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ABSTRACT:

The emergence of 5G communication technology has enabled the integration of extended reality (XR)—including AR, VR, and MR—into educational settings, creating new opportunities for immersive, cross-campus learning. This study investigates teaching practices and instructional challenges faced by a team of elementary school educators in Taiwan through the implementation of a 5G XR co-learning lesson focused on disaster preparedness. Drawing from direct teaching participation and qualitative data—including classroom observations, video recordings, and semi-structured interviews—the research explores how immersive technologies influence teaching roles and classroom dynamics in distance education. The findings highlight the importance of teacher adaptability, inter-school collaboration, and real-time classroom responsiveness in delivering effective XR-based lessons. This study proposes a practical framework for implementing digital co-learning under technological and logistical constraints, contributing scalable insights for instructional designers, policy-makers, and practitioners. It also underscores the potential of immersive technologies not only to enhance student motivation but to foster meaningful engagement with real-world problem-solving.

KEYWORDS: 5G XR Co-learning, Innovative Pedagogy, Teaching Practice, Distance Learning**1) Introduction:**

With the advancement and accessibility of 5G network technology, wireless communication speed has significantly improved, leading to new applications and conveniences for users. To promote the use of 5G technology in education, Taiwan's Ministry of Education initiated several programs aimed at integrating new technological equipment into classroom settings. The goal is to enhance the ability of elementary school teachers in Taiwan to utilize emerging technologies and develop innovative teaching and learning models. This study was conducted as part of the "2023–2024 5G Innovative Learning Demonstration Schools" project (Model 2), where the researcher participated in the program's instructional consultation and classroom observation. Through these experiences, the researcher identified three key stakeholder groups within the digital co-learning environment: teachers, administrative staff, and students. While the core focus of Model 3 teams is to evaluate student learning outcomes, administrative teams are typically composed of principals and faculty and play a supportive role, particularly in resolving technical issues. Teaching teams consist of broadcast (anchor) teachers, support staff, and on-site co-teachers. Each teaching session involves 5 to 8 personnel. Due to the innovative nature of the teaching model, many challenges are not apparent during pre-course planning. Teachers play a critical role in the success or failure of the lessons, especially given the limitations in human and material resources. Because the researcher had close contact with Model 2 schools, she also conducted additional fieldwork beyond consultation time, including teaching period planning and interviews with anchor schools, to deeply explore the instructional processes of XR-based co-learning in Nantou County. Teaching is a co-constructed process between teachers and students, with bidirectional influence (Chiu, 2010). This study employed full-course video recordings and semi-structured interviews to collect primary data, aiming to objectively reconstruct the teaching process using technology. Given that anchor teachers cannot directly observe the responses of students at receiving ends, the inclusion of on-site observation was essential. This allowed for a clearer comparison of teaching dynamics across different environments. This study aims to investigate the practical behaviors of teachers during the implementation of 5G XR co-learning and explore the challenges they encountered. The findings are expected to provide a reference for future schools developing similar digital learning models. Ultimately, teaching and learning are complementary—when both are harmonized, they can co-create enhanced educational quality and learning outcomes.

Research Objectives:

1. To construct a timeline of teaching behaviors in the implementation of 5G XR co-learning.
2. To examine the challenges faced by teachers participating in the 5G XR co-learning instructional process.

2) Literature Review:

2.1 5G XR-Based Co-learning. In recent years, the development of 5th Generation Mobile Networks (5G) has accelerated globally. With key features such as ultra-low latency, increased bandwidth, and high-speed data transmission, 5G offers transformative potential for educational practices. Technologies like mobile learning, IoT, artificial intelligence, virtual reality (VR), and augmented reality (AR) are becoming more feasible for classroom applications due to the advancement of 5G (Wang et al., 2020). Simultaneously, extended reality (XR), which encompasses AR, VR, and mixed reality (MR), gained rapid traction during the COVID-19 pandemic, as industries sought new ways to improve operational efficiency and collaboration. With 5G infrastructure in place, XR technology is expected to reach mainstream adoption and drive growth in education and telecommunications (Taiwan Institute of Economic Research, 2021). In Taiwan, the Ministry of Education initiated five digital education projects in 2023. Four of these projects aim to improve the public's competency in using digital technology. These efforts have quickly transformed educational resources and learning environments. Among them, the "5G Demonstration Classrooms" and device integration plans seek to create distance co-learning environments through the combination of 5G connectivity and XR headsets. These programs break the limitations of physical classrooms by enabling remote, collaborative, cross-campus learning—bridging gaps across urban, rural, and mountainous regions. The "2023–2024 5G Innovative Learning Demonstration School Project" integrates tablets and wearable devices with digital learning tools such as AR, VR, and the metaverse. Courses are designed to meet key performance indicators (KPI) across five levels of delivery—from 360-degree panoramic streaming to virtual teachers (VTubers) and 3D object-assisted learning. Most importantly, the project aims to establish a sustainable co-learning model where spatial barriers no longer impede shared educational experiences. The "2023–2024 5G Innovative Learning Demonstration School Project" integrates tablets and wearable devices with digital learning tools such as AR, VR, and the metaverse. Courses are designed to meet key performance indicators (KPI) across five levels of delivery—from 360-degree panoramic streaming to virtual teachers (VTubers) and 3D object-assisted learning. Most importantly, the project aims to establish a sustainable co-learning model where spatial barriers no longer impede shared educational experiences.

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Figure 1. KPI Structure for XR-enabled Learning Models (Adapted from the 2023–2024 5G Innovative Learning Demonstration School Project, Model 2 Office)

Level 1- 360攝影機XR直播授課

Level 2 -真人教師虛實整合XR直播授課

Level 3 -VTuber教師虛實整合XR直播授課

Level 4 -3D物件輔助XR直播授課

Level 5 -異地XR直播授課

Figure 2. Hierarchical Levels of XR Live Broadcast Modes (Adapted from the 2023–2024 5G Innovative Learning Demonstration School Project, Model 2 Office)

2.2 Innovative Teaching Models. Due to the novelty of the 5G XR co-learning model, existing literature on similar instructional approaches is limited. Therefore, this study draws upon related concepts such as blended learning and distance education to contextualize the model's pedagogical implications.

2.2.1 Blended Learning Models. Blended learning integrates digital tools into face-to-face classroom instruction, allowing students to engage in learning without constraints of time and space (Wang, 2021). Its core characteristics include: (1) individualization—tailoring instruction to diverse learners and promoting autonomy; (2) technological integration—enhancing motivation and engagement through tech-supported instruction; (3) hybridity—using varied learning environments and resources; and (4) real-time feedback—enabling ongoing performance monitoring and adjustment (Wu, 2015).

2.2.2 Distance Learning. Distance education refers to the instructional exchange between teachers and students via communication technologies such as internet platforms, video channels, and networked computers (Kang, 2020). Historically, this mode began as correspondence education in the 19th century, relying on mail-based delivery and written interaction. With the advent of radio, television (Tseng & Lin, 2000), computers, mobile devices, and now 5G, learning is no longer restricted to a classroom—any place with connectivity becomes a learning space. The year 2020 marked the beginning of the “distance learning era” in Taiwan (Pan, 2020). Furthermore, the integration of technology into teaching practices aligns with the Technological Pedagogical Content Knowledge (TPACK) framework, which emphasizes the intersection of technological, pedagogical, and content knowledge in effective teaching (Mishra & Koehler, 2006).

2.3 Summary. While blended learning offers a hybrid model of online and in-person instruction, it does not yet account for wearable device integration. Nevertheless, its features—particularly in supporting learner motivation—closely align with XR-based co-learning. Furthermore, though distance learning also spans space and time, both models often fall short in delivering real-time feedback.

The 5G XR co-learning model, by contrast, combines elements of both and introduces immersive engagement to enhance student motivation and performance. With anchor teachers guiding the overall learning experience and receiving-end instructors offering direct assistance, this dual-instruction structure helps create a more complete and interactive learning environment.

3). Research Methodology

This study adopts a qualitative, interpretive approach to explore the teaching processes and challenges associated with the implementation of 5G XR co-learning. Data were collected from primary sources, including classroom observations, individual and group semi-structured interviews, document analysis, and video recordings of the teaching process.

