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Real-Time Pedagogical Decision-Making of Simulation Specialists in Mixed Reality Teacher Education

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Abstract. Pre-service teachers generally lack the skills, confidence, and professional judgement required to navigate the complexities of classroom practice (Loughran, 2019). This study examines how simulation specialists make real-time pedagogical decisions during Mixed Reality Simulation (MRS) sessions and how these decisions shape pre-service teachers' pedagogical content knowledge (PCK) development. Guided by the Teacher Thoughts and Action Processes (TTAP) model and the Theory of Planned Behaviour (TPB), the study adopts a qualitative design involving eleven Simulation specialists. Data were generated through live observations of simulation sessions, stimulated recall interviews and focus group discussions. Thematic analysis revealed that simulation specialists' real-time decisions are driven by four primary factors: (1) observable gaps in pre-service teachers' PCK, particularly in content representation and instructional strategies; (2) minimal learner engagement within the simulation; (3) emerging classroom management difficulties; and (4) misalignment between instructional resources and lesson objectives. Specialists responded to these cues through immediate pedagogical adjustments, including scaffolding questioning techniques, redirecting instructional focus and modifying the level of challenge presented in the simulation. This study contributes to the field by providing empirically grounded insight into how simulation specialists interpret and respond to dynamic classroom interactions in real-time. These findings highlight the importance of targeted professional development that strengthens simulation specialists' diagnostic and responsive decision-making to better support PCK development in simulation-based teacher education.

Keywords: mixed reality simulation, simulation specialists, real-time pedagogical decisions, pedagogical content knowledge, pre-service teacher education.

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1. Introduction

Integrating MRS in teacher education has become an essential practice for preparing pre-service teachers to engage confidently with the complexities of real classroom environments, enabling them to refine and practice their pedagogical strategies in a controlled setting (Nzuza, 2025). Within these environments, simulation specialists facilitate and guide these experiences in real-time by adjusting their pedagogical decisions in response to pre-service teachers' instructional moves. To achieve this, they design and manage realistic, goal-oriented scenarios aligned with specific learning outcomes (Larson et al., 2020). Their capacity to make immediate pedagogical judgments is central to the effectiveness of MRS, as they continually interpret pre-service teachers' instructional actions and adjust the flow of the simulation to sustain meaningful and targeted learning opportunities.

Several studies have shown that MRS has gained prominence for its capacity to create immersive and interactive educational experiences (Dalinger et al., 2020; Freeman, Lee & Barsh, 2024). By bridging the gap between theory and practice, MRS technology enables simulation specialists to respond dynamically to emerging teaching situations, interpret pre-service teachers' pedagogical choices, and make immediate instructional adjustments that shape the direction and depth of the learning experience (Sullamo et al., 2023). Through real-time decision-making, they facilitate authentic classroom experiences within simulated environments, supporting pre-service teachers in addressing gaps in their PCK (Nygren et al., 2024).

During the simulations, Ireland (2021) highlights that simulation specialists manage avatars to facilitate dynamic and realistic interactions. As such, by responding in real time to pre-service teachers' actions and choices, they create meaningful dialogue and challenging scenarios that promote active learning (Lindgren et al., 2016). Their responsibilities include controlling the movements and voices of digital avatars, thereby bringing educational scenarios to life and accurately reflecting the complexities of real classrooms (Ke & Xu, 2020; Ireland, 2021). Through this adaptive approach, simulation specialists ensure that each scenario aligns with the intended learning objectives and mirrors the challenges pre-service teachers encounter in authentic teaching environments (Rosati-Peterson et al., 2021).

Despite these promising developments, there remains a need for empirical research to examine how simulation specialists utilise their real-time decision-making during micro-lesson interactions with pre-service teachers to support PCK development. These decisions are essential to support pre-service teachers in developing effective PCK as they make adaptive, real-time decisions that shape authentic classroom interactions. Most existing studies have examined the role of simulation specialists in supporting pre-service teachers' PCK development, yet there is limited understanding of the factors that influence their real-time decision-making (Dalinger et al., 2020; Rokhsaritalemi et al., 2020). This gap limits our understanding of how these adaptive choices directly impact pre-service

teachers' ability to integrate content and pedagogy effectively during the simulations.

As such, this study addresses this gap by investigating the factors that shape simulation specialists' decisions during micro-lesson interactions with pre-service teachers to enhance PCK development. Specifically, it explores pedagogical factors that shape simulation specialists' real-time decisions and their responses to pre-service teachers' pedagogical choices to optimise PCK development.

By doing so, the research contributes to a broader understanding of the design and implementation of MRS in teacher education and offers strategies to enhance PCK through adaptive, real-time pedagogical support. It further expands our understanding of the decision-making processes of simulation specialists, an area that remains relatively underexplored in teacher education. It contributes to these theories by exploring how simulation specialists manage the proximal processes of teaching-learning interactions with pre-service teachers in relation to the construct of PCK. The following research questions guide the study:

1. What factors influence simulation specialists' real-time pedagogical decisions during micro-lesson simulations?
2. How do simulation specialists enact pedagogical content knowledge (PCK) in their real-time instructional responses within micro-lesson simulations?

1.1 Research problem

Mixed Reality Simulation (MRS) teaching environments require simulation specialists to navigate complex, dynamic scenarios and make rapid, informed adjustments to facilitate effective learning (Lindgren et al., 2016). Despite the crucial role of these real-time decisions in shaping instructional outcomes, the specific strategies and decision-making processes employed by simulation specialists during interactive sessions remain underexplored, given the limited research on the factors influencing their real-time decision-making. This gap in research limits the understanding of how specialists respond to evolving classroom dynamics and address learner needs in simulated contexts. Addressing this gap is essential for enhancing the effectiveness of simulation-based learning and ensuring that teacher preparation programs fully leverage the potential of MRS technology (Morelli, Casagrande & Forte, 2022).

