Hakka Kitchen: Immersive Game-based Representation of Culinary Cultural Heritage

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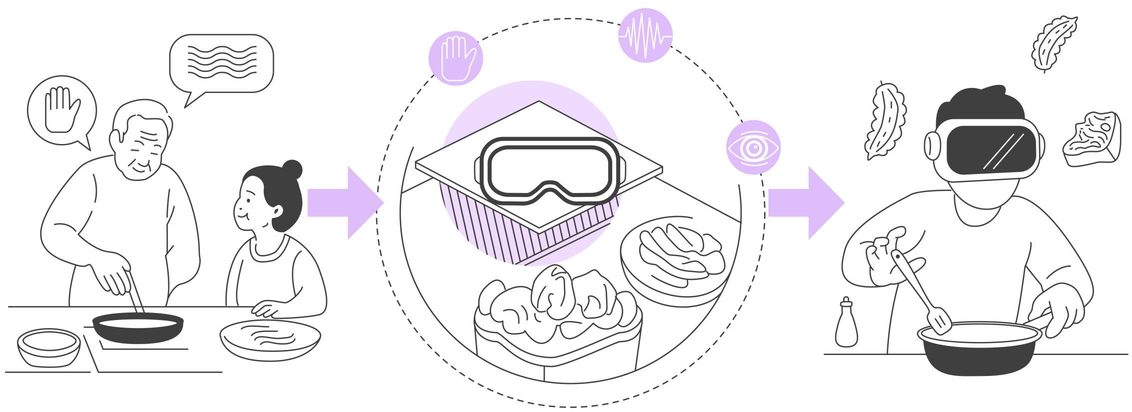

Fig. 1. Hakka Kitchen showing a learner in a VR kitchen guided by a Hakka chef to prepare stuffed bitter melon; highlights the paper's focus on embodied, procedural representation and its superior engagement over non-interactive VR video.

Intangible Cultural Heritage (ICH) experiences are difficult to share with the public because they are essentially processes that rely on physical interactions in a specific cultural context. We consume noninteractive media such as videos and books to learn about culinary ICH experiences, but they do not allow us to grasp the actual interactive procedures that embody the cultural knowledge. In order to engage people in a traditional cooking experience, we created a VR game where players are guided by a Hakka chef through a modeled physical process of making the traditional dish of stuffed bitter melon. Compared against watching a video in VR providing the same information noninteractively, our game led to increased sensory engagement with the culinary cultural heritage and willingness to transmit awareness for the ICH (N=40). Our work shows how representing interactive procedures instead of static content may empower cultural awareness.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: Edutainment design, Virtual reality, HCI, Intangible Cultural Heritage

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1 Introduction

Intangible cultural heritage (ICH) encompasses traditions or living expressions inherited from our ancestors and transmitted to descendants, including oral traditions, performing arts, social practices, and traditional craftsmanship[75]. It constitutes cultural identity, preserving millennia of communal memory, ancestral wisdom, and sociopolitical relationships that link societies over time[80, 82]. ICH is vital to maintain strong and diverse cultures in a rapidly changing world [3]. However, for process-based culinary ICH, theoretical knowledge alone is insufficient to ensure their vitality [84]. The core of this heritage lies in the embodied process of hands-on practice, where tacit knowledge and refined skills must be transmitted and comprehended through direct experiential engagement. Consequently, safeguarding this specific form of ICH necessitates approaches that facilitate active participation and firsthand experience[68].

Current mainstream methods for documenting and transmitting culinary ICH predominantly rely on non-interactive media, including documentary films, short videos, and recipe books [4, 70, 76, 83]. While valuable as information carriers, the passive nature inherent in non-interactive media fundamentally constrains their capacity to effectively communicate the multisensory experiences (e.g., olfactory, tactile, auditory dimensions) essential to cooking practices[17, 32, 67, 71], the nuanced operational knacks embedded within specific techniques, and the dynamic cultural contexts underpinning these traditions[16, 58].

Meanwhile, digital games, characterized by high interactivity and immersion, have significant potential for engaging users and simulating complex procedural systems[5, 12, 21, 37]. Specifically, their capacity to facilitate embodied simulation through kinesthetic and multisensory feedback aligns with the cognitive mechanisms through which culinary expertise is developed. However, existing applications in the culinary domain largely prioritize entertainment value[23, 63], often oversimplifying processes and cultural depth. Their potential for effectively preserving and transmitting the intricate, knowledge-intensive nature of process-based culinary ICH remains significantly underexplored and underutilized. This gap highlights a critical need for dedicated research to utilize interactive digital media, specifically designed games, for the effective education and transmission of culinary ICH.