3.1 Research Participants. The study was conducted at an elementary school in Nantou County during the 2023 academic year, which participated in the national 5G XR Digital Co-learning Project. The participants included one anchor (broadcast) teacher responsible for course delivery and two receiving-end teachers involved in facilitating the lesson on-site. All three teachers had over 20 years of teaching experience and had previously engaged in technology-integrated teaching for at least three courses. While elementary school students who participated in the lesson were observed, the study did not evaluate individual student performance; instead, student involvement and post-class assessment data served as contextual references for the analysis.

3.2 Research Design. This research focused on an interdisciplinary lesson titled “Typhoon Emergency and Drowning Survival”, designed to integrate 5G technology and local disaster awareness in Nantou County. The study included the planning and implementation stages of this co-learning course. Pre-study communications were held two to three times with the participating teachers to finalize the lesson plan. During instruction, video recordings were conducted using two cameras at the anchor site and four at one of the receiving-end classrooms. Following the lesson, three participating teachers engaged in both group and individual semi-structured interviews. The discussions covered topics such as pressures from project KPIs, real-time classroom management strategies, and feedback from the receiving schools. All qualitative data were then collated and analyzed to build an instructional model representative of 5G XR co-learning in Nantou County and to investigate practical implementation issues across different teaching roles.

4). Teaching Practice Process

4.1 Course Design. During the planning phase of the lesson, the teaching team was required to submit the instructional design to the Model 2 office for approval. Teacher A shared insights into how the course materials were selected and the lesson structure was developed:

“When it comes to materials, we usually start by searching for software. Last semester, we covered air pollution, so that’s what we looked for first. This semester, we originally planned a CPR lesson, but due to time constraints, we had to change direction. That’s when we landed on drowning survival. I found an AR picture book from the Fire Department that included a strong typhoon scenario, and it tied in perfectly with the landslide we experienced last summer in Ren’ ai Township. Everything just clicked.”

We also had two different models of virtual reality headsets this year, which made things even more complicated. Some apps worked on one model but not the other, so it took a lot of testing to find something that functioned reliably across both.”

From these reflections, it is evident that the anchor-site teacher’s responsibilities extended beyond teaching. They also had to manage hardware infrastructure at the broadcasting studio and oversee course planning. The lesson design had to align with KPIs and reflect local themes, while remaining appropriate for both elementary and junior high school students. Because each receiving school had different levels of hardware and student age ranges, the content needed to be adaptable. In Nantou County, the teaching team began their planning using locally relevant topics such as disaster prevention, which matched the geographic conditions of the region. Teachers used the Ministry of Education’s Digital Content Marketplace to find and test instructional materials that complemented their educational background, especially in reading instruction. These efforts culminated in the development of a themed lesson titled “Typhoon Emergency – Drowning Survival.” The lesson observed for this study lasted 70 minutes, including 10 minutes allocated for post-class surveys. The session involved one anchor teacher (Teacher A) teaching from a green-screen studio equipped with 5G, broadcasting, and editing tools, supported by two technical assistants. The receiving-end schools were located throughout various towns in Nantou County and included two to five classes from elementary and junior high levels. The recorded session involved fifth-grade students and two receiving-end teachers (Teachers B and C), with one technical assistant. Administrative staff initially coordinated with participating schools to schedule the sessions and discuss the lesson theme. Teacher A then managed all technical preparation, including lesson plans, streaming links, QR-coded learning tools, and equipment distribution. On the day before the class, software installations and web-based tools were tested. Sixty minutes before the lesson, both anchor and receiving schools conducted hardware and internet checks. Fifteen minutes before class, receiving-end students logged into the learning platforms and verified their setup. The lesson opened with a 360-degree video and a news segment introducing the effects of typhoons and flood preparedness. Students viewed the broadcast using a combination of tablets, VR headsets, and large display screens, then participated in an anonymous discussion on the HiTeach platform. Responses were visible to all, prompting further teacher-led summary and discussion.

The second phase of the session introduced hands-on experiences with:

AR Activity: An AR picture book-based simulation housed in the “Disaster Simulation Pavilion” (see Figure 3). VR Activity: A virtual experience based on drowning survival, sourced from Taiwan’s National Teaching Materials Portal (see Figure 4).