Despite the recognised potential of integrating Mixed Reality Simulation (MRS) in teacher education, there remains a need to better understand how simulation specialists make and enact pedagogical decisions during these interactions. While Nygren et al. (2024) highlight the potential of feedback in simulation environments, the role of specialist expertise remains critical in addressing complex instructional situations. Examining these decision-making processes is important for strengthening the effectiveness of simulation-based learning and preparing pre-service teachers for diverse classroom contexts. A clearer understanding of these dynamics can help optimise the use of MRS in teacher education.

1.2 Significance of the study

This study makes significant contributions to the field of educational technology adoption, particularly within the context of MRS in teacher education, by providing empirically grounded insights into how simulation specialists make real-time pedagogical decisions. Specifically, it identifies key decision-making factors, including PCK gaps, patterns of learner engagement, and misalignment between teaching resources and lesson objectives. In addition, the study demonstrates how these initiations prompt specific forms of pedagogical responsiveness, such as scaffolding questioning techniques, redirecting instructional focus, modelling alternative teaching strategies, and adjusting the level of challenge through avatar interactions. In doing so, the study extends existing understanding of teacher decision-making by showing that simulation specialists' actions are not only reactive but are shaped by ongoing interpretations of pedagogical practices and professional pedagogical judgement.

2. Literature review

2.1 Mixed reality simulation as a practice tool in teacher education

Several studies describe MRS as a valuable tool in teacher education, offering a dynamic and immersive environment for pre-service teachers to develop their PCK (Aguayo & Eames, 2023; Dalinger et al., 2020). Recent research underscores the pedagogical value of MRS, highlighting its capacity to provide pre-service teachers with highly interactive and engaging learning experiences, as well as opportunities to develop and refine teaching skills within a safe, low-stakes context (Freeman, Lee & Barsh, 2024). Through MRS, pre-service teachers can engage in real-time interactions with avatars representing students (Gravett et al., 2023; Rosati-Peterson et al., 2021), thereby rehearsing core instructional practices and classroom management strategies in a controlled environment.

During the simulation, pre-service teachers use video platforms such as Zoom to interact in real time with avatars representing learners. Peterson (2005) describes avatars as "online manifestations of self in a virtual world, designed to enhance interaction in a virtual space" (p. 30). Similarly, Deuchar and Nodder (2003) explain that avatars allow users to adopt a visible persona within a virtual environment, enabling them to engage in surreal and imaginative experiences that extend beyond the physical world. Bautista and Boone (2015) found that these avatars replicate authentic student responses and adapt their behaviours in response to predefined instructional scenarios created by teacher educators. These avatars are managed by simulation specialists through the TeachLivE™ system, which delivers a personalised and targeted learning experience by presenting life-size, computer-generated students and parent/teacher avatars in a realistic classroom setting, all controlled by a human operator (Dieker et al., 2014).

2.2 The role of simulation specialists in Mixed Reality Environments

Simulation specialists play a crucial role in MRS environments by ensuring that interactions between avatars and pre-service teachers are authentic and pedagogically meaningful. Dieker et al. (2014) note that these specialists prepare for sessions by familiarising themselves with the diverse personalities of learner avatars, which mirror the varied behaviours commonly found in real classrooms.

According to Dalinger et al. (2020), these specialists help align simulation activities with educational objectives and offer guidance on the skills, content knowledge, and competencies that pre-service teachers need to develop. This was supported by Lindgren et al. (2016), who highlight that simulation specialists not only support teacher development but also provide insights into areas where pre-service teachers require additional assistance.

Beyond preparation, simulation specialists are also responsible for designing and managing realistic environments aligned with specific learning goals (Larson et al., 2020). Their ability to make real-time decisions is essential for the success of these simulations, as they continuously respond to pre-service teachers' actions and adapt scenarios accordingly. This role requires not only a strong understanding of the technological tools that support simulations but also a deep knowledge of pedagogical principles that underpin effective teaching (Wernick, 2023). Through informed decision-making during simulations, they help pre-service teachers navigate complex teaching situations and support the constructive, meaningful development of their PCK.

2.3 Factors influencing real-time decisions during classroom interactions

Existing research consistently shows that real-time decision-making is essential to shaping classroom interactions, as it enables teachers to respond dynamically to students' needs, fostering a more engaged and adaptive learning environment. Studies suggest that teachers rely on observable cues such as learner engagement, behavioural responses, and conceptual misunderstandings to make immediate instructional adjustments (Griffith et al., 2015; Jasien & Amick, 2022). However, little is known about how these decisions are enacted within simulated teaching contexts, where interaction is mediated through avatar behaviour and technological systems.

An earlier study by Eggleston (2018), emphasised that real-time decisions are essential in classroom practices as they permit teachers to adjust their pedagogical strategies based on student behaviour, level of engagement and confusion due to misunderstanding of content. Teachers adjust their instructional strategies in response to other students' misbehaviour and accommodate those who are losing interest and disrupting others due to content misunderstandings (Griffith, 2017). However, this body of research predominantly focused on teachers, with limited attention given to simulation specialists operating within the MRS environment. This gap is essential to this study, as simulation specialists play a key role in shaping and interpreting pedagogical interactions through avatar-mediated responses.

2.4 The significance of real-time decision-making in classroom interactions

Real-time decision-making during interactive lessons plays a crucial role in fostering a dynamic and responsive learning environment, which ultimately enhances the effectiveness of teaching and learning (Kourti & Potari, 2024). According to Griffith (2017), such decisions guide teachers in shaping their pedagogical approaches and instructional strategies, enabling them to make informed choices in the classroom. This capacity allows teachers to navigate classroom interactions effectively, address individual student needs, and optimise

learning outcomes. As such, simulation specialists' real-time decision-making is crucial in facilitating micro-lesson interactions that promote pre-service teachers' development of PCK, as these decisions directly influence the quality of instructional support and the effectiveness of teacher preparation.

Research by Davis et al. (2019) demonstrates that during the lesson interactions, teachers utilise real-time decision-making to promote word-solving strategies, assess and extend students' knowledge, and reinforce learning through praise and prompts. Similarly, Kooloos et al. (2022b) highlight the significance of managing classroom dynamics and applying these principles to respond promptly to students' immediate needs within an active learning environment. Furthermore, Kourti and Potari (2024) stress that these practices are essential for engaging students during lessons, fostering critical thinking, and supporting the collaborative construction of subject content.

