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Using Virtual Reality to Support Retrieval Practice in Blended Learning: An Interdisciplinary Professional Development Collaboration between Novice and Expert Teachers

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Abstract: This small-scale study comprised an evaluation of a teacher professional learning experience that involved the collaborative creation of resources using immersive virtual reality (VR) as a retrieval practice tool, specifically focusing on the open access aspects of the SchooVR platform. SchooVR offers teachers and students tools to enhance teaching and learning by providing a range of virtual field trips and the ability to create customised virtual tours aligned with curriculum requirements. By leveraging the immersive 360° learning environment, learners can interact with content in meaningful ways, fostering engagement and deepening understanding. This study draws on the experiences of a group of postgraduate teacher education students and co-operating teachers in Ireland and Northern Ireland who collaborated on the creation of a number of immersive learning experiences across a range of subjects during a professional learning event. The research showcases how immersive realities, such as VR, can be integrated effectively into blended learning spaces to create resources that facilitate retrieval practice and self-paced study, thereby supporting the learning process. By embedding VR experiences into the curriculum, students are given opportunities for independent practice, review, and personalised learning tasks, all of which contribute to the consolidation of knowledge and the development of metacognitive skills. The findings suggest that SchooVR and similar immersive technologies have the potential to enhance educational experiences and promote effective learning outcomes across a variety of subject areas.

Keywords: virtual reality; retrieval practice; online pedagogy; professional development; collaboration; teacher education

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1. Introduction

The research to date has focused on the immersive nature of virtual reality (VR) to aid student engagement by facilitating the construction of mental models through immersion in the subject matter [1]. Enhanced understanding [2], greater participation [3], and increased time commitment to the learning activity have been shown to positively impact overall learning outcomes [4]. During COVID-19, VR offered an accessible alternative to field trips and site visits [5]; however, the lengthy use of VR headsets was found to present challenges to the young and old alike. Reports of dizziness or cybersickness when using Google Cardboard [6] and eye strain or disorientation [7] from prolonged VR usage also emerged in the early research studies, leaving teachers and educators questioning the true educational value of the financial investment needed for a class set of headsets [8–10]. The initial perceptions of VR as 'just an over-priced gimmick' [11], where the positive effects were a result of the 'novelty effect' [12], may be attributed to the absence of pedagogical foundations from established learning models. Early research on VR in education primarily emphasised its affective impact on the classroom, neglecting the necessary pedagogical adaptations required for its effective utilisation [13].

This paper proposes the potential of the collaborative creation of resources enabled by VR to be used as a pedagogical tool for retrieval practice in secondary school education, emphasising its ability to offer immersive and realistic learning experiences, foster context-dependent memory retrieval, and facilitate the practical application of knowledge. Retrieval practice is a well-established learning strategy that involves actively recalling information from memory rather than merely reviewing it passively. It has been widely demonstrated to promote meaningful learning and long-term retention of information [14]. There is a growing body of knowledge highlighting how VR provides an unparalleled opportunity for students to interact with content in a realistic and engaging environment that fosters context-dependent memory retrieval [15]. As students engage in virtual simulations and scenarios, they can better connect their knowledge to real-life applications, enhancing understanding and retention. Furthermore, the capacity of VR to provide context-specific cues during retrieval practice enhances the transfer of learning to real-world applications, effectively equipping students to tackle practical challenges [15].

This research study investigates the experiences of postgraduate education students in Ireland and Northern Ireland who leveraged the open access elements of SchooVR to explore the creation of customised VR learning experiences spanning upper primary to lower secondary and postgraduate teacher education levels. SchooVR represents a pioneering approach to education, empowering teachers and students with innovative tools that enhance the teaching and learning process. The platform has an open access area for teachers and offers a range of immersive experiences, including pre-existing virtual tours to various locations worldwide and the ability for educators to create their own customised virtual tours aligned with curriculum requirements. These 360° learning environments foster meaningful interactions with content, enabling self-directed study and whole-class learning. Learners can access differentiated content, engage in personalised learning tasks, and benefit from quizzes, polls, and embedded video clips within the VR experience. By incorporating VR experiences into existing online courses via platforms like Google Classroom, the study demonstrates the potential of infusing retrieval practice strategies with VR technology to expand blended learning within the classroom [16] and promoting self-paced study and memory retention.

2. A Review of the Literature

2.1. Retrieval Practice in Education

The concept of retrieval practice, rooted in the Ebbinghaus Forgetting Curve (1885), has its origins in the observation that individuals tend to experience a rapid decline in memory of newly acquired knowledge over time unless they engage in active review of the learned material. Ebbinghaus suggests that this decline follows a pattern of continuously halving memory retention within a matter of days or weeks [17]. Early research on retrieval practice, conducted by Abbott (1908) at the University of Illinois, provided evidence that the opportunity for recall during or immediately after the learning process is highly advantageous for individuals [18]. This finding aligns with the conclusions of Peterson and Peterson [14], who demonstrated that almost all information stored in short-term (working) memory is lost within 18 to 30 s if it is not rehearsed.

Retrieval practice involves the active and deliberate act of recalling information from memory rather than relying on passive methods of review [19]. Extensive empirical evidence substantiates its efficacy in significantly enhancing learning and knowledge retention [20,21]. When students engage in retrieval practice, they actively "pull information out" from memory, which strengthens memory traces and fosters a deeper understanding of the material [22]. This cognitive exercise is instrumental in facilitating metacognitive skills, enabling students to identify their knowledge gaps and refine their learning strategies [23]. By incorporating retrieval practice as a regular component of the learning process, learners are equipped with valuable study skills and self-assessment abilities that extend beyond the confines of the classroom [24]. As educators, embracing the significance of retrieval practice can transform pedagogical approaches. Encouraging students to engage in a variety of retrieval exercises, such as quizzes, self-testing, and question–answer sessions, empowers them to become more effective and autonomous learners [25]. By shifting the focus from merely presenting information to actively retrieving it, teachers may foster a culture of active and enduring learning, promoting deeper comprehension and knowledge retention.

While the work of Rosenshine is not restricted to retrieval practice, regular review and recall is an important aspect of his seminal key principles of instruction [24]. Sherrington [26] amplifies and augments the principles and further demonstrates how they can be put into practice in everyday classrooms. Classroom-based works by Jones [27], Morrison McGill [28], and Agarwal and Bain [29] have brought the research and practice of retrieval to a new generation in diverse and engaging ways, such as websites, blogs, infographics, and video clips on social media. This has resulted in an online community of practice emerging where established and student teachers share and exchange subject-specific applications of retrieval practice and a myriad of visual tools to ignite the imaginations of teachers worldwide. Moreover, the ubiquitous nature of smartphones and other mobile devices presents new opportunities for technology-driven approaches to retrieval practice to be utilised both within the classroom and at home through polls, quizzes, and other real-time online learner engagement.

2.2. Virtual Reality as a Conduit for Retrieval Practice

Amidst the increased use of digital technology in teaching, learning, and assessment, VR has also shown significant promise as a retrieval practice tool offering a range of potential benefits [30]. Studies have highlighted VR's ability to provide immersive and realistic learning experiences, which engage students in a multisensory and interactive manner, leading to deeper encoding of information [31]. The use of VR also allows for exposure to diverse stimuli and cues, encouraging students to interact with complex scenarios and apply their knowledge practically, which in turn promotes memory reactivation and reconsolidation [15]. One notable research study involving a library of universal virtual reality experiments (luVRe) demonstrated that retrieval using VR experiences stimulates autobiographical retrieval mechanisms, distinct from conventional recall experiences [31]. This finding highlights the unique impact of VR on memory retrieval mechanisms compared to traditional recall methods. Research by Cooper and Thong [32] indicates that the immersive nature of VR enhances engagement and increases the time committed to learning activities, leading to improved learning outcomes. Studies by Cheung et al. [33] and Huang et al. [34] further support the promising effects of VR, including improved time on task, high levels of satisfaction, inspiration, and long-term commitment. Additionally, Allcoat et al. [35] found that immersive virtual reality outperformed video or textbook instruction in recalling information, establishing VR as a valuable pedagogical tool.

However, Cooper and Thong [1] assert that challenges to VR integration in the classroom, such as teacher self-efficacy, professional development opportunities, school leadership priorities, and access to VR technology, must be addressed. They go on to suggest that implementing virtual and mixed realities may require a considerable pedagogical shift for many in-service teachers. The following section looks at the theoretical framework underpinning a novel model of mutual professional learning for the implementation of VR-based retrieval practices in teacher education supported by co-operating teachers.

3. Theoretical Framework

This study examines the collaborative and reciprocal learning process within professional learning relationships between learning leaders (student teachers) and their mentors (subject method tutors and co-operating teachers) through a theoretical framework rooted in social constructivism [30]. Social constructivism recognises knowledge as socially situated and constructed through collaborative interactions. The learning process is enriched when a 'more knowledgeable other' (MKO) interacts with learners within their zone of proximal development (ZPD), as proposed by Vygotsky [36]. Furthermore, collaborative artifact generation, inspired by Papert's social constructionism, highlights learning through the collaborative creation of artifacts within social interactions [37]. In this study, student teachers collaborate with their co-operating teachers to design, create, implement, review, and improve VR-based learning resources, integrating VR technology and retrieval practice techniques into subject pedagogy across different subject areas and age groups.