To bridge this gap and explore this potential, we developed "**Hakka Kitchen**", an immersive VR game, using the Hakka culinary heritage as a specific case study. It moves beyond passive consumption by enabling players to actively engage with Hakka culinary heritage within a virtual hands-on environment. Players interact with authentic ingredients, learn traditional techniques through step-by-step guidance, explore relevant cultural narratives, and virtually prepare Hakka dishes. The core design of the game focuses on simulating critical sensory cues (e.g., visual changes, sound feedback), replicating precise motor skills, and embedding contextual cultural knowledge within the procedural gameplay. This study has a dual purpose: (1) to present the design of this VR game as an intervention for culinary ICH transmission, and (2) to empirically assess its impact. Specifically, we investigate the following research questions:

RQ1: How can we represent culinary ICH using interactive game mechanics?

RQ2: How do players interact with elements in the game in engaging with culinary ICH content?

RQ3: What is the effect of the game experience on players interest, knowledge, and awareness of culinary ICH?

Our contributions are: (1) We contribute an embodied representation of culinary ICH that couples a chef-elicited procedural dictionary with physics-based manipulation, natural hand interactions, and multisensory feedback to encode tacit, process-based know-how in situ. Cultural narration is interleaved with step execution so meanings surface at the moment of action; guidance is step-synchronous via lightweight instructions, optional hints, and immediate feedback to support exploration and error-recovery. (2) We contribute a player–environment interaction model for

ICH learning that blends diegetic scaffolds (glowing affordances, audio mentorship) with an apprentice framing to sustain immersion and motivate practice. The design emphasizes recoverable errors, friendly undo, and real-kitchen semantics so players can iterate safely while maintaining ecological validity; optional hints and timed reminders adapt support to behavior in the moment. (3) We contribute an empirical comparison of an interactive VR cooking game with a matched VR video, examining interest, procedural knowledge, and cultural-heritage awareness, and qualitatively tracing how enactment, pacing control, and recoverable mistakes shape engagement and perceived transfer, yielding concrete design implications for ICH technologies.

2 Background

2.1 Intangible Cultural Heritage

Intangible cultural heritage (ICH) encompasses "the practices, representations, expressions, knowledge, and skills" that communities recognize as part of their cultural legacy. Unlike physical artefacts, these traditions are embodied, socially transmitted, and highly vulnerable to erosion under globalization and demographic change [28]. Culinary ICH exemplifies this complexity, requiring the transmission of not only what is done but how and why it is done, which is difficult to store in purely textual or audiovisual media [40].

Diverse modalities contribute to safeguarding process-rich ICH. Early digitization prioritized object-centric media (scans, photos, videos), neglecting procedural and affective layers [81]. Community-based inventorying formalizes participatory documentation, positioning practitioners as co-authors and improving authenticity and uptake [74]. Social live-streaming and short-video platforms (e.g., TikTok/Douyin) have emerged as large-scale dissemination channels for ICH performance and practice, associated with increased public engagement and cross-cultural awareness [53, 77]. Interactive web documentaries and mobile storytelling scaffold non-linear sense-making around heritage, complementing archives with context and affect [56]. While recent scholarship proposes data-centric resources such as Recipe1M+ (recipes–images) [44], FoodKG (semantics-driven graph)[24] as richer data infrastructures to model culinary knowledge as linked, computable structures for retrieval, substitution, and pedagogy, ontology-driven extraction of subject–predicate–object triples from heritage texts to build linked data graphs [72], GIS-powered mappings that fuse tangible and intangible layers of urban history [29], and motion-capture pipelines that visualize folk dances to safeguard choreographic knowledge [81], they remain limited in conveying embodied, sensorimotor-dependent practices. These multi-modal forms expand reach, searchability, and community control, yet they rarely enact the closed sensorimotor loops needed for learning tacit, stepwise skills.