According to Griffith (2017), teachers' decision-making process in the moment is guided by two concepts, "what goes in teachers' minds and what happens around them." All these concepts occur in classroom conversations in which teachers engage with students to prioritise their needs, interests, and learning styles, ensuring that instruction aligns with learning objectives (Kourti & Potari, 2024). Figure 1 displays the model of a teacher's decision-making during student interactions (Kooloos et al., 2022a).

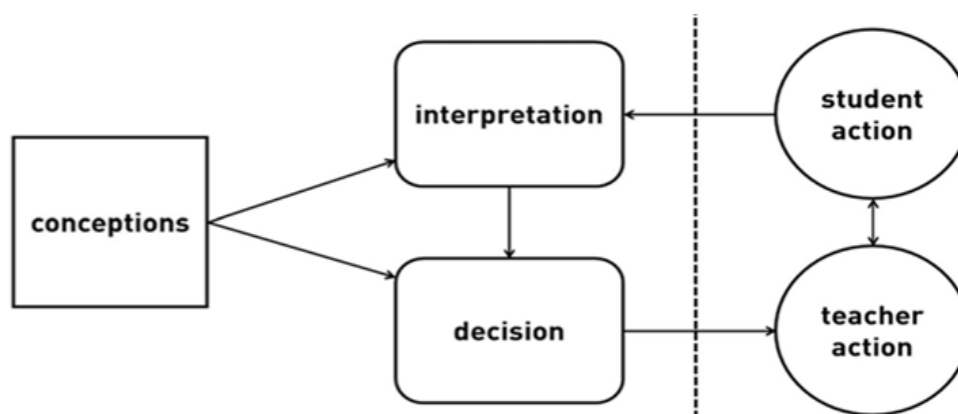


Figure 1: Teacher's decision-making model during student interactions (Kooloos et al., 2022a)

2.5 Mixed reality lab

Within MRS lab, the Mursion® with objects like whiteboards, books, and desks, resembles an elementary, middle, or high school classroom, creating a space for pre-service teachers that feels authentic as they begin to engage with realistic teaching scenarios (Dieker et al., 2014). As shown in Figure 1, a broad set of student avatars, representing a variety of personality types and knowledge levels, are seated at a desk and may display behaviours based on the simulation's goals (Dieker et al., 2014). What makes this environment particularly valuable is how simulation specialists through avatars create a space that feels both realistic and supportive, allowing pre-service teachers to practise managing classroom interactions without the high stakes of a real classroom. These avatars respond in

real-time to instructional approaches, questioning strategies, and behaviour management techniques. In platforms such as TeachLivE, the avatars mimic authentic learner responses, enabling pre-service teachers to engage in realistic teaching scenarios and adjust their teaching strategies based on avatars' immediate feedback (Lindgren et al., 2016; Bautista & Boone, 2015).

As such, this immersive experience enables simulation specialists to observe and analyse how pre-service teachers navigate different situations, identifying both strengths and areas for development. In some cases, pre-service teachers may also embody avatars themselves, interacting within the simulated environment to deepen their understanding of classroom dynamics and presence (Dieker et al., 2014; McPherson et al., 2011). Figure 2 shows the virtual classroom with avatar learners in simulation lab (Mursion, Inc., 2009b).



Figure 2: Virtual classroom with avatar learners in simulation lab (Mursion, Inc., 2009b)

The avatars represented a range of personas within the escalation cycle scenario, as shown in Table 1. Through these personas, simulation specialists were able to recognise and respond appropriately to pre-service teachers' different stages of behavioural escalation in a structured and supportive setting. The avatars could think about and respond to questions, engage in a discussion with their peers, individually respond to questions and use gestures such as raising or moving their hands and arms. However, their actions were limited, they could not complete worksheets/activities, get up and move around, respond as a group, work with manipulatives or 'hands-on' resources and throw objects. Table 1 provide avatars personas.

Table 1: Avatar Personas

LEARNER PICTURE	NAME	ABOUT AVATAR
	DEV	Dev is a quiet, reserved learner with a sharp analytical mind. He often takes longer to speak up, preferring to observe first and speak when he has fully formed ideas. He can excel in problem-solving but may miss opportunities in fast-paced discussions. To draw Dev into the conversation, a teacher might invite him with a specific question that taps his strengths, “Dev, how would you approach this challenge?” and then allow a moment for him to gather his thoughts before expecting a response.
	JASMINE	Jasmine is an average learner known for her calm, cooperative attitude. She listens attentively and contributes steady, well-reasoned comments when asked. She doesn’t seek the spotlight, but she won’t shy away from responsibility if given a clear role. However, she can struggle to engage when tasks lack structure or purpose. A teacher can help Savannah by clearly outlining each student’s contribution and checking in regularly, ensuring she feels confident about her part and motivated to join in.
	SAVANNAH	Savannah is an average learner who brings bold opinions into every discussion and isn’t afraid to question what she’s told. She values independence and prefers to find her own path through a task rather than follow a set procedure. When directions feel too rigid, she pushes back verbally and may withdraw her effort. To work with Savannah, a teacher can invite her to propose alternative approaches and then guide her to align those ideas with the lesson goals, showing her that collaboration can strengthen her innovative solutions.
	ETHAN	Ethan is an energetic, extroverted learner who thrives on lively debate and sharing his thoughts. He jumps into discussions eagerly but may struggle when the topic shifts quickly or when peers need time to reflect. His enthusiasm can dominate smaller groups if unchecked. A teacher can channel Ethan’s energy by giving him brief speaking turn “Ethan, you have one minute to explain” and then directing a question to someone else, helping him learn to balance his strong participation with listening to others.