During the COVID-19 lockdown, research by Farrell [38] revealed a shift in the co-operating teacher/student teacher hierarchy, positioning student teachers as mentors or 'learning leaders', supporting experienced teachers in schools as they transitioned to new pedagogies associated with online teaching. This state of 'reverse mentoring' involved a reciprocal relationship between experienced and novice teachers, with dual mentoring in opposite directions, facilitated by student teachers' use of technology-enhanced learning and co-operating teachers' pedagogical mastery in the classroom [39,40].

The social constructivist framework also incorporates these principles of cognitive apprenticeship and reverse mentoring. As student teachers acquire digital skills, such as using VR technology in the university setting, they become 'reverse mentors' in VR technology when in their hosting placement school, while their co-operating teachers remain the pedagogy experts and VR technology novices. Through a bi-directional cognitive apprenticeship model, student teachers mentor experienced teachers in VR creation skills, while experienced teachers mentor student teachers in the pedagogical skills needed to incorporate VR experiences effectively into the classroom (see Figure 1). Further information on the evolution of this model can be found at Cowan and Farrell [39].

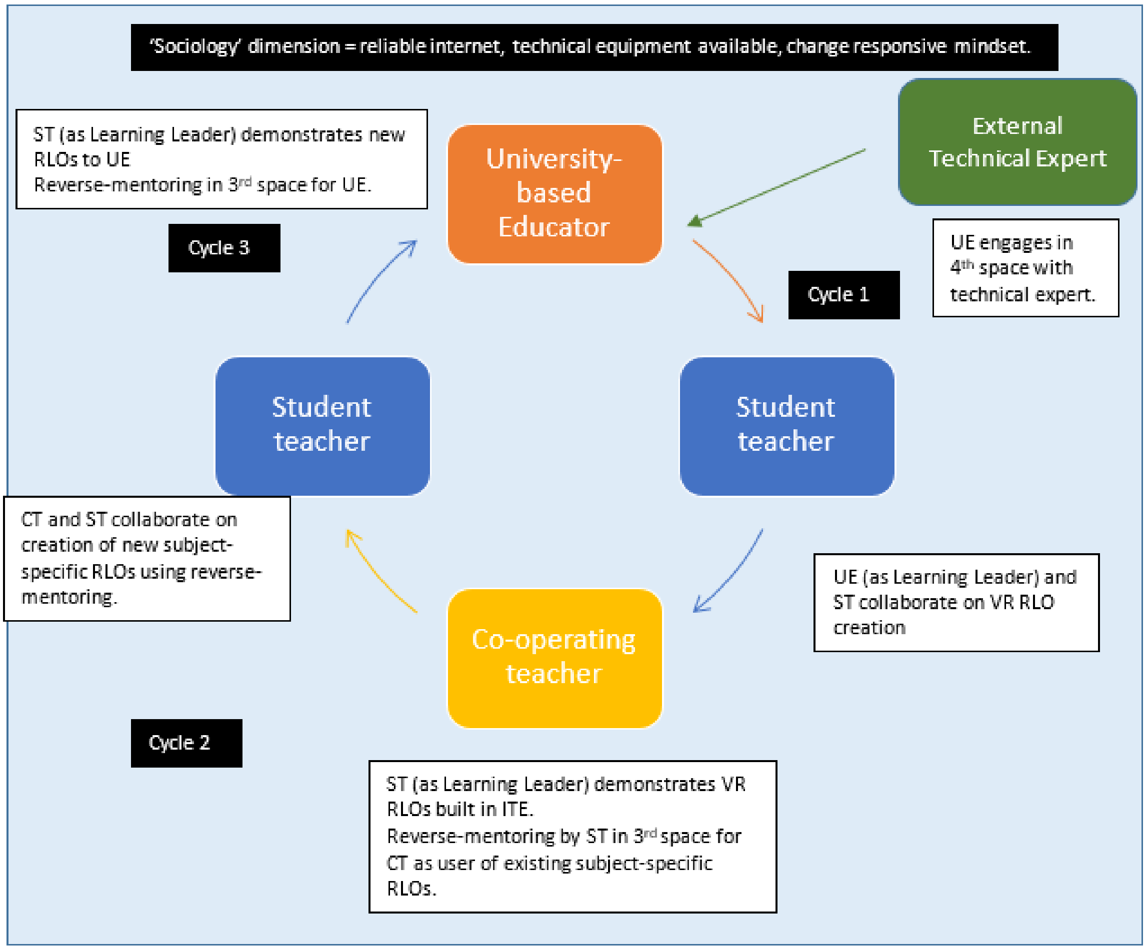

Figure 1. Reverse mentoring model of professional learning for learning leaders aligned to cognitive apprenticeship cycles [40].

This paper focuses on Cycle 2 in the diagram and the connection between the experienced teachers or co-operating teachers in host schools and the novice student teachers on placement. The underpinned aim of this study was to establish if this reverse mentoring model would work in reality when used as an online model for professional development. In addition, from a pedagogical perspective, it was important to add to the existing research in the area of VR and retrieval practice, when using the open-access platform SchooVR. The two research questions for this study are:

- How effective was the reverse-mentoring model when used for the professional development of teachers interested in using VR?
- Does the functionality of SchooVR facilitate the use of the core features of the information retrieval model in a blended learning space?

4. Methodology

4.1. Research Design

Due to the general teacher supply crisis and shortage of teacher substitutes in schools in Ireland and Northern Ireland (NI) [41,42], being absent from school to attend an external professional development course puts a strain on an already under-staffed workforce. As a result, a different model of professional development (PD) was explored in this study, namely reverse mentoring. Due to the small-scale study, a purposive sample [43] of six student teachers from NI met in a computer suite on the university campus, while seven experienced teachers from Ireland came together online from their school location for a one-day hybrid training event facilitated by the researchers. By retaining their presence on the school site, internal cover could be provided by departmental colleagues for the experienced teachers. By having the student teachers on campus, the on-site researcher could monitor and support any issues arising from the partnerships. The main research goal of the PD session was to test the reverse-mentoring model during the creation of SchooVR experiences; however, the pedagogical challenge set for the pairs of teachers was to embed the elements of retrieval practice and establish the intuitiveness of the SchooVR platform during the creation of their subject-specific SchooVR immersive experience. The dual nature of the PD activity was a novel approach designed to ensure all participant pairings had at least one SchooVR product ready for use by the end of the event.

Prior to the PD event, the participants were matched as far as possible by subject specialisms to allow for a purposeful collaboration in their North–South pairings. After an initial demonstration of the SchooVR platform from a learner's perspective, highlighting how a variety of the features could be embedded into the panoramas (360° scenes), the participants were encouraged to work in pairs as creators of a new SchooVR experience relevant to both the NI and Irish curricula for their subject. Over a period of two hours, the pairings utilised collaborative and co-operative learning strategies to produce a five-scene VR experience with associated retrieval practice activities for their agreed topics.

Both participants logged in to their shared SchooVR account, allowing for dual interactions and the parallel production of content for each panorama. Some of the topics chosen for the SchooVR VR experience included:

- History and English: War poetry on location at the Somme;
- Sustainability and Geography: Wind turbines and where they are located around the island of Ireland;
- The Science of Sustainable Energy: Water turbines and how they work;
- Maths in the real world: Angle of elevation at various world landmarks;
- Religious Education: Searching for Meaning through Ancient Architecture.

The following is a list of retrieval practice strategies that were embedded into the immersive experiences, some of which are illustrated in Figure 2:

- Scenario-Based Quizzes are embedded within the VR environment and present users with multiple-choice or open-ended questions based on those scenarios.

- Time-Pressure Challenges are designed where users have a limited amount of time to recall information based on the VR experience helping to simulate real-world pressure and improve retention.
- In Spatial Recall Tests, learners explore a VR environment and are then asked questions about specific objects or locations within that environment.
- Virtual Memory places are created to enable users to navigate through a space and recall information associated with specific locations.
- Historical Re-enactments involve designing scenarios where learners interact with historical events or figures and where they are then quizzed on their understanding.
- Math Problem Solving involves the crafting of VR math problems that learners need to solve using virtual tools or environments.
- Geography and Navigation Challenges involve creating a geography quiz where users navigate a VR map to answer questions about countries and landmarks.
- Literature Analysis involves learners exploring virtual literary worlds and answering questions about plot, characters, and themes.
- Speak Like an Expert requires pupils to 'speak like an expert' based on their new knowledge gained from the VR experience.
- Analysing and Connecting Images requires learners to do so in the VR experience and relate it to the knowledge learned and real-world situations.