Virtual- and augmented-reality have become central to communicating embodied skills. Controlled studies report that VR cultural-heritage applications increase retention, concentration, and learner motivation compared with non-immersive media [42]. In tourism contexts, AR overlays situational narratives onto real sites, eliciting higher emotional engagement and perceived authenticity [69]. Design research has also explored panoramic VR maps that document craft techniques at scale [19] and 360° video tours that heighten immersion for remote audiences [65]. Nevertheless, most empirical work still targets visual-spatial heritage (architecture, performance), leaving process-rich culinary practices under-examined. Game-based learning provides an established paradigm for situated cognition in heritage contexts. The SandBox Serious Game model situates micro-tasks within realistic 3-D worlds to foster exploratory learning [2] . Subsequent work has extended this logic to AR treasure-hunts in historic villages [6] and VR titles whose continuance intention is driven by immersion and cultural relevance [57]. Yet comparative reviews note that the majority of ICH games focus on visual spectacles rather than intricate, step-wise skills such as traditional food preparation [59].

Previous works demonstrate a trajectory from static digitization toward immersive, interactive, and AI-mediated experiences that better embody the “live” qualities of ICH. Early culinary deployments and AR cooking assistants report viable task performance and learner satisfaction while avoiding safety/cost constraints of real kitchens [49]. Moreover, augmenting VR with olfactory and haptic/thermal feedback increases presence and decision fidelity, strengthening preconditions for skill transfer [46, 54]. However, complex culinary traditions—where tacit know-how, multi-sensory cues and sociocultural meanings intertwine—remain sparsely represented across these modalities. For culinary ICH specifically, VR is compelling because it can (i) simulate kitchen contexts safely and repeatably; (ii) couple user actions with multisensory cues (appearance, timing, and sound) that underpin judgment in cooking; and (iii) embed narrative, feedback, and progression typical of serious games to externalize tacit techniques as assessable interactions. Evidence from adjacent domains indicates VR training can improve motivation, presence, and psychomotor performance versus video/desktop baselines [8]. *Lost Recipes* is a commercial VR game that invites players to cook historical dishes from cultures such as Mayan, Chinese, and Greek [52]. Although it explicitly positions itself at the intersection of education and entertainment, no systematic evaluation of its cultural or procedural learning outcomes has been reported. This highlights both the promise of VR for culinary ICH and the need for empirically grounded, expert-informed approaches—an agenda our work seeks to advance.

2.2 Embodied Cognition

The effective transmission of culinary ICH is fundamentally based on the theory of embodied cognition [66]. This posits that human cognition, which encompasses perception, learning, memory, and skill acquisition, occurs not solely through abstract symbol manipulation within the brain, but emerges dynamically from the ongoing sensorimotor interaction between an individual’s physical body and its surroundings [18, 78]. In culinary practice, the dynamic interaction is fundamental to how tacit knowledge and refined skills inherent in culinary heritage are formed and transmitted [1, 34].

However, current mainstream methods for documenting and transmitting culinary ICH, such as videos, books, and other non-interactive media, face inherent limitations in capturing its embodied, situated, and sensorimotor-dependent nature. These disembodied and passive approaches, while capable of visually depicting or describing actions, intrinsically fail to provide learners with a full situational context extending beyond visual representations. Consequently, this disembodiment creates a significant barrier to effectively transmitting the nuanced, tacit, and sensorimotor-dependent core knowledge and skills characteristic of a process-based culinary heritage such as Hakka cuisine.

VR addresses this gap by enabling embodied simulation. Through head/hand tracking, VR immerses users in simulated culinary environments, fostering spatial presence. Users virtually manipulate tools/ingredients; linking actions to visual/auditory cues provides critical kinesthetic feedback. Crucially, VR creates dynamic sensorimotor loops: actions (e.g., stirring) trigger sensory consequences (visual/sound/vibration changes), requiring user response to approximate real-world feedback mechanisms for skill acquisition. Applications such as *Digital Diabolo* [35] and *ShadowPlayVR* [25] demonstrate VR’s capacity to externalize tacit cultural techniques through embodied interaction, offering precedents for how similar principles can be applied to culinary ICH.

2.3 Educational Awareness for ICH safeguarding

Given the valuable role of education in safeguarding ICH, the UNESCO 2003 Convention for the Safeguarding of Intangible Heritage explicitly recognizes the transmission of ICH "through formal and non-formal education" as a core safeguarding measure[27].This institutional recognition underscores the imperative to promote educational awareness in safeguarding ICH[9, 10, 15], ensuring that people not only acquire knowledge but also develop a deeper understanding and appreciation, which is essential for ICH continuity.