	HARRISON	Harrison is a high-achieving learner who strives for perfection and approaches every assignment with meticulous care. He prefers to think things through alone before sharing, and he may stay quiet in group work until he is certain of his answer. If feedback is not delivered carefully, he worries he is underperforming and can become hesitant to participate further. To support Harrison, a teacher can set clear checkpoints, “You’re right on track; now let’s build on that” and offer brief, positive affirmations that help him balance precision with participation.
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2.6 Theoretical framework

This study is grounded in the theoretical construct of the Teacher Thoughts and Action Process (TTAP), developed by Clarke and Peterson (1978) and the Theory of Planned Behaviour (TPB), proposed by Ajzen (1985). TTAP emphasises the significance of teacher planning, interactive thoughts, decisions, and the underlying theories and beliefs that inform teachers’ actions. The TTAP model assumes that teaching is a complex cognitive process in which teachers continuously engage in cycles of planning, interactive thinking, decision-making, and action.

Central to this model is the idea that teachers’ real-time decisions are shaped by their interpretations of classroom events and their underlying beliefs about teaching and learning. This assumption is particularly relevant to the present study, as simulation specialists are required to observe, interpret, and respond to pre-service teachers’ instructional practices in real-time within MRS environments. Prior studies have applied TTAP to explain how teachers’ thought processes influence instructional choices and classroom interactions (Peterson & Clark, 1986; den Brok, 2001), demonstrating its validity in capturing the dynamic nature of teaching practice.

Within the context of this study, TTAP provides a useful framework for understanding how simulation specialists identify pedagogical cues such as content gaps, learner disengagement, and classroom disruptions and translate these observations into immediate instructional actions through avatar behaviour and pedagogical prompts. It therefore enables an analysis of decision-making as a continuous and context-sensitive process rather than a set of isolated responses. In contrast, the TPB model offers a complementary perspective by focusing on the factors that influence individuals’ intentions and actions.

Emerging from limitations in earlier action-based theories, TPB addresses the gap in explaining how behavioural intentions are formed and enacted. It assumes that behaviour is shaped by three key components: attitudes towards the behaviour, subjective norms, and perceived behavioural control (Ajzen, 1985). These assumptions are particularly relevant to simulation specialists, whose decisions are influenced not only by immediate classroom conditions but also by their beliefs about effective teaching, professional expectations, and their perceived

ability to manage complex instructional situations. Previous studies have utilised TPB to explain behaviour in educational and professional contexts, particularly in understanding how individuals translate intentions into action (Cameron et al., 2012; Trabelsi et al., 2023). In this study, TPB helps explain why simulation specialists enact specific pedagogical responses, such as using avatar questioning, signalling disengagement, or introducing controlled disruption, as these actions reflect intentional, belief-driven practices.

These two models provide a comprehensive framework for examining simulation specialists' real-time decision-making. While TTAP explains how decisions are formed through cognitive interpretation of classroom interactions, TPB accounts for the motivational and intentional factors that shape these decisions. The integration of these theories is therefore essential for understanding how simulation specialists interpret instructional situations, make pedagogical judgements, and enact responsive teaching strategies within MRS environments.

3. Research methodology

3.1 Research design

This study employed a qualitative research approach, consistent with Creswell et al.'s (2007) principles, which emphasise the exploration of participants' experiences within their natural context, the use of multiple data sources, and the development of in-depth, context-rich understandings of complex social phenomena. Specifically, it adopted a qualitative case study design to explore how simulation specialists enact their real-time pedagogical decision-making during MRS micro-lesson interactions with pre-service teachers. This design was appropriate as it enabled an in-depth examination of decision-making processes within a real-life simulation context, drawing on multiple data sources. It facilitated a comprehensive understanding of the dynamic nature of teaching and learning in simulated environments, as well as the complex and context-sensitive ways in which simulation specialists interpret and respond to instructional situations in real time.

3.2 Research setting and participants

The research was conducted at a selected comprehensive university in Gauteng, South Africa, characterised by limited digital infrastructure and limited access to MRS equipment. This university offers Postgraduate Certificate in Education (PGCE) in Senior and Further Education Teaching (FET), in various disciplines such as Languages, Commerce, Arts and Culture for the Senior Phase, and Design Arts for the Further Education and Training (FET) Phase, as well as Science and Mathematics for the senior and FET phase.

Participants were selected through purposive sampling based on specific inclusion criteria aligned with the study's objectives (Magnone & Yeziarski, 2024). Selected participants were required to (1) be actively involved as simulation specialists in Mixed Reality Simulation (MRS) sessions, (2) have prior experience facilitating micro-lesson interactions with pre-service teachers, and (3) possess a background in teacher education or related pedagogical training. Those without the required subject-specific PCK aligned with the PGCE offered were not

considered. These criteria ensured that participants had the relevant expertise and experience to make informed real-time pedagogical decisions within MRS environments.

The selected participants represented diverse cultural and racial backgrounds and brought varied experiences in teacher education. Simulation specialists with extensive experience were selected to participate in this study; six were female, and five were male. Nine of these participants identified as African, while the remaining two identified as Coloured, and all speak English as the language of instruction. These participants were aged 26 to 33 years, representing a diverse group of early-career professionals with substantial exposure to teacher education and MRS practice. The sample of 11 participants provided ample opportunity for the researchers to engage individually with each simulator specialist and gather rich data for analysis.

These specialists underwent MRS training to acquire the knowledge, skills, and experience necessary for enhancing their teaching practice during micro-lessons. The selected participants hold an education qualification at NQF level 9 and understand the pedagogical needs of PGCE pre-service teachers, as well as the process of PCK development. This ensured that they possessed the advanced academic grounding, pedagogical expertise, and contextual understanding necessary to make informed, adaptive decisions during the MRS micro-lesson interactions.

A total of nine participants had three or more years of tutoring experience within their subject methodologies. In contrast, only one participant had two years of classroom teaching experience, and none reported more than two years. These experiences enabled them to recognise and respond effectively to the unique pedagogical needs of each pre-service teacher during their MRS micro lessons. The participants were assigned pseudonyms from P1 to P11 for easier coding process. Table 2 provides the participants' biographic information in terms of gender, teacher education experience, qualifications and methodology specialisation.