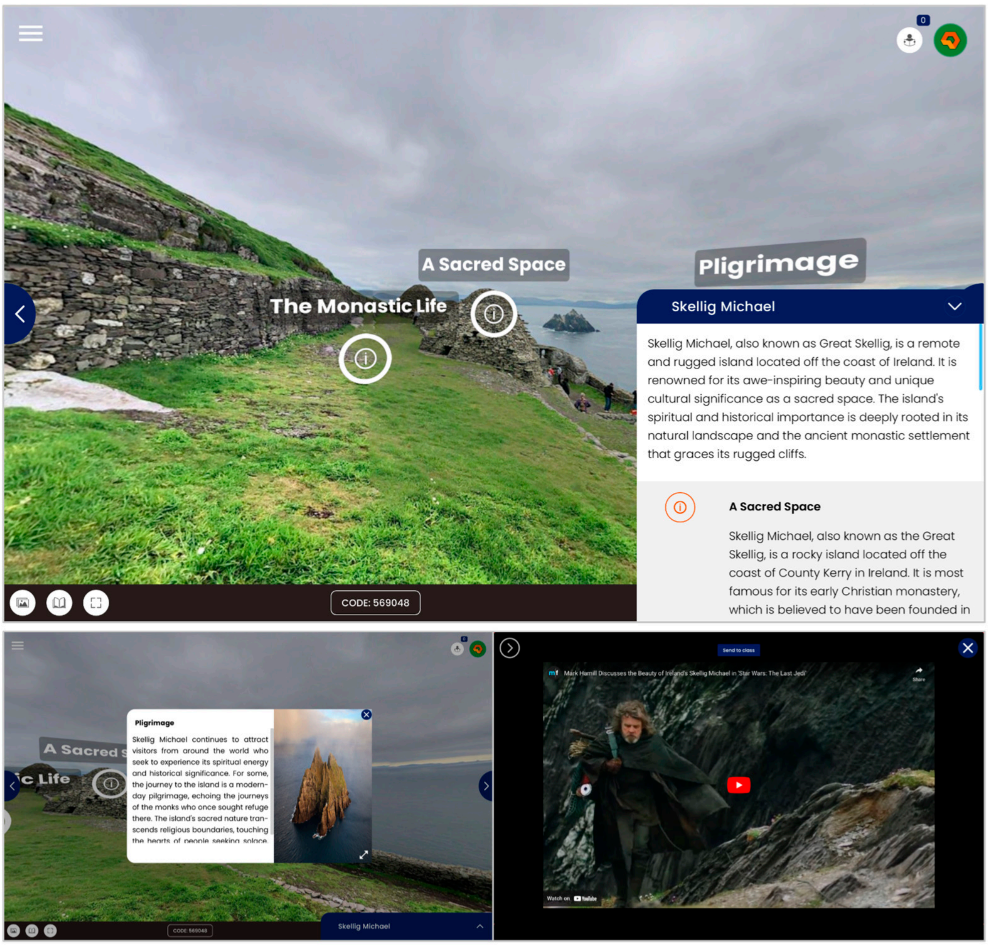

Figure 2. Examples of interactive panorama used in a Religious Education immersive experience.

The participants were encouraged to create a minimum of five panoramas with associated text, video, or sounds relevant to the experience. Hotspots, labels, and PowerPoint slides were used to focus on the curriculum content, and interactive tasks, such as quizzes or polls, were included. An assessed task was also set, which was the production of a digital artefact that could range from a poster or infographic to the learner's own poem or image based on the VR experience.

All participants were asked to reflect on their PD experience and to complete an online survey at the end of the two-hour slot and before taking a lunchbreak of one hour. Upon returning, another 30 min was provided for some final tweaks to their SchooVR artifact before each pair completed a brief micro-teaching session with the other participants as learners in their newly created SchooVR environment by sharing their PIN. Once all the learning experiences had been completed, the participants were encouraged to take five minutes of self-reflection to focus on what they had learned through their personal experiences in SchooVR and also through collaboration with their partner. The second online survey, which included seven specific items on retrieval practice based on Rosenshine [24], was then completed. The event concluded with a final discussion as one large focus group, evaluating the effectiveness of the reverse-mentoring model, the usefulness of the collaborative partnership, and what they learned from viewing each other's SchooVR products. Finally, the organisation and management of the day were discussed, along with the intended next steps in the research process.

4.2. Data Collection Instruments

The surveys were designed by the authors based on prior knowledge and experience with ICT evaluations, literature reviews, and teaching educational theory to ITE students. Two surveys were used to collect data on the participants' own attitudes over the duration of the event as pre- and post-intervention measures. As the participants had not used SchooVR before nor had they met their partners in advance of the PD session, a five-point Likert scale was designed to establish the intuitiveness of the SchooVR platform, the effectiveness of collaboration via reverse-mentoring, and some initial reflections on the participants' experiences. The second survey revisited some of these attitudinal questions but mainly focused on the elements of retrieval practice and how the participants viewed the usefulness of SchooVR for their future classroom practice.

The focus group was used to discuss any of the items on the survey requiring justification or elaboration. The researchers used prompting and '*playing devil's advocate*' to initiate the debate. The comments from the survey were combined with the observations from the focus group and were collectively analysed using Braun and Clarke's [44] thematic analysis. The next section reports the findings from both surveys and includes the key themes emerging from the comments. Data triangulation [44] is used to draw conclusions in the final section.

5. Findings

Although this was a small-scale study of 15 participants, the descriptive statistics reveal interesting patterns of responses from the survey data and demonstrate consensus on the attitudinal measures. The data were checked for linearity and sampling adequacy, based on the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (>0.6) and Bartlett's test of sphericity, and the existence of significant outliers. For each subset of the data in both surveys, these assumptions were met despite the low sample size. In addition, the recommended requirement of 5 to 10 cases per variable as a minimum sample size was met; in this research, each variable had 15 responses, allowing for exploratory factor analysis (EFA) to be completed. The data reported in Figure 3 relate to the training and experience of using the SchooVR platform. The blue sections down the right-hand side are the 'Agree' and 'Strongly Agree', confirming the value of modelling good practice with the use of SchooVR initially so that the navigation of the SchooVR platform becomes intuitive. Once the SchooVR learning resources had been demonstrated, the participants reported feeling confident that they could create their own subject-specific VR experience in pairs, as noted by the level of disagreement (in orange) in items suggesting they need guidance or might be feeling overwhelmed by the expectations of the event.

The larger grey chunk for Statement 6, denoting a neutral response by over half (53.8%) of the participants, indicates that a longer period of time using SchooVR may have been required before there was any impact on teachers' pedagogical planning process. It may also be the case that teachers would benefit from some authentic experiences of using SchooVR in the classroom with learners to assist them in determining how to utilise the blended environment to maximise the positive learning gains of pupils.

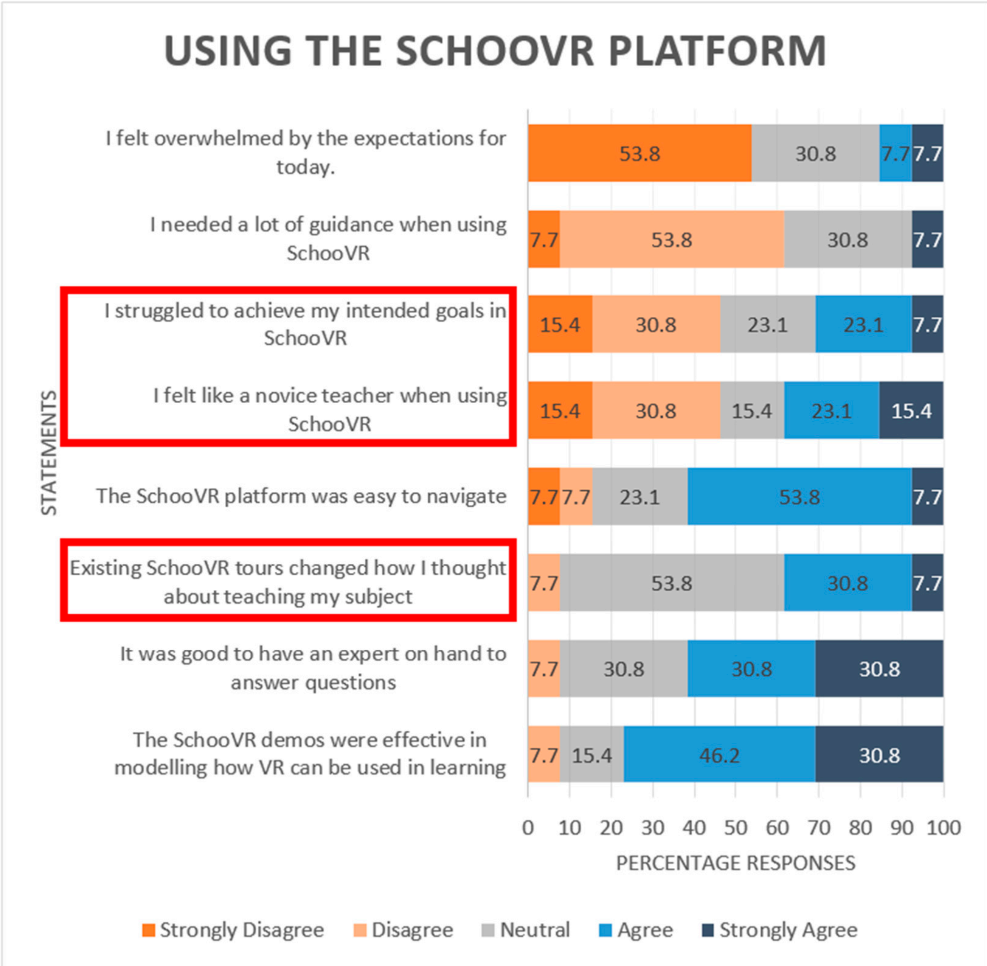

Figure 3. Using the SchooVR platform.