Figure 3. Virtual Disaster Simulation Experience (AR Book Interface) from Fire Department educational materials.



Figure 4. Drowning Survival VR Experience Interface, from Taiwan’s National Teaching Materials Marketplace.

Students were divided into two groups and rotated through the AR and VR stations. The final stage included summary remarks by the anchor teacher and a follow-up survey facilitated by the receiving-end teachers. Since this was the third iteration of the lesson, several improvements had been made:

1. AR and VR activities were conducted in parallel to reduce wait times caused by limited devices.
 2. AR materials were printed on paper rather than viewed via shared screens to enhance scan accuracy and reduce distractions.
 3. Some VR headsets were upgraded to include monitoring software that allowed teachers to track student progress and focus.
- The actual implementation of the lesson closely followed the planned schedule and instructional content. Based on the video recordings, a time-distribution chart (Figure 5) was created to compare scheduled and real-time execution. The following breakdown highlights how the class was conducted:
1. Student Setup and Preparation: Upon entering the pre-assigned classrooms, students performed equipment checks and logged into the required platforms. This process was originally estimated to take 15 minutes but was completed in 12, indicating increased student familiarity with the tools.
 2. Video Introduction and Lesson Opening: The class officially began with a news clip about Typhoon Khanun, shown by the anchor teacher. Students, using tablets and VR headsets, accessed the live stream and engaged with the content, which emphasized the impact of typhoons in mountainous areas like Ren'ai Township. This segment helped activate prior knowledge and raise awareness about disaster prevention. Students then participated in a discussion using the HiTeach platform, which allowed anonymous answers. These responses were used as prompts for a short teacher-led debrief. This phase extended slightly beyond the planned time by about one minute.
 3. AR/VR Operation Tutorial: Teachers provided step-by-step instructions on using the devices and platforms for the two interactive learning segments. On-site teachers supported students through setup and transitions.
 4. AR/VR Experience: Students, divided into pairs due to equipment limitations, alternated between the AR and VR stations on a 15-minute rotation schedule.
 5. Lesson Summary and Post-class Activities: After the main activities, the anchor teacher summarized the key takeaways. Due to time constraints, the lesson allowed only limited additional discussion. Follow-up surveys and classroom resets were completed afterward. If needed, post-surveys were administered later based on each class's timeline.

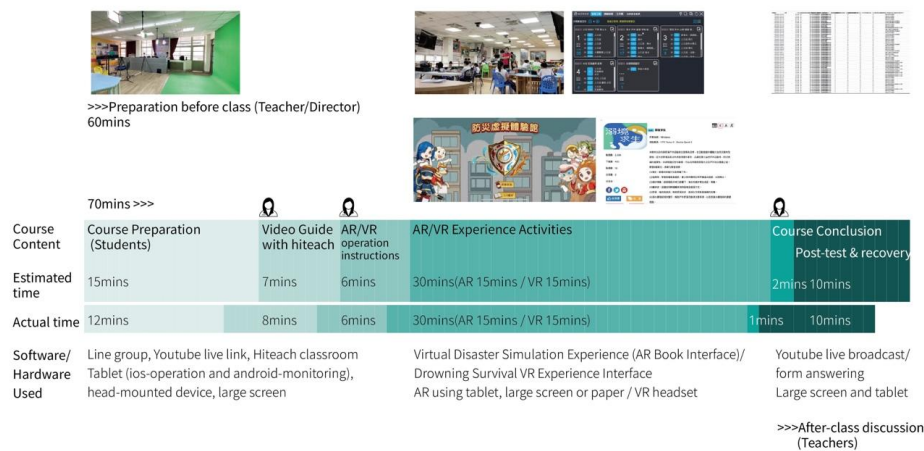









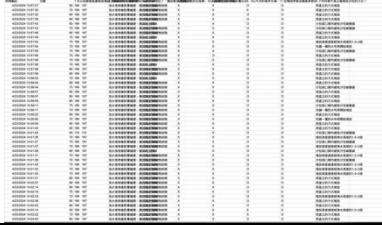
Figure 5. Comparison of Planned vs. Actual Lesson Time Allocation

Teacher A, who had taught over six live-streamed sessions, reflected on the technical challenges of synchronizing the course flow with the broadcast visuals. Initially, a detailed script was used to help the director manage timing. However, without a verbatim script, teachers often strayed from the plan, making it hard for the director to cue the visuals at the right moments. To resolve this, Teacher A and the director agreed to use on-screen subtitles with cue words that would signal when to switch scenes. This improved timing control significantly, though it also required the anchor teacher to bring more energy and personality to animate what could otherwise be a rigid script.