Table 2: Participants biographic information

PARTICIPANT	GENDER	EXPERIENCE	QUALIFICATION ENROLLED	SUBJECT AREA
P1	Male	Three years' experience as a tutor and one year as a teacher	Master's degree in education	Mathematics
P2	Male	Two years' experience as a tutor	Master's degree in education	Afrikaans
P3	Female	Four years of experience as a tutor and student assistant	Master's degree in education	English and IsiZulu
P4	Female	Four years' experience as a tutor and one year's experience as a teacher	Master's degree in education	Accounting, Economics, Business Studies, and Management Sciences
P5	Female	Three years' experience as an assistant lecturer, one year of teacher experience and three years of tutor experience	Doctor of Philosophy in Education (PHD)	Design Arts and Economics and Management Science
P6	Female	Four years of experience as a tutor and one year of experience as a teacher	Master's degree in education	IsiZulu
P7	Female	Four years' experience as a tutor and two years as an instructional designer	Master's degree in education	English
P8	Male	Two years' experience as an assistant lecturer, one year of teacher experience and three years of tutor experience	Doctor of Philosophy in Education (PhD.)	Life Sciences, Physical Sciences and Geography

P9	Male	Four years of tutoring experience and two years of teacher experience	Master's degree in education	Northern-Sotho
P10	Male	Two years' experience as a tutor and one year as a teacher.	Master's degree in education	Life Orientation
P11	Female	Three years' experience as a senior tutor	Master's degree in education	History

3.3 Data collection

This study employed multiple data collection methods to explore simulation specialists' perceptions, decision-making processes, and pedagogical practices within MRS. Firstly, focus group discussions were used to capture simulation specialists' collective perceptions. According to Mendelson (2022), this data collection method provides a platform for simulation specialists to discuss their experiences and identify their pedagogical practices within MRS. Secondly, stimulated recall interviews were employed to investigate the rationale behind simulation specialists' decision-making during MRS sessions. Dempsey (2010) revealed that this technique involves presenting audio or audiovisual recordings of participants' behaviours in social contexts and discussing various aspects of those recorded interactions.

As such, participants were able to reflect on their decision-making processes concerning their actions and behaviours while reviewing their recorded lessons. Lastly, micro lesson video recordings were used to capture live learning during MRS sessions. These videos provide good conditions for analysing patterns in specialists' decision-making, as well as their avatars and attitudes towards feedback, which makes it easier to investigate case practices more deeply (Kelley et al., 2024). During the data collection, my role as a researcher was non-participant during the focus group and video-stimulated recall interviews (Flick, 2018). I ensured that I did not influence events during data interviews. Keeping these interviews natural allowed participants to freely discuss their perspectives and experiences. As such, I adhered to specific interview guidelines, such as informing participants of what was required and reminding them of the purpose of the interviews. Table 3 summarises the data collection methods employed, their rationale, and timeline.

Table 3: Summary of data collection methods

DATA SOURCE	RATIONAL	TIMELINE	PARTICIPANTS
40 MRS video recordings	To capture live learning involving pre-service teachers and simulation specialists during MRS sessions.	May 2025- August 2025	All participants (n=11)
22 Stimulated-recall interviews	To enable simulation specialists to reflect on their decision-making processes concerning their actions and behaviours while reviewing their recorded lessons	September 2025	All participants (n=11)
Two Focus group interviews	To capture simulation specialists' views, perceptions, and interactions with MRS micro-lessons involving pre-service teachers.	October 2025	All participants (n=11)

3.4 Data analysis

Data were transcribed and analysed using a thematic analysis approach after being collected through video recordings, focus group discussions and stimulated-recall interviews. Braun and Clarke (2006) describe thematic analysis as a process involving identifying, analysing, and reporting patterns or themes within the data. The process involved the following steps: (1) the analyses began with the familiarisation phase, where all data sets were read multiple times to gain an understanding of the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining themes and (6) producing a report. This approach allowed for data to be coded and clustered to develop various themes, meaning it was labelled and organised to allow certain themes to crystallise (Nowell et al., 2017). To facilitate the analysis process, ATLAS.ti software was used to manage and organise the data systematically. The software supported the coding process by enabling the researcher to assign codes to segments of text, and group related codes into categories.

3.5 Trustworthiness of the study

To ensure the study's trustworthiness, several measures were utilised in line with qualitative research criteria. To ensure the study's credibility, the researcher used multiple data sources (e.g., focus group interviews, micro-lesson video recordings and stimulated recall interviews) to corroborate findings. This enabled the study to cross-verify findings across different data sets. To strengthen transferability, the researcher provided rich, detailed descriptions and incorporated participants' own voices where appropriate. In addition, the transcripts and audio recordings were revisited to ensure that participants' views were captured accurately and to enable careful comparison of insights across the various data sources.

3.6 Ethical considerations

Ethical clearance and institutional permission (gatekeeper approval) were obtained prior to the commencement of the study, authorising the research to be conducted in accordance with the university's regulations and protocols (certificate number SEM 1- 2025-082). The participants were fully informed about the study's purpose, procedure and potential risks prior to data collection. This includes confidentiality, which was rigorously maintained by anonymising participants' information and securely storing data to prevent unauthorised access. This was essential in ensuring that participants' identities remain undisclosed. Additionally, participation was entirely voluntary, with no coercion or undue influence exerted on pre-service teachers. This adherence to ethical protocols reinforced the integrity and trustworthiness of the research process. As such, the study prioritised minimising harm, ensuring that any discomfort was addressed and that MRS specialists' well-being was safeguarded throughout the study process.

4. Results

The findings from this study suggest that simulation specialists' real-time decisions during the MRS microlessons are influenced by factors such as pre-service teachers' gaps in pedagogical knowledge, gaps in teacher content knowledge, limited learner engagement, and inadequate classroom management skills. These factors shaped how simulation specialists adapted scenarios, adjusted learner responses, and scaffolded instructional interactions within the MRS environment. These key themes are presented in the following sections below.