The pursuit of educational awareness faces heightened challenges for process-based ICH, exemplified by culinary traditions. These heritage forms depend intrinsically on embodied skills and tacit knowledge[43], making them difficult to teach through conventional methods. Traditional documentary methods including films, videos, and recipe books play a crucial role in archiving static information[41] such as ingredient lists, basic steps, and cultural narratives. Yet their inherently non-participatory and observational nature[11, 55] imposes fundamental constraints. They cannot effectively support hands-on practice, sensory engagement, or experiential learning[1]. For example, watching videos or reading instructions may convey factual knowledge, but they cannot provide the complete sensory experience[73], such as the tactile, olfactory, and motor coordination that comes only through hands-on practice[51, 64]. Similarly, passive learning fails to impart appreciation for nuanced skills, such as the subtle control of timing, pressure, or ingredient handling that defines authentic cultural tradition. While these media formats remain valuable for archival purposes, they ultimately cannot create the profound, practice-based understanding needed for effective safeguarding through education.

To overcome these limitations, recent studies have explored interactive digital technologies as a means to foster deeper educational awareness in ICH safeguarding[20, 61]. VR cooking games, in particular, offer a promising avenue for simulating culinary ICH. However, prevailing applications remain predominantly entertainment-focused[33, 50], prioritizing gameplay mechanics[62] and recreational enjoyment, or designed for medical rehabilitation purposes[39] such as motor skill recovery[22] and cognitive therapy[36, 79]. Crucially, neither orientation addresses the dual core imperatives of culinary ICH transmission: the effective conveyance of embodied skills (e.g., wok-tossing techniques, fire modulation) and the preservation of sociocultural meanings interwoven with food preparation rituals.

Thus, a critical preservation gap persists: UNESCO's educational mandate remains unrealized due to the passive constraints of traditional media—which preclude embodied practice for process-based ICH like Hakka cuisine—and the misaligned objectives of existing VR tools—which subordinate cultural education to entertainment or therapeutic goals. This dual inadequacy leaves the procedural, sensory, and cultural dimensions of culinary heritage transmission fundamentally unaddressed. To bridge this gap, our research leverages Hakka cuisine as a paradigmatic case, developing a VR game explicitly designed to encode procedural knowledge through embodied simulation while embedding socio-cultural narratives.

3 Game Design

3.1 Game Overview

Hakka Kitchen is an immersive VR cooking game designed to preserve and transmit intangible cultural heritage (ICH) through embodied, interactive learning. The game centers on the preparation of stuffed bitter melon—a representative Hakka dish—and situates players as apprentices within a virtual kitchen environment.

The gameplay is structured around a five-stage cooking sequence: (1) mixing minced pork with seasonings, (2) slicing bitter melon rings, removing pith, and blanching, (3) stuffing melon rings with meat mixture, (4) steaming, and (5) preparing the sauce and finishing (See details in Figure 2). Each stage combines procedural practice (e.g., removing the pith, managing stuffing quantity) with cultural storytelling (via Chef Lin), embedding tacit culinary knowledge within the flow of action. Players actively perform each stage of the cooking process using natural hand interactions with virtual tools and ingredients to experience embodied learning.