Statements 3 and 4 show a mix of positive and negative responses towards feeling like a 'novice' teacher and the associated concerns of meeting the intended learning goals for their chosen topic or VR learning resource. Like teaching a new course specification or entering a new school, there will always be feelings of uncertainty when tackling something for the first time, and so this mixture of positive and negative responses was expected for these items.

The exploratory factor analysis (EFA) of these items revealed a two-factor model accounting for 75.62% of the variance as shown in Table 1. There was no statistically significant difference between the attitudes of the student teachers and their experienced teacher partners in terms of using the SchooVR platform; $F(11, 1) = 0.07$, $p = 0.794$, as illustrated in Figure 4.

In terms of the North–South pairings of teachers, despite having only met that morning, the novice and expert teachers enjoyed working together in an almost equitable partnership, as indicated by Statements 5 and 6 in Figure 5, which address the mentor/mentee relationship. Item 4 confirms that their technical and pedagogical skills complemented each other, leading to a final product they were both proud of and beyond what they could have achieved alone

(Item 2). Interestingly, the respondents were divided on whether their newly created VR experience would really motivate their pupils, with approximately half of the replies in the neutral (grey) category, as shown in Item 1 in Figure 5. Upon reflection, this may have been due to the limited preparation time assigned to the task, the teachers' desires to develop their SchooVR resource more in terms of its functionality, or their inability to visualise how the resource could be used in their existing classroom context.

Table 1. Reliability of the factors and mean factor scores (standard deviations).

Using SchooVR Factors	Cronbach's Alpha	Ireland (Experienced Teachers)	NI (Student Teachers)	Overall Mean Score (s.d.)
Confident user (*6 items*)	0.893	3.833 (0.953)	3.389 (0.779)	3.628 (0.872)
Felt like a novice (*2 items*)	0.713	2.786 (1.350)	2.583 (0.665)	2.692 (1.052)

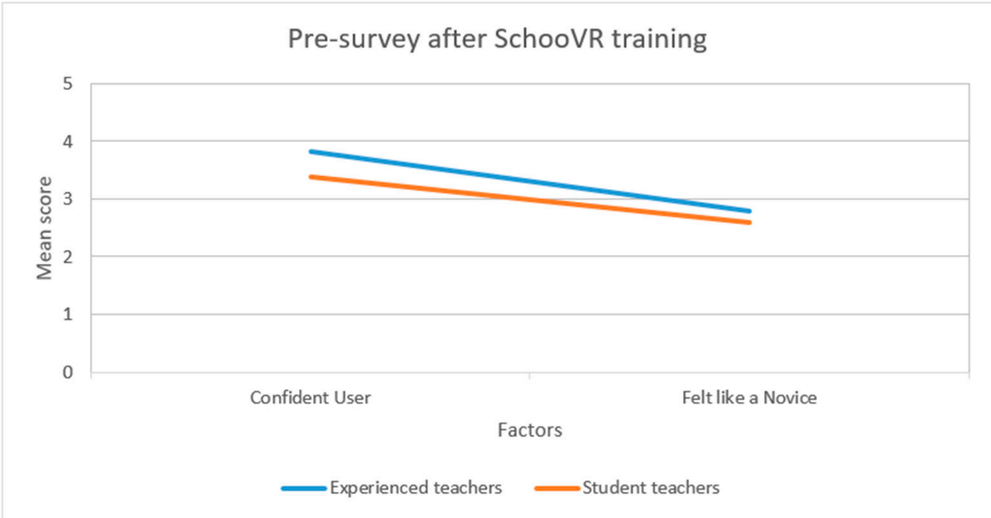

Figure 4. Profiles of experienced and student teachers after SchooVR training.

Nonetheless, the statements highlighted in the green boxes on the left-hand side of Figure 6 reveal that both partners felt happy with how they had shared the workload and the blend of technical and pedagogical expertise they brought to the task. The red boxes on the left-hand side are indicative of the next steps in the teachers' professional development, as this collaborative experience made the partners appreciate that their VR experience could have been more exciting, and they now see the educational value of SchooVR to the learner. In addition, the comments from the open-ended questions (Figure 7) support the concept of reverse-mentoring as an enjoyable process but recommend the VR training process spans more days spread over a number of weeks to give the teachers time to reflect and develop more creative ideas in a less pressurized environment. Since this is the view of one person (out of 15 attendees), it would be valuable to determine if other small groups react similarly, wanting a slower pace in their online professional development, or if the short timespan combined with the intensive creation of the SchooVR experience is viewed as more efficient. From the researchers' perspectives, the goal was to ensure that the participants left with skills, knowledge, and a useable teaching resource at the end of the PD session, in the hope that the teachers would at least pilot it with their pupils in the coming weeks. The final comments about in-person training relate back to the feasibility of obtaining a full day of teacher release from school in light of the limited availability of supply teachers to cover staff absences [40,41].

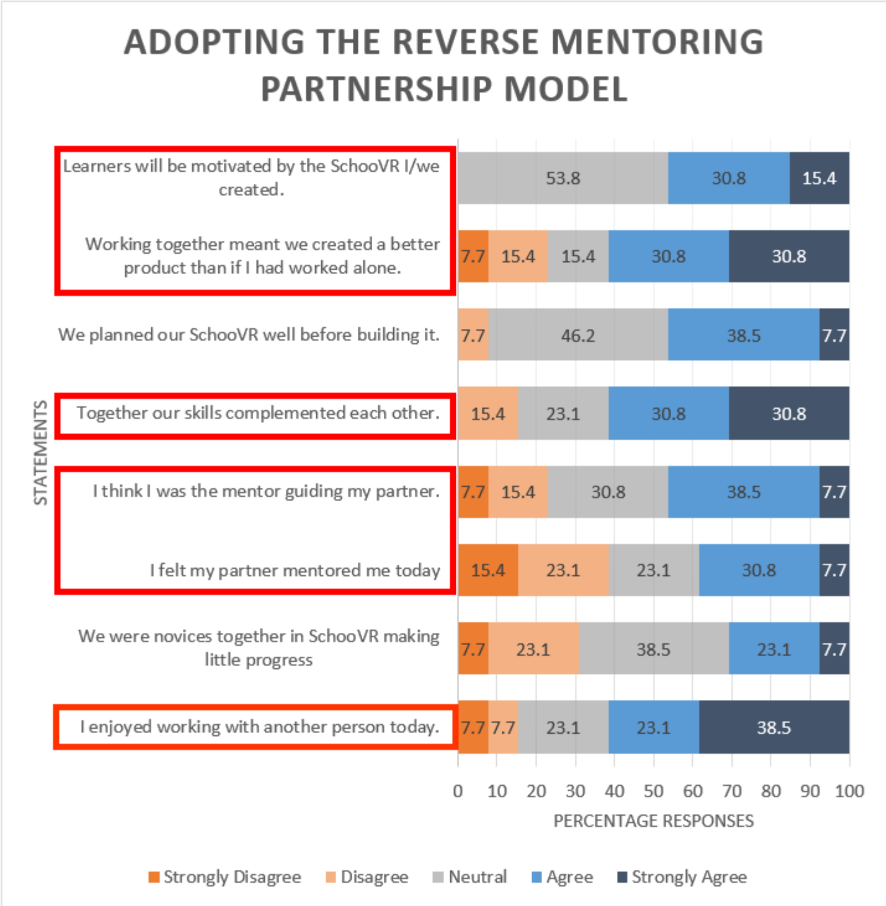

Figure 5. Adopting the reverse-mentoring partnership model.

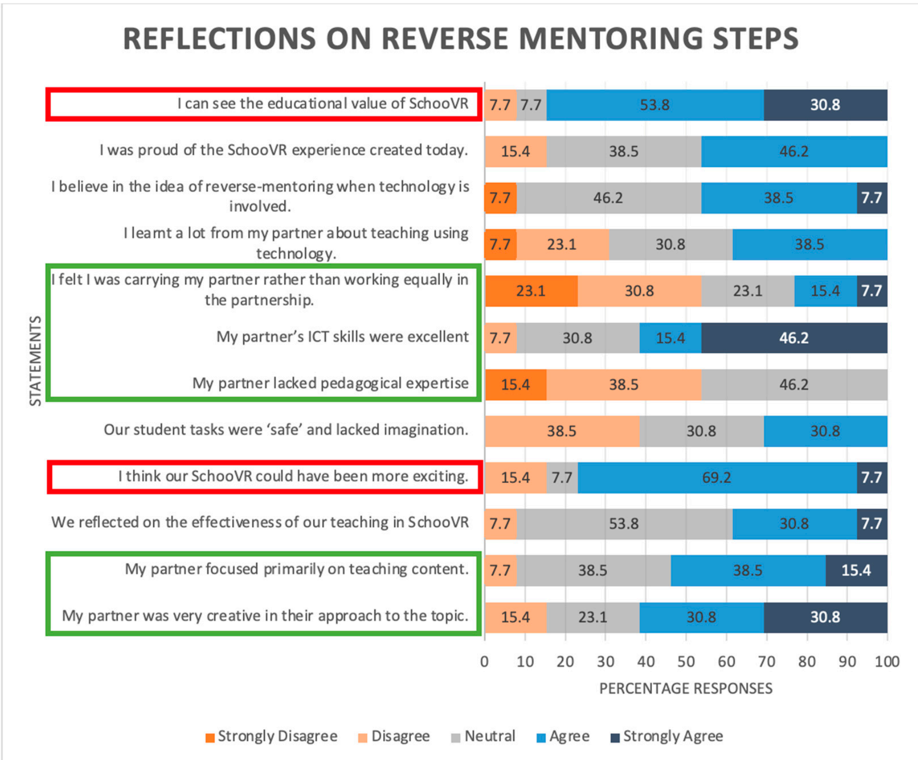

Figure 6. Reflections on reverse-mentoring steps.