4.1 Theme 1: Pre-service teachers' pedagogical knowledge gaps

Simulation specialists' real-time decision-making was shaped by the pedagogical gaps and appropriateness of instructional resources used during micro-lessons. These decisions were guided by the simulation specialists' ability to identify areas where pre-service teachers struggled with PCK during micro-lessons. Key challenges included difficulty eliciting learners' prior knowledge, an overemphasis on content delivery that led to cognitive overload, insufficient scaffolding, failure to simplify complex concepts, and a predominant reliance on teacher-centred instructional approaches. The following excerpts below illustrate participants' views on pre-service teachers' difficulties in eliciting learners' prior knowledge:

"The lesson was about the distance formula for Grade 10. The introduction was interesting; however, the pre-service teacher did not check what students knew about the distance formula, and he missed the learners' prior knowledge. That's when I applied my real-time decisions to stop and alert the pre-service teacher that prior knowledge was missing." (P1)

Another simulation specialist explained how she made her real-time decisions based on pre-service teachers' overemphasis on content delivery that resulted in cognitive overload. She explained:

"In other sessions, the pre-service teachers would have an overload of information about inhlolokhono (interviews) on the slides. This made me

use Savanna as a bold avatar to pause the pre-service teacher, requiring more explanation because avatars like Dev and Jasmine, who are considered average students, were not just confused, but they were lost because there was no flow." (P6)

Other participants emphasised that some pre-service teachers struggled to break down complex concepts into manageable steps that learners can understand. They explained:

"In the IsiZulu lesson, the pre-service teacher failed to scaffold some of the terminologies, like inani lemigqa (the number of lines in poetry). The pre-service teachers could not explain and simplify this when teaching IsiZulu poetry. He could not simply explain some of the concepts which were asked by Savanna." (P3)

Pre-service teachers' pedagogical gaps were also evident in the study, as they over-relied on teacher-centred instructional approaches. Participants highlighted that some pre-service teachers used direct instruction, while others did not interact with avatars. This hindered the avatar's ability to engage and participate, as they felt excluded. Participants shared their views:

"The teacher was not engaging, hence there was confusion between Ethan and Dev. The pre-service teacher's teaching strategy was more teacher centred. Using Ethan's confused facial expression, I wanted these pre-service teachers to note that some avatars are not following at all." (P4)

"Teaching skills from these pre-service teachers were not effective at all. Their teaching was exclusive because it was more teacher centred. To address this, I used Savanna to force engagement by asking questions even though she was ignored. This shows me that they didn't have the pedagogical skills to adapt to students' needs and to make content meaningful. Even Ethan, who initially showed interest, began to withdraw. The teacher never bothered to re-engage them." (P10)

These findings demonstrate how simulation specialists provided pre-service teachers with an opportunity to practice and refine their teaching strategies. They demonstrate a form of pedagogical judgement in which specialists rapidly diagnose pedagogical gaps and enact targeted interventions to support improvement. This finding was supported by Dalinger et al. (2020), who highlighted that simulation specialists offer pre-service teachers an opportunity to rehearse their teaching skills before entering the field with natural students. Similarly, Griffith et al. (2015) support this finding, highlighting that real-time decision-making during classroom interactions can help pre-service teachers adjust their teaching approach and ensure their teaching meets students' needs.

4.2 Theme 2: Gaps in teacher content knowledge

This study found that simulation specialists' real-time decision-making was influenced by their identification of gaps in pre-service teachers' content knowledge during micro-lesson interactions. They noticed that some pre-service teachers used acronyms without sufficient explanation, provided vague or incomplete explanations of content, and relied on examples that were either

irrelevant or lacked real-world context. The following excerpts below illustrate participants' views on pre-service teachers' gaps in content knowledge:

"During the EMS lesson, several EMS pre-service teachers used acronyms such as Folio, CRR, CRJ, and CPJ even though these concepts were being introduced to the learners for the first time. Many of the pre-service teachers were unable to explain the abbreviations themselves. Some did not even know the meaning of "folio," which made it clear they lacked foundational knowledge of the topic. Avatar like Harrison, who is highly attentive, asked for the meanings of these acronyms and requested a deeper explanation. However, some pre-service teachers were unable to provide clear or accurate responses." (P5)

Similarly, another participant highlighted how gaps in content knowledge became evident when pre-service teachers were required to elaborate on key concepts. They explained:

"Some pre-service teachers demonstrate gaps in content knowledge, particularly when required to provide detailed explanations during Mathematics sessions. In such cases, I used Ethan as a vocal avatar to pose questions and request clarification, prompting the pre-service teacher to refine and strengthen their explanation." (P8)

Similar patterns were observed during the analysis of video recordings as seen in Figure 3, where avatars such as Ethan were seen raising their hands to signal confusion and prompt further explanation from pre-service teachers.



Figure 3: Ethan seeking detailed explanations from a pre-service teacher

This intervention demonstrates how simulation specialists actively use vocal avatar behaviour to highlight gaps in content understanding and encourage more detailed instructional responses.

These findings highlight the importance of making real-time decisions during teaching interactions, as simulation specialists made decisions based on pre-service teachers' inability to contextualise lessons and apply real-world examples due to a lack of content knowledge. This resonated with the TTAP model by Peterson and Clark (1978), as these interactive decisions demonstrate how simulation specialists made their real-time decisions based on the content knowledge gaps observed during the lesson.

4.3 Theme 3: Limited learner engagement

Simulation specialists' real-time decision-making was strongly influenced by their observation of limited learner engagement during MRS sessions. During the simulations, they noticed that some pre-service teachers often relied on vocal avatars while neglecting less responsive avatars. In response, simulation specialists enacted purposeful pedagogical decisions by manipulating avatar behaviour. For instance, they made certain avatars fall asleep during the simulation as a deliberate signal of disengagement and withdrawal, prompting pre-service teachers to recognise and address the lack of inclusive learner participation. Figure 4 illustrates avatars withdrawals due to pre-service teachers limited engagement during the MRS session.