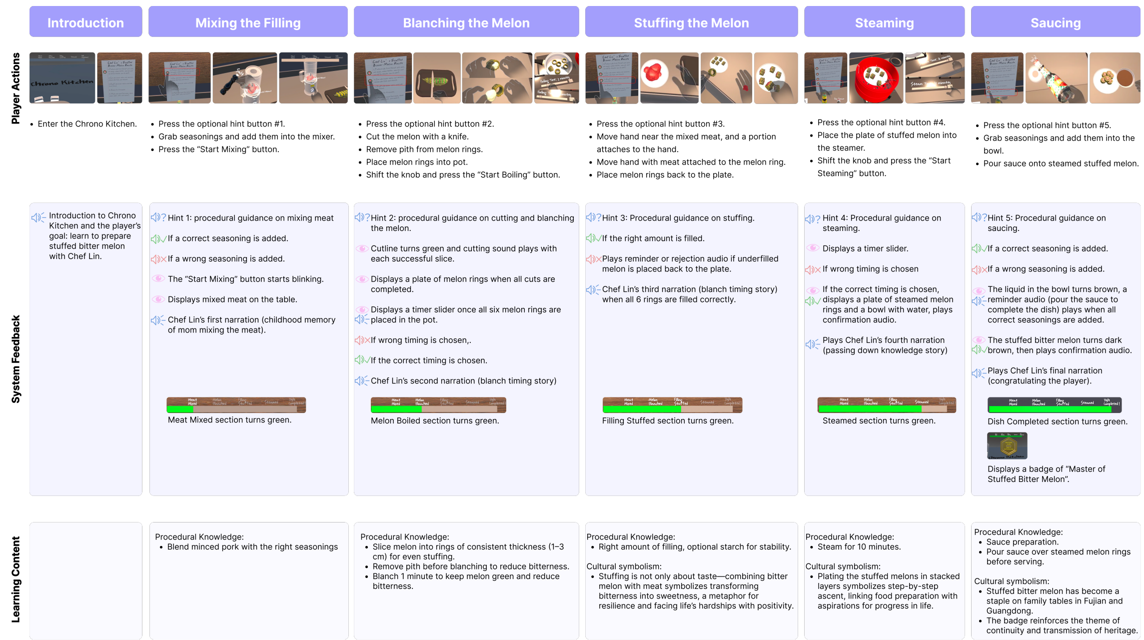

Fig. 2. Game Flow. Players progress through stages of introduction, mixing, blanching, stuffing, steaming, and saucing. Each stage aligns player actions, system feedback, and learning content, illustrating how procedural steps, feedback, and cultural narratives are integrated across the experience.

3.2 Formative Interview and Design

To ensure the scientific rigor and feasibility of the intervention, this study collected formative data through semi-structured expert interviews prior to formal implementation. Three chefs with over 10 years of experience in Hakka cuisine were recruited as interviewees. The interview guide revolved around four themes: i) Historical context of stuffed bitter melon; ii) Pre-cooking ingredient preparation techniques; iii) Standardized cooking procedures; and iv) Cultural symbolism, comprising 13 questions focused on embodied cooking techniques, sensory markers for doneness, and cultural narrative frameworks. Audio recordings of the interviews were transcribed verbatim and analyzed via thematic coding by two researchers, yielding a procedural dictionary structured as "action verb + utensil + ingredient + cultural annotation" to inform both the interactive logic and video storyboarding of the VR game. Cultural implications, as described by experts, were implemented as hidden narrative to be unlocked when each stage of preparing the dish is completed.

Formative data analysis underscored the need to address common pitfalls in preparing stuffed bitter melon, which we emphasized in our game design. In the slicing and blanching stages, experts highlighted the importance of maintaining consistent thickness ("not too thin, not too thick"), leading us to embed the desirable range of 1–3 cm into the hint system. They also highlighted that removing the pith prior to blanching is essential to reduce bitterness. To reflect this, if players attempt to blanch melon rings without first removing the pith, a reminder audio is triggered to draw attention to this critical step. Additionally, experts stressed the importance of blanching time ("no more than one minute"), which inspired the implementation of a timer slider requiring players to experiment with different durations.

Finally, during the stuffing stage, insights on "quantity control" were operationalized into physics-based interactions that mimic real-life stuffing practices, with feedback mechanisms guiding players to recognize the appropriate amount of filling.

Using Unity 6, we developed a VR game integrating embodied interaction with cultural storytelling. Each scene enables physics-based interactions (e.g., grabbing, cutting, stuffing), provides diegetic guidance through audio cues and optional hints, delivers cultural narration through Chef Lin.

To construct the control condition, we stitched together multiple video segments of the stuffed bitter melon recipe into a continuous sequence. We selected source material filmed from a chef's-eye perspective wherever possible. The composite video was then presented within the VR headset, ensuring participants experienced the task sequence with a consistent visual angle and pacing. While this method preserved cross-media alignment in viewpoint, it necessarily differed from the VR game by removing player agency, thereby isolating interactivity as the key contrast.

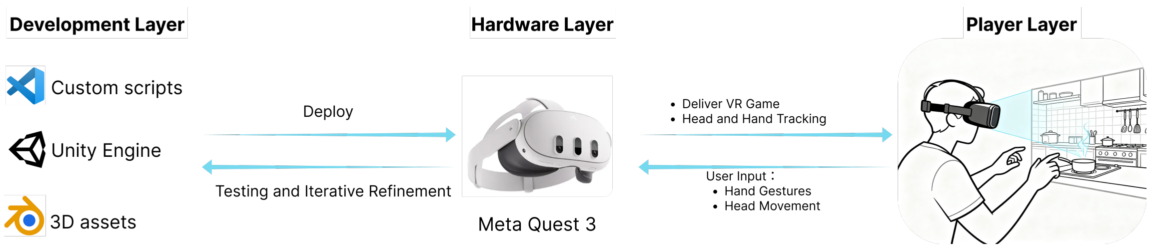

Fig. 3. System architecture. The VR game is developed in Unity and deployed to the Meta Quest 3, with iterative testing feeding results back into the development environment. On the hardware, Quest 3 delivers the game to the player while capturing head and hand inputs, which are processed and returned through the system to sustain real-time interaction.