4.2 Classroom Implementation. The research team arrived at the anchor site approximately 40 minutes before the scheduled lesson to set up video recording equipment. Two iPad minis were used to record different angles of the green-screen studio and the broadcasting director's control station. At the receiving-end site—configured as a tiered lecture hall—two additional devices were positioned at the front podium and rear equipment area for continuous front and back recording. The implementation documented in this study was the third iteration of the "Typhoon Emergency – Drowning Survival" lesson. Table 1 captures segmented screenshots and observational notes from both the anchor and receiving-end locations. These include visual breakdowns of teaching phases and commentary on in-situ challenges. Teacher A continuously refined the lesson content based on feedback from the receiving-end instructors. As a result, the overall fluency and timing of this session closely matched the planned lesson script. However, several areas for future improvement remain and are addressed in the next section.

Table 1. Summary of 5G XR Co-learning Classroom Observations

Classroom Observation		
Lesson Theme: Typhoon Emergency		
Instructor: Teacher A		
Observed Students: Fifth-grade students at an elementary school in Nantou County		
Other Simultaneous Participants: First-year junior high school students		
Date of Observation: April 23, 2024		
Time: 13:00–14:10		
Location: Tiered lecture hall and green-screen studio at an elementary school in Nantou County		
Lesson Content	Green-screen studio (anchor)	lecture hall (receiving site)
Personnel	1 anchor teacher + 2 broadcasting directors	receiving-end teachers + 1 technical support staff
Teaching Spaces	Green-screen studio (anchor)	lecture hall (receiving site)
Pre-Class Setup		

	<p>Teacher A used LINE to confirm student login statuses with teachers at the various receiving-end locations.</p> <p>Observed Issues:</p> <p>Some receiving-end teachers did not report back on their students' login status.</p> <p>The anchor teacher had to adjust HiTeach class permissions and reissue the QR code. This delayed the entry process for some receiving sites, as they needed time to receive and process the new information. However, all participants successfully logged in before the scheduled lesson start time.</p>	<p>Teacher B supported login and platform access confirmations for students.</p> <p>Observed Issues:</p> <p>Students who completed device setup early had no alternate activity and were idle while waiting.</p> <p>Elementary school periods are shorter than junior high sessions, so the class was scheduled during the lunch break for synchronous participation.</p>
<p>Opening Phase</p>	 <p>On-site Observation – Anchor Site (Lesson Opening): The broadcast director at the anchor site initiated scene delivery, and Teacher A began the opening segment and motivational framing.</p> <p>Observed Issues:</p> <p>Scene switches by the director occasionally lagged by a few seconds, causing Teacher A to lose confidence in the timing of verbal explanations.</p> <p>The large monitor at the anchor studio did not display the real-time status of students at the receiving sites, limiting the anchor teacher's ability to adjust based on student feedback.</p>	 <p>On-site Observation – Receiving Site (During Broadcast Monitoring): Teacher B monitored the student experience by logging into the session via mobile phone to view what students were seeing. Additionally, by using headphones, the teacher was able to listen in on the broadcast to understand exactly what students were hearing. Students participated in the lesson using tablets paired with headphones, or via large screens operating in silent mode.</p> <p>Observed Issues:</p> <p>Teacher B noticed that the background audio was louder than Teacher A's voice and immediately reported the issue to the anchor-site director.</p> <p>Real-time feedback from other receiving schools—especially those not physically co-located with the anchor site—could be delayed or blocked due to network instability or communication lapses, leading to potential disruptions that would require on-site teachers to improvise based on their own judgment.</p>
<p>Mid-Class Briefing Instruction on upcoming AR book and VR experience</p>	 <p>On-site Observation – Anchor Site (Instructional Guidance): Teacher A provided operational guidance for both the AR picture book and the VR platform by sharing a demonstration of the software interface.</p>	 <p>On-site Observation – Receiving Site (Student Engagement): Students at the receiving end were visibly eager and enthusiastic, showing clear anticipation to proceed to the next stage of the lesson.</p>
<p>Hands-On Activities</p> <p>Group-based rotation between AR and VR stations</p>	 <p>On-site Observation – Transition Phase: The broadcast director displayed a countdown timer on screen while Teacher A temporarily assisted students at the receiving-end site.</p> <p>Observed Issues:</p> <p>The director was responsible for tracking the schedule and needed to remind Teacher A to return to the anchor station before the activity rotation.</p> <p>The director attempted to monitor classroom conditions at receiving schools via LINE messages, but this method did not provide a fully real-time view of students' actual interactions or engagement.</p>	 <p>On-site Observation – Receiving Site (Hands-on Activity Phase): Half of the students were stationed at the front podium area to engage with the AR picture book, while the other half remained at their seats to experience the VR simulation.</p> <p>Observed Issues:</p> <p>Students using the AR interface occasionally scanned the wrong picture book, resulting in disrupted progression and mismatched content.</p> <p>The AR and VR sessions could not be perfectly confined within the 15-minute rotation window. Some students finished early, while others were unable to complete the experience, leading to fragmented learning continuity.</p> <p>A few students were unfamiliar with the device operations. While receiving-end teachers assisted in resolving technical issues, in the observed class, some students were proactive in helping their peers troubleshoot and continue the learning activity.</p>
<p>Wrap-Up Phase</p>	 <p>On-site Observation – Anchor Site (Lesson Conclusion): Teacher A provided a final summary of the session and reminded the receiving-end teachers to assist their students in completing the post-lesson test and end-of-term feedback questionnaire.</p>	 <p>On-site Observation – Receiving Site (Post-lesson Activity): After completing the interactive sessions, students used their tablets to view a summary screen and complete the post-lesson assessment and final questionnaire.</p>

