future research.

In addition, we do not know whether improved enactment within the MRS environment will necessarily transfer to and persist in the real-world context of teaching actual learners in real classrooms. This aspect requires further investigation.

7. Conclusions

Ensuring effective practice learning experiences for preservice teachers is crucial. Currently, these experiences are primarily delivered through school practicum. However, school practicum often presents challenges. Moreover, the dilemma of over-reliance on school practicum to provide practice learning experiences for preservice teachers became especially evident during the COVID-19 pandemic, when school placement for preservice teachers was restricted or not possible at all.

Our research interest pivoted around whether MRS presents a viable pathway to strengthen the practice learning experiences of preservice teachers and, consequently, whether MRS could effectively complement traditional school practicum experiences. Our findings showed that MRS as an approximation of teaching practice offers significant potential for expanding and strengthening the practice learning experiences for preservice teachers. The affordances of MRS include that it facilitates a low-risk, low-stress learning environment which is experienced by student teachers as authentic. This allows for creating of a learning environment that is conducive to implementing deliberate practice, a key element for nurturing adaptive expertise. Our research findings also underscore the importance of coaching for maximizing the benefits of MRS. The absence of coaching will most likely limit the benefits of MRS as an approximation of teaching practice.

Due to the limited scope of our research, we were unable to fully determine the practicality of implementing MRS on a larger scale, given the resource-intensive nature of such an endeavor. Further investigation would be necessary to explore the feasibility of integrating MRS into preservice teacher education more comprehensively.

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