3.3 Game Design

3.3.1 Embodied Learning. A core design principle of *Hakka Kitchen* is embodied learning: the use of natural, bodily interaction to transmit tacit culinary knowledge that is otherwise difficult to capture through non-interactive media. Drawing on theories of embodied cognition, the game leverages tracked hand gestures and physics-based manipulation of virtual tools and ingredients to approximate the sensorimotor processes central to cooking practice.

Natural hand interactions. Players employ intuitive gestures to complete every stage of the recipe. They grab seasonings and pour them into the mixer, tilt sauce bowls to drizzle liquid, slice through bitter melon rings with a knife, remove the pith by hand, and place the plate of stuffed melons onto the steamer for steaming. These gestures mirror the embodied micro-actions of real kitchens, creating a sense of presence that reinforces motor memory and procedural flow.

Multisensory feedback. To reinforce embodied cognition, the game integrates layered sensory cues that tie each action to an immediate perceptual response. Visual indicators (e.g., the meat mixture becomes slightly darker after being mixed with seasonings like soy sauce, the stuffed bitter melon deepening in color after brown sauce is poured) provide players with concrete markers of doneness and process progression. Auditory cues (e.g., the slice sound when the knife cuts the melon, the mechanical whir of the mixer) further simulate real-world cooking and how it relies on sensory feedback to refine their technique. Collectively, these multimodal cues create sensorimotor loops where actions trigger perceptible consequences, and players must respond accordingly. This enhances the embodied learning of the cooking process while simultaneously deepening the player's immersion in the game.

Environmental realism. Embodied learning is further situated within a virtual kitchen environment designed to evoke the affordances of a real cooking space. The virtual kitchen approximates the layout, dimensions, surface textures of a real-world kitchen, populated with common culinary objects and utensils. Through recreating a familiar kitchen setting, we anchor abstract cultural narratives in a recognizable environment to reduce cognitive load for the player while enhancing immersion.

3.3.2 Game Narrative Design. Narrative plays a central role in situating the player within the cultural and pedagogical framework of Hakka Kitchen. From the very outset, an audio welcomes players to the "Chrono Kitchen" where timeless skills and flavors are preserved. At this entry point, players are positioned as apprentices of Chef Lin–a virtual mentor who provides cultural narration and cooking guidance through voiceover. This framing keeps players motivated by giving them a clear goal of learning to prepare the dish. We also considered an alternative framing in which players would assume the role of a family member cooking during the Spring Festival under the guidance of their grandmother. We ultimately rejected this approach, as it risked breaking immersion due to discrepancies with players' diverse personal family contexts. The apprentice framing, by contrast, was judged to be more universally relatable and effective in maintaining immersion.

Chef Lin's narration unfolds progressively as players complete each of the five procedural stages of cooking stuffed bitter melon. After mixing the filling, he recalls childhood memories of watching his mother blend minced pork by hand. Following the blanching step, he shares a personal anecdote about accidentally overcooking the melon the first time he assisted his mother in preparing the dish. This underscores both the importance of precise timing during blanching and his personal connection to the dish. Upon stuffing the melon rings, Chef Lin conveys the cultural symbolism he learned from his own master when he was an apprentice: that the combination of bitter melon and savory meat embodies the transformation of bitterness into sweetness, a metaphor for resilience and the ability to turn hardship into joy. Once the steaming is complete, he highlights plating practices he now passes on to his apprentices—stacking the melon pieces to symbolize step-by-step ascent. Finally, upon completion of the dish, Chef Lin situates stuffed bitter melon in its contemporary social context as a staple on family tables in Fujian and Guangdong, while congratulating players for unlocking their first recipe in the "Chrono Kitchen".