Theme 1: Enjoyed the reverse-mentoring process:

I enjoyed today's tasks as it was good working with more experienced people. (N)

I really enjoyed working with other people on a project! (N)

Good to work together. (E)

Theme 2: Professional development context and suggested improvements:

Longer collaborations, over a term perhaps, would be really fruitful. (E)

In person would probably be better. (E)

In person so the partner can't leave. (N)

Needs more motivation to make the workload worthwhile. (N)

Figure 7. Two themes from participants' comments in pre-survey (N = novice and E = experienced teacher).

An exploratory factor analysis of the items included in Figures 5 and 6, revealed a five-factor model accounting for 82.59% of the variance, as shown in Tables 2 and 3.

Table 2. Reliability of each factor in the 5-factor model for reverse-mentoring items.

Reverse-Mentoring Factors	Cronbach's Alpha	Number of Items
Reverse-mentor partnership was effective	0.938	8
Pedagogical focus within SchooVR	0.692	3
Educational value of SchooVR for learners	0.734	3
'Playing design safe' in SchooVR	0.750	3
One dominant partner	0.718	2

Table 3. Mean scores (standard deviations) of each factor for reverse-mentoring items.

Factors → Teachers ↓	Reverse-Mentoring Partnership	Pedagogical Focus within SchooVR	Educational Value for Learners	Playing Design Safe	One Dominant Partner
Ireland	3.857	4.000	3.667	2.571	2.571
(Experienced)	(0.663)	(0.609)	(0.720)	(0.600)	(0.673)
NI	2.958	3.278	3.444	3.444	3.250
(Student teachers)	(1.008)	(0.680)	(0.807)	(0.404)	(1.332)
All teachers	3.442	3.667	3.564	2.974	2.885
	(0.928)	(0.720)	(0.738)	(0.673)	(1.044)

When the factor score profiles were compared between the experienced teachers and the student teachers, the difference in the means for 'Playing Design Safe' in SchooVR was statistically significant; $F(44, 4) = 3.55$, $p = 0.014$, as shown in Figure 8.

In the second part of the professional development using SchooVR event, the participating pairs demonstrated their SchooVR creations by 'teaching' the rest of the group using the PIN code to take the learners on a tour through the panoramas and information hotspots that had been co-constructed by the partners. Some partners had also uploaded presentations or created a short quiz within their SchooVR experiences, but due to limited time, not all pairs reached this point.

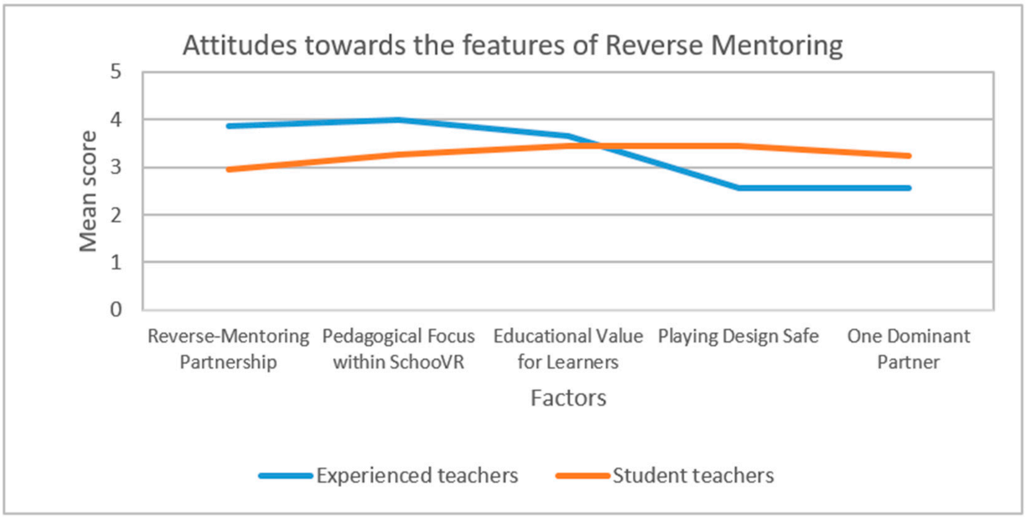

Figure 8. Profiles of experienced and student teachers' attitudes towards reverse mentoring.

The EFA of the items in Figure 9 revealed a three-factor model, with reliabilities shown in Table 4 and accounting for 76.22% of variance. The difference in the mean scores between the experienced and student teachers for this approach in the factor 'Successful PD opportunity' resulted in a statistically significant difference in their profiles; $F(18, 2) = 4.50$, $p = 0.026$, as illustrated in Figure 10.

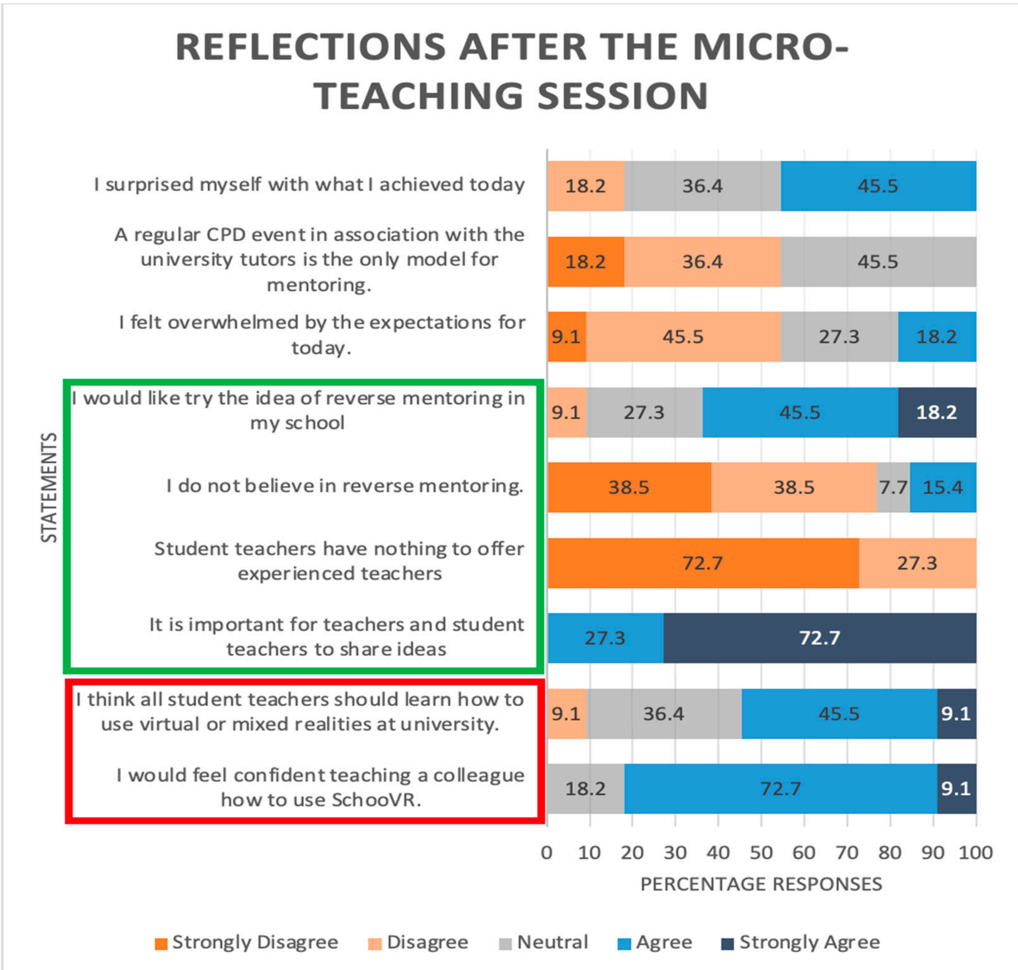

Figure 9. Reflections after the micro-teaching session.

Table 4. Reliability of the 3-factor model and mean scores (s.d.) of each factor.