4.3 Classroom Implementation. Following the lesson, both group and individual interviews were conducted. Prior to the session, an outline of the discussion topics was provided to all three participating teachers. During the interviews, these topics were further expanded based on real-time teaching experiences and specific classroom scenarios. Although the discussion covered multiple courses, this study focuses solely on the lesson titled "Typhoon Emergency – Drowning Survival." The interview protocol explored the course in three phases: before, during, and after implementation.

1. Pre-class Preparation: Teacher A, who served as the anchor teacher, was responsible for designing the lesson plan and coordinating with the Model 2 office. Scheduling discussions, student selection, equipment needs, and software deployment were addressed during pre-course meetings with the participating schools. Teacher A managed all communication, including one consensus meeting per cycle and ongoing LINE communication with the receiving-end teachers. This was the third time Teacher A had taught this lesson, and the course was continually refined based on previous feedback:

"The KPI wasn't a problem this year... As long as the way I'm teaching works for the teachers, that's good enough. I've taught this same course three times, and each time, the feedback has helped me revise it. Like this time—I changed how I used the materials again. It's improved. I even printed out the AR book pages today because last time, they just photocopied it in black and white and it worked well. So I followed that too. It's actually been a benefit."

"The work meetings just set the initial schedule. Everything else we worked out via LINE. The schools at the receiving end were great—they really cooperated well."

Teacher B also reflected on their role in preparation:

"We're not the ones developing the materials, so our job is to make the class flow smoothly. We try to communicate expectations clearly so students understand how to participate, especially when the content is complex or time-consuming. Right now, there aren't many available teaching resources like this, so our options are still limited."

2. During the Lesson: The lesson involved two major instructional components. At the anchor site, Teacher A guided students with a blend of pre-recorded content, HiTeach interaction, and demonstrations—accounting for approximately 14 minutes of airtime. Direct instruction totaled less than six minutes, as the lesson emphasized multimedia interaction to stimulate learning motivation. At the receiving end, teachers led most of the activities, including technical setup, device management, and student guidance. From the recorded session, it was clear that five teachers were involved in real-time support. Students faced a variety of challenges: some were confused even after receiving instructions, others were distracted by peers, and several had difficulty completing the VR experience due to unfamiliarity with the equipment. Notably, some students spontaneously helped their peers, and even protected classmates immersed in the VR activity.