This narrative design serves multiple functions. First, by grounding the story in Chef Lin's personal experiences and presenting it in the first-person perspective, we aimed to make the narration more relatable and interesting for players. Second, the narration embeds both cultural meanings (e.g., the symbolic transformation of bitterness into sweetness) and procedural knowledge (e.g., the importance of blanching time) in a non-instrumental manner, enabling players to absorb knowledge and build awareness through context rather than didactic instruction. Finally, the narrative is structured around a recurring motif of transmission: Chef Lin learning from his mother, from his master, and later passing knowledge on to his own apprentices. This motif not only mirrors the apprentice role assigned to players but also resonates with the broader theme of continuity underpinning both Hakka cuisine and intangible cultural heritage safeguarding. Ultimately, it anchors the "Chrono Kitchen" as a symbolic world of inheritance, where embodied learning and cultural transmission converge.

3.3.3 Instructions and Hints. **Procedural instructions.** The game provides procedural instructions that broadly align with the traditional recipe flow, guiding players through the five stages of preparing stuffed bitter melon. These instructions indicate what action should be taken next (e.g., mixing the minced pork with seasonings, blanching melon rings, steaming the stuffed pieces for ten minutes) but deliberately do not prescribe every micro-detail. By doing so, we intentionally leave room for players to explore, experiment, and make small mistakes, reinforcing tacit knowledge acquisition through embodied trial and error.

Optional hints. To supplement these baseline instructions, we implemented an optional hint system. Hints can be activated once a preceding step is completed, and they provide more detailed guidance. These hints vary in function: some advance the procedure by clarifying the next step (e.g., add seasonings into the blender or the bowl; place the plate of stuffed bitter melon into the steamer), while others embed culturally significant or technically critical knowledge (e.g., 1-3 cm slices; remove pith; do not overfill or underfill; starch can stabilize filling). Although this creates the possibility that certain players may not access all knowledge, we embed such knowledge in hints to frame it as discoverable and to empower players to self-regulate their learning pace and deepen engagement by rewarding curiosity. This balances the fidelity of cultural transmission with the agency of player-driven exploration.

Feedback mechanisms. The game integrates multiple forms of immediate feedback to reinforce procedural knowledge. Correct and incorrect actions are distinguished through confirmation or rejection audio throughout the game. This helps players immediately recognize mistakes, adjust their behavior, and reinforce accurate techniques. Beyond these binary cues, the game provides targeted reminders to highlight to the players key knowledge identified during chef interviews. For example, if a melon is underfilled or if the pith has not been removed before blanching, an audio is triggered to draw attention to the error.

3.3.4 Error-responsive Design. To complement the instructions and hints system, we deliberately withheld certain key information to encourage trial-and-error learning. This design draws on Metcalfe's Error-Based Learning Theory [48], which shows that making errors and then receiving corrective feedback leads to deeper processing and longer-lasting memory than error-free practice. In the blanching stage, players are presented with a timer slider ranging from 1 to 10 minutes but are not told the "correct" duration upfront. If they over- or under-blanch the bitter melon, a rejection audio plays and they cannot advance. Only after players select the correct timing does Chef Lin's narration confirm the optimal blanching time of one minute. This attempts to reinforce procedural knowledge by leveraging mistakes as a learning mechanism, making the correct blanching time more durable in memory than if it were provided upfront. It also reflects how culinary skills are traditionally acquired—through embodied practice, mistakes, and gradual refinement.

3.3.5 Engagement Strategies. Achievement systems can serve as powerful motivators in serious games [13]. To sustain player motivation and ensure continuity across the cooking sequence, we integrated several engagement strategies that operate at both procedural and cultural levels.

Progress Indicator. A visual progress bar tracks advancement through the five cooking stages. This scaffold provides players with a clear understanding of the structured, sequential nature of preparing the dish. It signals what they have already accomplished and how each achievement brings them one step closer to the final goal. Players are encouraged to remain engaged and persist through the entire game.

Unlocking Cultural Narratives. Each completed stage unlocks a new segment of Chef Lin's narration, embedding cultural knowledge into the flow of gameplay. This incremental reveal of stories serves as a form of reward, enhancing players' interest in the cooking process while deepening their awareness of the cultural meanings embedded in the dish.

Achievement Badge. Upon successfully completing all five stages, players earn a "Chrono Kitchen" badge that certifies their accomplishment in mastering the stuffed bitter melon. This motivational closure provides a tangible symbol of recognition and accomplishment, sustaining engagement through to the end of the game.