Factors	Cronbach's Alpha	No. of Items	Ireland (Experienced)	NI (Student Teachers)	Overall Mean (s.d.)
Successful PD opportunity	0.759	3	2.533 (0.380)	3.333 (0.471)	2.970 (0.586)
Supportive of reverse mentoring	0.784	4	4.350 (0.576)	3.875 (0.518)	4.091 (0.573)
Good collaboration	0.605	2	4.100 (0.652)	4.083 (0.665)	4.091 (0.625)

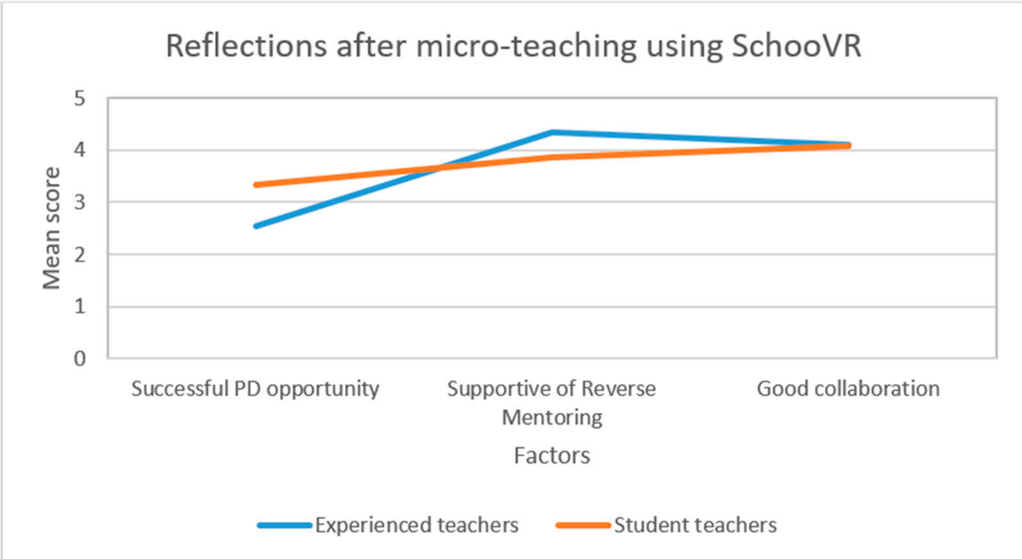

Figure 10. Profiles of experienced and student teachers' reflections after the micro-teaching session.

The final part of the day encouraged participants to reflect on the following research questions:

- How effective was the reverse-mentoring model when used for the professional development of teachers interested in using VR?
- Does the functionality of SchooVR facilitate the use of the core features of the information retrieval model in a hybrid learning space?

In Figure 9, it is apparent that there was agreement that student teachers had a lot to offer, and the group as a whole believed in the process of reverse mentoring—even as far as wanting to try it out in their school (see the statements in the green box). The final two statements (in the red box in Figure 9) further indicate the confidence of both the student teachers and the co-operating teachers in using SchooVR and/or mixed reality to cascade the training within their own schools and the important role of the ITE providers in ensuring that the student teachers have the capacity to offer in-house professional development to teachers while they are on placement at the hosting school.

Considering the second research question ('Does the functionality of SchooVR facilitate the use of the core features of the information retrieval model in a blended learning space?'), Figure 11 addresses the cognitive elements of retrieval practice, while Figure 12 considers the pedagogical challenges being addressed in the hybrid VR experience.

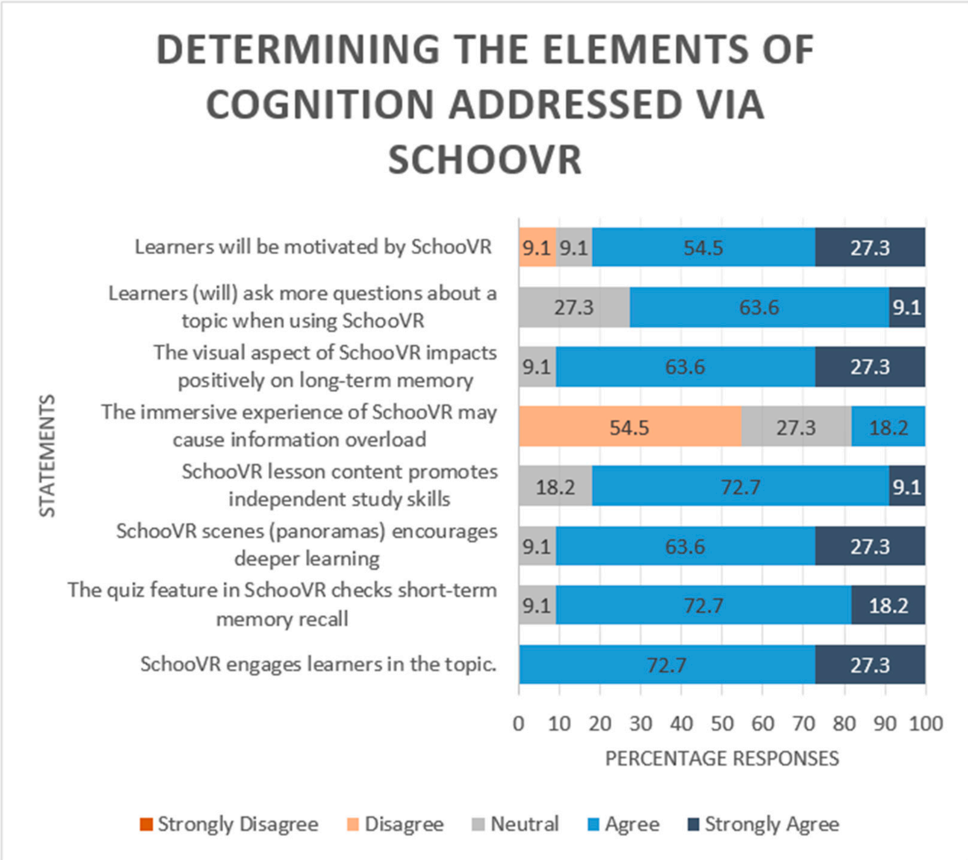

Figure 11. Determining the elements of cognition addressed via SchooVR.

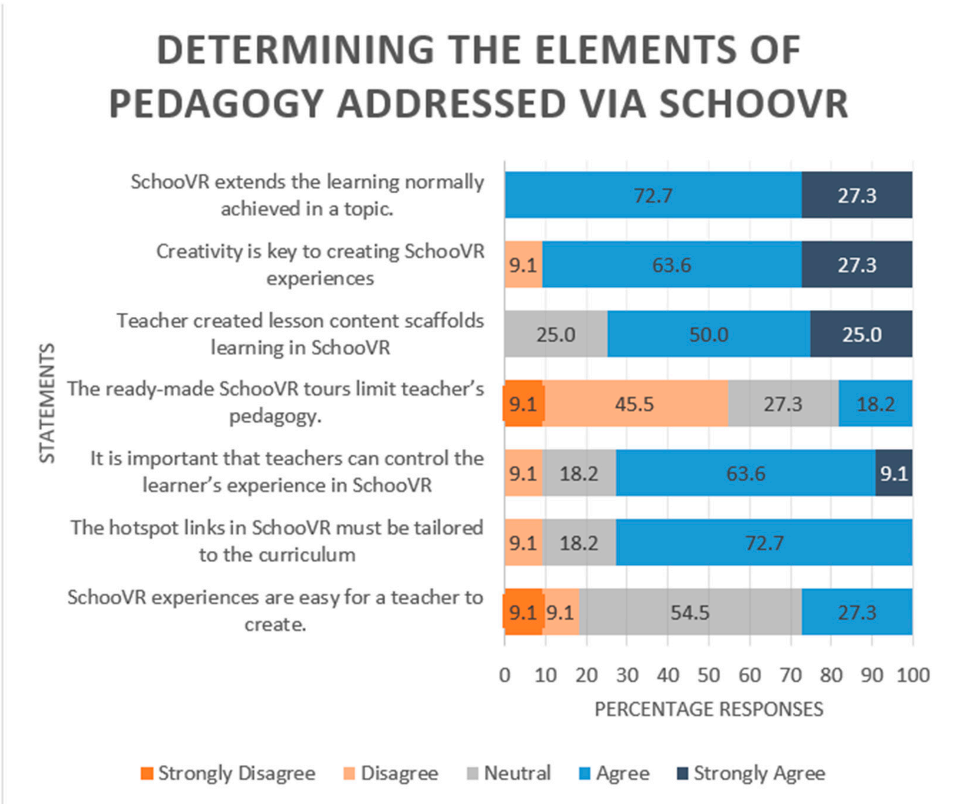

Figure 12. Determining the elements of pedagogy addressed via SchooVR.

Figure 11 demonstrates there was strong agreement with all the positively worded items relating to SchooVR as a tool to develop cognition, including engagement in the topic, deeper learning, independent study, and motivation. Specific features, such as the visual stimulation of the immersive experience and the use of the quiz, were noted as promoting long-term and short-term recall of knowledge, respectively. The negatively worded item about the immersive experience potentially causing information overload was generally not supported, and it was anticipated that learners are likely to ask more questions as a result of using the immersive VR resource, linking to Rosenshine's assertion that questions allow teachers to determine pupils' learning, address misconceptions, and scaffold learners' production of mental models or neural networks.

The EFA of the items in Figure 11 resulted in a two-factor model accounting for 73.71% of the variance. The mean factor scores of the experienced and student teachers were not significantly different, as shown in Table 5 and Figure 12; $F(9, 1) = 2.47$, $p = 0.150$.

Table 5. Reliability of the 2-factor model of cognition and mean scores (s.d.) of each factor.