Figure 4: Avatars withdrawals due to pre-service teachers limited engagement

These interaction patterns were interpreted as indicators of a predominantly teacher-centred approach that limited inclusive participation in the simulation. This finding underscores that pre-service teachers' pedagogical strategies were largely teacher-centred, characterised by an overreliance on vocal avatars and on slides, rather than on actively interacting with the avatars. In support of this finding, participants shared their thoughts:

"My real-time decisions were highly influenced by pre-service teachers' minimal engagement with avatars. What I observed is that some pre-service teachers were often prioritising and relying on vocal avatars, which resulted in limited interactions, as quiet or introverted avatars were not engaged." (P10)

"When the pre-service teacher was relying on reading the slides without engaging, I would also use avatars to disengage, either by fidgeting, sleeping, or using a cell phone. Most times, the pre-service teachers would miss these off-task behaviours. This was to signal pre-service teachers that some avatars are disengaging, and they lost interest due to not being engaged." (P11)

These findings were further supported by another participant who reflected:

"Pre-service teachers' failure to create inclusive opportunities for all avatars during the lesson affected quiet and pre-served avatars to engage. Jasmine and Dev are known as quiet avatars, and they are not easily engaged unless they are being invited to participate. That is why Ethan is informing their teacher to check with Dev and Jasmine, as they have not been engaged." (P1)

Some participants noted that pre-service teachers, when focusing on vocal students, often prioritise avatars who actively contribute, while neglecting quieter or introverted avatars. This engagement limited equal opportunities for inclusive participants, as quiet avatars were overlooked. P6 shared his thoughts:

"If the pre-service teacher keeps directing questions to Savanna, that is when I will use Ethan to highlight to the pre-service teacher that she is not accommodating all avatars in the class. I will inform the pre-service teachers that they need to pay attention to Dev and Jasmine, who have been ignored, and that's when the teacher will start paying attention to those avatars."

These responses align with Eggleston (2018), who found that real-time decision-making enables teachers to adjust their pedagogical strategies based on student behaviour and level of engagement. A similar finding was observed in this study: simulation specialists noted that their real-time decisions were influenced by pre-service teachers' instructional methods, which provided minimal engagement with avatars during lessons. This finding resonates with Griffith (2017) and the TTAP model by Peterson and Clark (1978), which demonstrated that real-time decisions enabled pre-service teachers to quickly adjust their strategies in response to students' misbehaviour and to accommodate students who lost interest and disrupted others.

4.4 Theme 4: Inadequate classroom management skills

Simulation specialists' real-time decision-making regarding classroom management was shaped by their interpretation of disruptive behaviours as pedagogical opportunities rather than merely as challenges to control. During MRS sessions, participants observed instances where pre-service teachers struggled to manage off-task behaviour, over-relied on vocal learners, or failed to establish clear classroom expectations. These behaviours were interpreted as indicators of limited classroom management strategies and an inability to respond effectively to dynamic classroom situations.

In response, simulation specialists deliberately introduced and escalated disruption through avatars such as Savanna and Ethan, using their behaviour to prompt instructional awareness and intervention. For example, avatars were made to engage in off-task behaviours such as talking out of turn, using mobile phones, or showing signs of disengagement. Figure 5 shows evidence of Ethan sleeping during the lesson as a sign of disengagement.



Figure 5: Evidence of Ethan sleeping during the lesson

These interventions were not incidental but intentional, as simulation specialists used disruption to create teachable moments within the simulation. The following excerpts below illustrate participants' views on how these classroom management challenges shaped their decision-making during the simulations:

"In some sessions, pre-service teachers were unable to manage and control disruptive avatars and ensured that there were effective sessions with them. They couldn't discipline avatars like Savanna and Ethan, who were disruptive while playing on phones, because they were frustrated with pre-service teachers relying on slides when teaching. Another thing I observed was that there was no classroom rules posed for students." (P3)

"My real-time decisions were often influenced by instances where pre-service teachers struggled to manage disruptive avatars. Many were unable to effectively respond to behaviours from avatars such as Savanna and Ethan, particularly when these disruptions stemmed from limited engagement. Rather than applying appropriate classroom management strategies, some pre-service teachers resorted were telling avatars that they will be chased from the class." (P9).

While the four themes are presented as distinct factors influencing simulation specialists' real-time decision-making, the findings indicate that they are closely interconnected and often co-occur within MRS interactions. For instance, gaps in pedagogical content knowledge frequently contributed to limited learner engagement, which in turn led to increased classroom management challenges.

Similarly, weaknesses in content knowledge often resulted in unclear explanations, prompting disengagement and, in some cases, disruptive behaviour among avatars.

Simulation specialists did not respond to these factors in isolation; rather, they interpreted them holistically and enacted integrated pedagogical responses. For example, when specialists identified content-related misunderstandings, they simultaneously addressed engagement by prompting interaction through avatar-based questioning and managed emerging disruptions. This highlights that real-time pedagogical decision-making within MRS environments is dynamic and multidimensional, with specialists continuously balancing content, engagement, and classroom management considerations in the moment.

These findings align with those of Zhang et al. (2024), who found that simulation specialists provide pre-service teachers with opportunities to practice classroom management and learn to manage disruptive students before entering the real-world classroom. This was further supported by Hudson et al. (2019), who found that using simulation specialists can aid pre-service teachers in developing and learning classroom management skills and in identifying areas for improvement when they encounter challenging behaviours, diverse learning needs, or unexpected classroom dynamics. Simulation specialists' behaviour resonates with the TPB model by Ajzen (1985), which underscores that classroom management is regarded as an observable action that is influenced by attitudes and perceived control.

5. Discussions

These findings provide a deeper understanding of real-time pedagogical decision-making in MRS environments. Rather than functioning as isolated reactions to pre-service teachers' performance, simulation specialists' decisions appear to be shaped by continuous cycles of observation, interpretation, and action. This suggests that real-time decision-making in MRS is a dynamic and context-sensitive process in which multiple pedagogical factors, such as content knowledge, learner engagement, and classroom management, are interpreted simultaneously. In addressing Research Questions 1 and 2, this study found that gaps in pre-service teachers' pedagogical knowledge significantly influenced simulation specialists' real-time decision-making during MRS interactions.