Teacher B emphasized the crucial role of receiving-end teachers:

"We have to keep track of the entire lesson flow, constantly remind students what's happening, and solve problems as they come up. We also need to relay important issues back to the anchor site. Every class and school is different, so adaptability is key."

"We're always trying to improve the process. Like today—I brought wireless earbuds so I could hear the main instructor clearly. That's how I realized the background noise was too loud. So I gave quick feedback and helped fix it. That's the kind of thing on-site teachers need to handle in the moment."

"We also noticed differences in what students were seeing. Some were watching the wrong thing—YouTube, Threads, even missing transitions. Clearer cues from the anchor site would help prevent that kind of confusion."

3. Post-class Assessment: Students participated in a pre-lesson discussion using HiTeach to explore the concept of typhoons—natural versus human-induced disasters. Results (Figures 6–7) showed a solid grasp of the topic, with only a few students submitting irrelevant answers. In the post-lesson assessment, 79 students participated. All but one student passed, and 38 students achieved full marks (Figure 8). This suggests that the immersive experience contributed positively to understanding the core course themes.



Figure 6. All but one student passed, and 38 students achieved full marks



Figure 7. All but one student passed, and 38 students achieved full marks

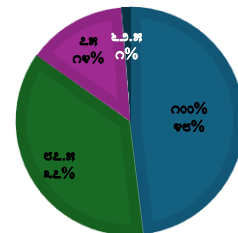


Figure 8. All but one student passed, and 38 students achieved full marks

Teacher A reflected on their instructional choices across multiple iterations of the course:

"In the past two runs, I didn't do any post-tests. This time, I thought, hey, maybe I should give it a try. Before, we had HiTeach discussions, so I felt a post-test wasn't necessary. But this time, without the HiTeach component, I added the post-assessment."

This suggests that adjustments were made based on contextual needs and accumulated teaching experience. While elementary school teachers may not always apply statistical frameworks to assess reliability and validity, the content of student responses offered qualitative evidence that learning objectives were met.

Teacher B, also the classroom instructor, provided insight into interpreting student performance:

"Interest is always there—especially with something this novel. They were excited. But when they answer incorrectly, it's probably because of their mindset at that moment. Some might just be focused on passing the challenge, not really integrating the concept. That's why guidance is so important."

This reflects how student mindset during activity engagement can affect learning outcomes, and indicates the potential value of future research into affective learning factors.

Teacher C, the anchor teacher for the next session, added:

"What I really hope is that students can reflect—if they ever face something like this at home, they'll know how to respond."

This highlights a broader perspective on learning achievement that extends beyond test scores to real-world application—suggesting another valid metric for evaluating learning effectiveness.

5. Conclusion and Recommendations

Based on classroom observations, lesson recordings, and post-lesson interviews, this study synthesized key insights into the implementation of 5G XR co-learning. Several challenges and corresponding strategies were identified:

Expanding Modalities and Materials

The integration of 5G XR technologies has enabled innovative instructional models that transcend spatial limitations and foster inter-school collaboration. This new learning approach offers diversified experiences for both teaching and learning. However, one key limitation lies in the scarcity of available instructional materials tailored for XR formats. Most teachers are unable to develop content independently and must rely on educational platforms such as Taiwan's National

Teaching Materials Marketplace. While the Ministry of Education continues to invite collaboration between university scholars and K–12 teachers to expand content offerings—such as locally themed disaster-preparedness lessons—there remains a need for more diversified, accessible content to support curriculum development at scale.

Teacher Preparedness and Cross-Site Collaboration

The success of 5G XR-based co-learning depends heavily on the psychological readiness and adaptability of the teachers involved. All three teachers interviewed in this study had over 20 years of teaching experience and demonstrated a high degree of openness toward emerging technologies and instructional software. Their mutual support and real-time adaptability played a vital role in ensuring smooth lesson delivery. However, due to time constraints, this study was unable to gather data from additional receiving-end teachers. As such, future research could further explore how co-teaching relationships and technological confidence vary across different sites and school types.

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7] **Data Availability:** “No new data were created or analyzed in this study. Data sharing is not applicable to this article”.

8] **Conflict of interest:** "None"

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