Cognition Factors	Cronbach's Alpha	Ireland (Experienced)	NI (Student Teachers)	Overall Means (s.d.)
Process of learning with VR (*5 items*)	0.887	4.120 (0.657)	3.967 (0.320)	4.036 (0.480)
Learner's VR experience (*3 items*)	0.679	4.200 (0.558)	3.611 (0.491)	3.879 (0.583)

Moving on to consider the pedagogy associated with adopting VR learning resources, again, SchooVR was viewed positively in terms of the teacher's control of the learning process—content and pace—as well as in-built scaffolding and the opportunity to be creative to extend the pupils' learning (see Figure 13). Again, the negative statement about ready-made SchooVR tours limiting the teacher's pedagogy was not supported, while the uncertainty around the SchooVR experiences being easy for a teacher to create could be a result of the limited time in this one-day professional development opportunity.

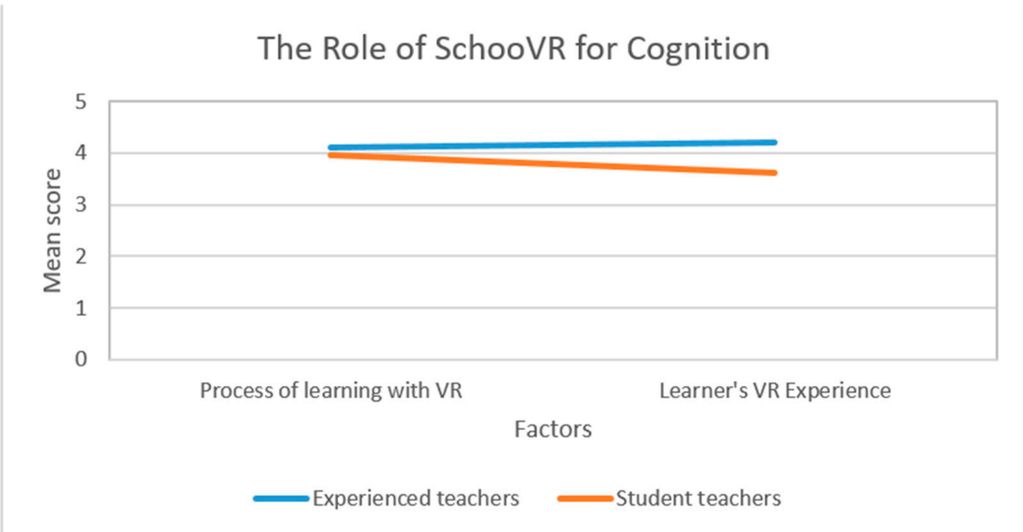

Figure 13. Profiles of experienced and student teachers' perceptions of the role of SchooVR in cognition.

The EFA of the items in Figure 12 resulted in a two-factor model accounting for 63.97% of the variance. The mean factor scores of the experienced and student teachers were not significantly different, as shown in Table 6; $F(9, 1) = 0.610$, $p = 0.454$ and Figure 14.

Table 6. Reliability of the 2-factor model for pedagogy and mean scores for each factor.

Pedagogy Factors	Cronbach's Alpha	Ireland (Experienced)	NI (Student Teachers)	Overall Means
User of SchooVR (*4 items*)	0.700	3.800 (0.716)	3.542 (0.431)	3.659 (0.562)
Creator of SchooVR experience (*3 items*)	0.678	3.867 (0.298)	3.278 (0.574)	3.545 (0.543)

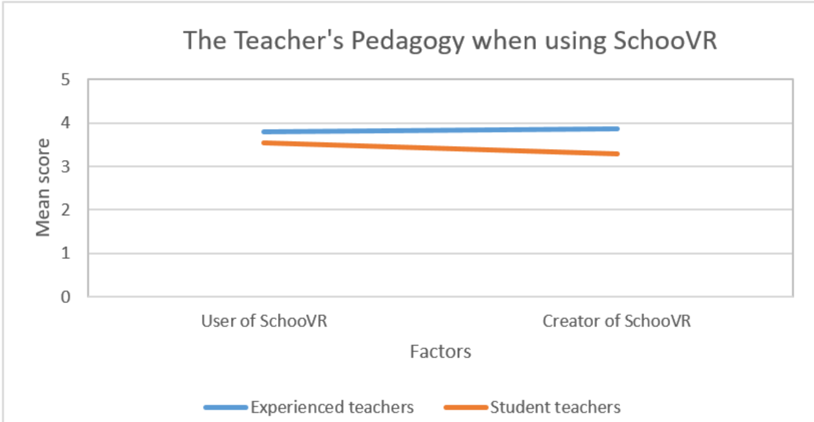

Figure 14. Profiles of experienced and student teachers' pedagogy when using SchooVR.

When the specific features of information retrieval were considered, there were high levels of agreement that SchooVR was not a chore for learners, but instead it supported the core areas of learning, such as building mental models, encouraging critical thinking by learners, and facilitating home access to the resource to allow for retrieval practice (see Figure 15). Only learner metacognition and content coverage compared to traditional classroom teaching were viewed less positively by the respondents. Again, this could reflect the lack of opportunity to pilot the SchooVR ready-made resources with their classes; however, when the participants were asked if they intended to use VR this school year, there was a mixture of positivity and uncertainty, as discussed next.

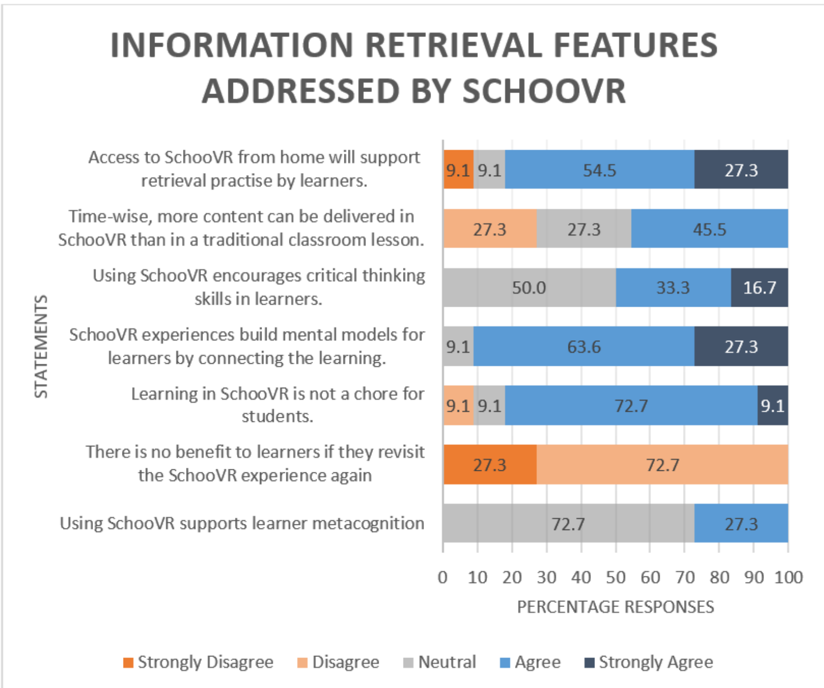

Figure 15. Information retrieval features addressed via SchooVR.

The EFA of the retrieval practice items in Figure 15 resulted in a two-factor model accounting for 75.16% of the variance. The mean factor scores of the experienced and student teachers were not significantly different, as shown in Table 7 and Figure 16; $F(9, 1) = 0.00$, $p = 0.973$.

Table 7. Reliability of the 2-factor model for retrieval practice and mean scores of each factor.

Retrieval Practice Factors	Cronbach's Alpha	Ireland (Experienced)	NI (Student Teachers)	Overall Means (s.d.)
SchooVR as a tool to support learners (*5 items*)	0.836	4.120 (0.540)	3.667 (0.653)	3.873 (0.621)
Promoting learners' thinking skills (*2 items*)	0.694	3.800 (0.570)	3.333 (0.258)	3.545 (0.472)

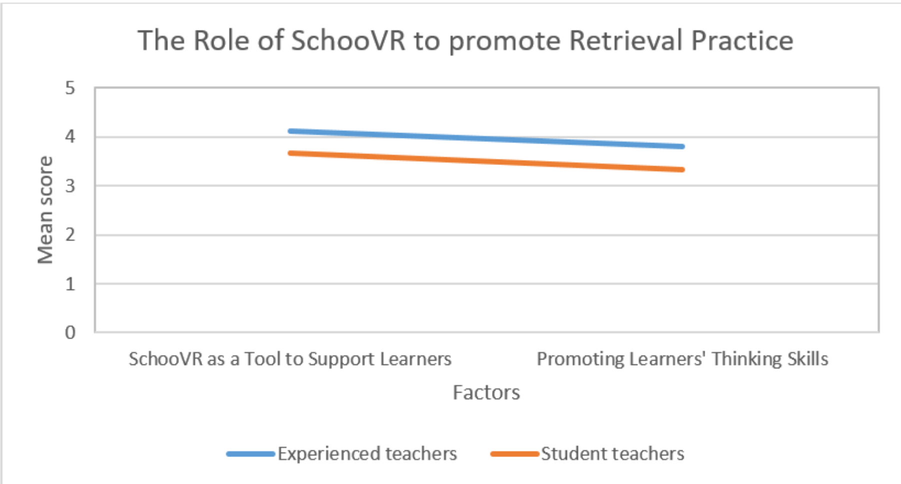

Figure 16. Profiles of experienced and student teachers' perceptions of the role of SchooVR in promoting retrieval practice.