This gap was supported by Eggleston (2018), who noted that pre-service teachers' pedagogical gaps are a critical factor shaping in-the-moment decisions in classroom interactions. This corroborates with Clark and Petersen's (1978) teacher's thoughts and action process model, which emphasises the importance of real-time decision-making and reflective thinking during classroom interactions to guide instructional adjustments. For instance, some studies have found that during MRS interactions, simulation specialists ensure that pre-service teachers can engage meaningfully with the content and develop the necessary pedagogical reasoning for effective classroom practice (Solheim, Ertesvåg & Dalhaug Berg, 2018). Griffith (2017) echoed the findings of Solheim, Ertesvåg, and Dalhaug Berg (2018), revealing that real-time decisions allow pre-service teachers

to modify strategies for managing misbehaviour and re-engaging students who are losing interest.

The study further found that simulation specialists' decisions were shaped by pre-service teachers' gaps in content knowledge. This was evident when pre-service teachers used unexplained acronyms, vague explanations, lacked authentic examples, and offered irrelevant illustrations, all of which disrupted lesson coherence and hindered meaningful learning and engagement. Maguire (2023) notes that limited content knowledge among pre-service teachers often results in poor student engagement and classroom misbehaviour, as they often struggle to address learners' questions. Similarly, Soeharto and Csapó (2022) emphasise that the inability to apply content knowledge restricts students' academic achievement by denying them authentic, real-world learning experiences.

Limited learner engagement during MRS interaction was another factor influencing simulation specialists' real-time decision-making. The study's findings revealed that pre-service teachers' pedagogical strategies were predominantly teacher-centred, over-relying on vocal avatars and slides rather than interacting with all avatars. This led the simulation to make its real-time pedagogical decisions, aiming to encourage pre-service teachers to create opportunities for a student-centred approach and active participation, in which students are involved in the lesson. Skae et al. (2020) echoed this finding, emphasising that making real-time decisions during classroom interactions is essential for enhancing engaged learning, as pre-service teachers can shift from a teacher-centred approach to an interactive lesson that engages all students.

The findings of this study indicate that simulation specialists play a pivotal role in providing pre-service teachers with authentic opportunities to develop classroom management skills through interactions with avatars representing diverse learner personas. Simulation specialists explained that their real-time decisions were often influenced by factors such as pre-service teachers' inability to manage disruptive behaviours due to excessive reliance on slides and notes, and by avatars becoming disengaged when pre-service teachers focused primarily on vocal learners, neglecting others in the simulated classroom.

From theoretical perspectives, these findings resonate with the TTAP model proposed by Petersen and Clarke (1978), which explains how teachers' real-time decisions emerge during classroom interactions. In this study, simulation specialists first identified pre-service teachers' pedagogical gaps, such as an over-reliance on a teacher-centred approach and a failure to activate prior knowledge of avatars during the lesson introduction phase. These observations informed their immediate interpretations of pre-service teachers' pedagogical gaps, which enabled them to apply their real-time pedagogical decisions during the simulations. This led the simulation specialists to modify the outspoken avatar to prompt the pre-service teacher for clarification. This process illustrates the TTAP thought process and actions, which categorise teachers' thinking, planning, and decision-making, which constitute a large part of the psychological context of teaching (Wilhelmsson, 2012). As such, simulation specialists' intervention

demonstrates how real-time decisions during interactions influence immediate decisions and classroom practices.

In addition to examining how simulation specialists enacted these decisions, the TPB model by Ajzen (1991) helped the study understand the factors influencing simulation specialists' real-time decision-making, with the goal of enhancing the effectiveness of simulations in developing pre-service teachers' PCK. Mohebi (2021) emphasised that the TPB model identifies specific parameters and factors that contribute to a person's intent to engage in a particular behaviour. Their attitudes in this study are evident in their commitment to improving the PCK and classroom management skills. Therefore, their actions were shaped by their professional intentions to develop and support effective, meaningful learning, as well as by their beliefs about the effectiveness of pedagogical practices within the MRS environment.

6. Conclusion

This study explores factors influencing simulation specialists' real-time decision-making during micro-lesson interactions with pre-service teachers to support PCK development. The findings demonstrate that simulation specialists are shaped by multiple factors, including pre-service teachers' gaps in content and pedagogical knowledge, limited learner engagement, and inadequate classroom management skills. During the simulation, the study found that simulation specialists continuously observe, interpret, and respond to instructional situations by enacting targeted pedagogical interventions, including the strategic use of avatar behaviour, questioning techniques, and controlled disruption.

These findings highlight that real-time decision-making in MRS is dynamic, context-sensitive, and driven by ongoing pedagogical judgement rather than fixed instructional routines. As such, their ability to make real-time pedagogical decisions is crucial to the success of the simulations, as they respond to pre-service teachers' actions and adjust the scenarios accordingly. This role demands not only a sophisticated understanding of the technological tools used in simulations but also a deep knowledge of pedagogical principles that underpin effective teaching.

7. Implications of the study

Based on the findings of this study, there is a need for teacher education programmes to better prepare simulation specialists to meaningfully integrate MRS into teacher education. Firstly, the study highlights the need for targeted professional development programmes that explicitly train simulation specialists to identify pre-service teachers' PCK gaps and respond to them in their real-time pedagogical decisions. Such training should equip specialists to identify PCK gaps, interpret learner engagement cues, and respond effectively through real-time instructional adjustments. This emphasises the importance of strengthening simulation specialists' capacity to make informed, adaptive decisions to improve the quality of learning experiences within MRS environments.

Secondly, the study underscores the importance of ongoing professional development for simulation specialists. This should focus on enhancing their ability to manage classroom disruptions pedagogically, support inclusive learner engagement, and use avatar-mediated strategies to scaffold real-time understanding. Such development initiatives are essential for strengthening the quality of simulation-based teacher preparation and ensuring that MRS environments effectively support pre-service teachers' PCK development. As such, these implications aim to foster real-time decision-making that promotes student-centred learning and ensures that pre-service teachers receive meaningful opportunities to practice and refine both content delivery and classroom management strategies.

Conflict of interest

The authors declare that they have no conflicts of interest.

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