In terms of the next steps, only one teacher did not intend to use VR this academic year for financial reasons (revealed in the comments), and one teacher was not anticipating any uptake or interest in VR in their school (see Figures 17 and 18).

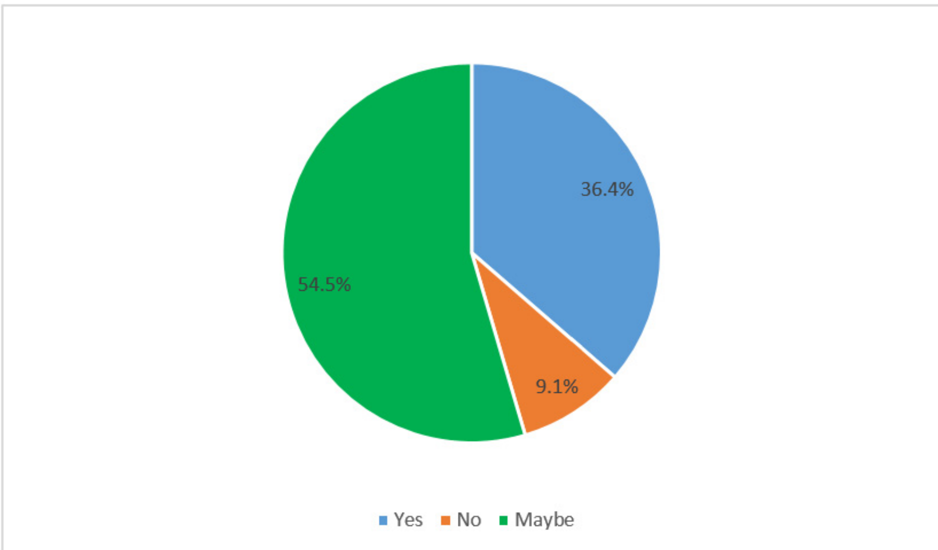

Figure 17. Do you intend to use VR this academic year?

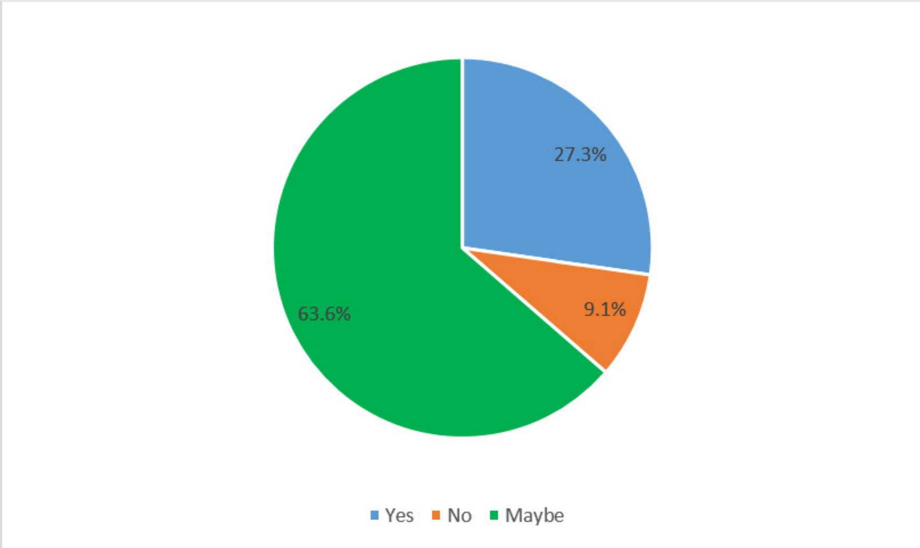

Figure 18. Do you think other teachers in your school would be keen to learn about VR?

Although the co-construction of the subject-specific VR experience worked effectively between the novices and experts using the reverse-mentoring model, there was a greater intention to use VR by the experienced teachers compared to the novice student teacher group, as shown in the responses to the open-ended question (see Figure 19). The themes emerging from the comments include self-improvement (pink), intention to use (green), subject connections (grey), time (blue), finances (red), pedagogy (purple), motivation (yellow), and demotivation (teal).

Experienced teachers' responses:

- *I need to get better at it;*
- *I hope to use it with my Geography group;*
- *intend to use this with my PME CSPE students next term*
- *Funding devices at the moment is an issue as we have had to spend most of this year's technology budget on upgrading existing school devices in the building;*
- *I aim to use SchooVR to assist with topics I am teaching - as a lesson hook or overview of a topic and quick revision for students before exams*

Student teachers:

- *It will give a better visual of ideas*
- *I'm unsure how I will fit it in*

Possible use of SchooVR by others teachers?

- *It could benefit History, Geography, RE and more social science subjects but teachers appear to be burnt out with more technology being brought into the classroom*
- *It's a brilliant way to introduce the possibilities of VR to PME students as well as co-operating teachers.*
- *I think some teachers would love the idea while others who are not as able with IT would not use it*

Figure 19. Intention to use VR this academic year?

Although the open comments varied, the issue of teacher burnout and/or less digitally literate staff emphasized the importance of personal teacher traits. Some aspects were repeated, while new ones, such as technical difficulties, emerged. Nonetheless, the message was positive, as were the final comments (in Figures 20 and 21) from the participants who enjoyed working together and experiencing a new platform.

- *Not very clear to use for English. Would probably work better with History. (E)*
- *Lack of participation (N)*
- *Interesting to explore SchooVR in my second subject (E)*
- *Need more time to play around with it would be great, but hard to find the time (E)*
- *I wish the tech infrastructure (wifi etc) could actually function reliably. It does make it all a bit frustrating when there is a glitch. This is true for all tech in education though. (E)*
- *Difficulty working online in a group and trying create the VR. Only one realistically can do all the editing and I would of preferred to do some of this work myself. (E)*
- *A lot of technical difficulties not worth the hassle to create a VR experience* (N)

Figure 20. Comments after training demo—subject (grey), time (blue), motivation (yellow), technical issues (brown), intention to use (green), frustration (teal).

- *I very much enjoyed working alongside professional teachers in making a project together;*
- *Thank you for today's session. Was very insightful to see how VR has changed in the last 5-6 years since my PME training;*
- *Grateful to have had the time to play with this. It builds confidence when you have moments like these for experimenting and learning from experience;*
- *Thanks for sharing your platform with us and best of luck with it.*

Figure 21. Final thoughts from participants—self-improvement (pink), intention to use (green), motivation (yellow), time (blue).

6. Discussion and Conclusions

In this research paper, the focus was on exploring the educational benefits of SchooVR, a virtual reality (VR) platform, in supporting retrieval practice and enhancing the learning experience in secondary education. The study drew on the work of a number of cognitive scientists and education psychologists, including Rosenshine [24], who highlighted the importance of retrieval practice in strengthening memory connections and reducing cognitive load. By creating immersive VR experiences, student teachers, supported by co-operating teachers, had the opportunity to create resources for learners to practice retrieval, ask questions, and receive the necessary support to scaffold the learning process so that they could independently use this in their own classroom practice effectively.

The study emphasised the pedagogical aspects of using VR, with a focus on effective teaching and learning, rather than merely prioritising fun and enjoyment, which had been a common perception in the previous literature [11,12]. The use of text labels in VR resources, as suggested by Mayer [45], served as a helpful tool for summarising and focusing learners' attention on key learning goals, reducing the cognitive load [46] associated with distractions and superfluous information, and encouraging the generative processing needed for deeper understanding of VR content knowledge [47].

One notable aspect of the research was the implementation of a reverse-mentoring model [40] for online PD with student teachers and co-operating teachers. This model was also supported by technical expertise, which proved valuable for both novice and experienced teachers alike. The hybrid PD learning space, which combined in-person and online elements, was particularly well-received by novice teachers, given their prior experience with online learning during COVID-19 lockdowns. Collaborative exchanges between the experienced and student teachers were found to be mutually beneficial, with a high-level focus on the pedagogy of VR experiences.

While the study confirmed the innovative use of SchooVR as a resource for retrieval practice and highlighted the effectiveness of the reverse-mentoring model, there were methodological limitations, such as the small sample size and the absence of a control group for comparison. Looking to the future, further research is recommended to explore the development of resources that blend VR and retrieval practice across different subjects and age groups within secondary education. Long-term studies could investigate the retention of knowledge acquired through VR-based retrieval practice. Additionally, conducting comparative studies to assess the added value of VR-based retrieval practice compared to traditional methods would provide valuable insights into the benefits of VR integration in educational settings.

This research contributes valuable insights regarding the integration of VR technology into blended learning spaces, particularly in the context of concerns surrounding the educational effectiveness of technology in classrooms [48]. By combining best practices in retrieval practice [27–29], principles of instruction [24], and the effective utilisation of multimedia [45,47], this study underscores the potential for fostering meaningful pedagogy through the incorporation of VR technology. The multisensory nature of VR aligned with research-informed pedagogy, such as retrieval practice, has the potential to contribute to knowledge consolidation and the development of metacognitive skills through collaborative approaches to resource development and sharing.

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