4 Methods

4.1 Study Design

We conducted a two-arm, between-subjects experiment comparing an *interactive VR cooking game* to a *non-interactive VR video* control. In the game condition, participants executed the full preparation workflow using 6-DoF tracked controllers with in-world guidance and optional on-demand hints (e.g., slicing, blanching, stuffing, steaming). In the control condition, participants passively viewed a first-person capture of the same workflow presented at natural pace. This arrangement avoids cross-medium carry-over while enabling dish-level comparisons within each medium. To mitigate order effects, dish order was counterbalanced within each condition using a Latin square. The study process is shown as Figure [**?**].

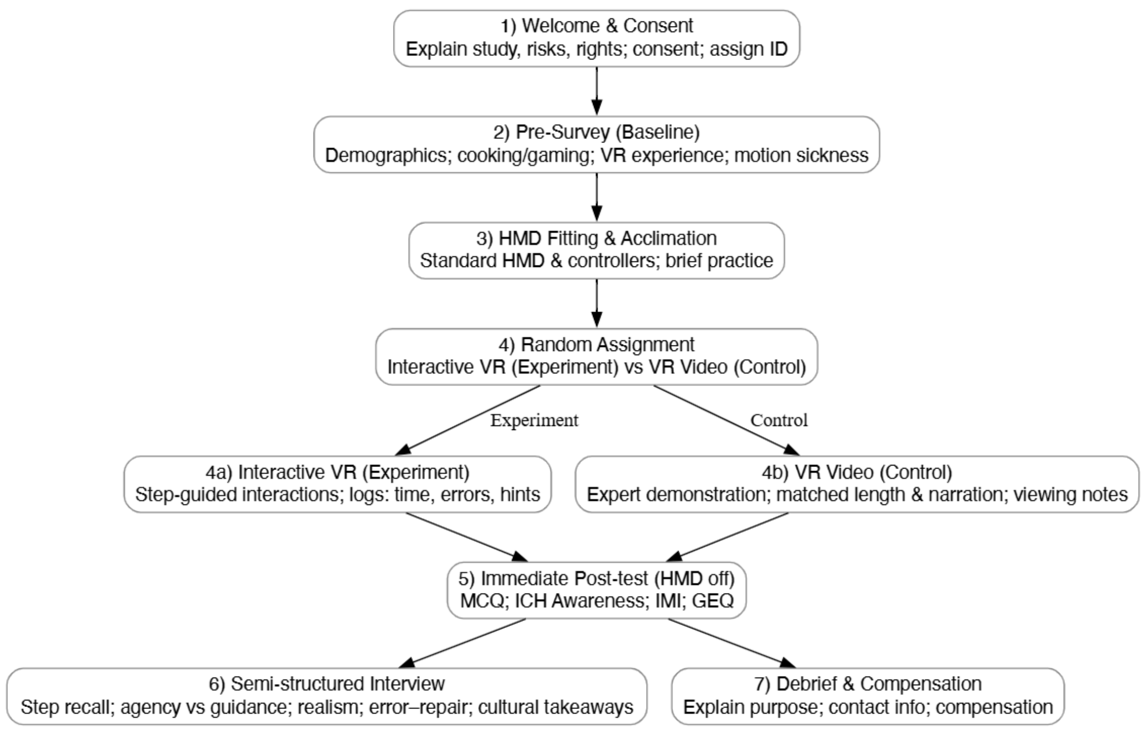

Fig. 4. User Flow.

4.2 Participants

As shown in details in A.1, we recruited adult volunteers (18+ years) from the local community and university mailing lists. Eligibility required normal or corrected-to-normal vision and no history of severe motion sickness or vestibular disorders. Prior to the session, participants provided demographics (age, gender identity, highest qualification, cultural background), weekly gaming hours, and self-reported cooking experience. All participants gave informed consent and received a small gift card honorarium.

4.3 Procedure

4.3.1 *Session Flow.*

(1) **Orientation and consent.** Participants reviewed the information sheet and provided written informed consent.
(2) **HMD setup and safety.** The researcher fitted the HMD, verified comfort and interpupillary distance, and explained safety boundaries.
(3) **Exposure.** Participants experienced exactly one condition (interactive VR game or matched VR video) in a single sitting. The software logged time-on-task and in-experience events (e.g., hints used, errors) where applicable.
(4) **Post-test battery.** Immediately after exposure (HMD removed), participants completed: (i) procedural knowledge (MCQ), (ii) ICH awareness (ICH Image Scale), (iii) motivation (IMI short form), and (iv) game experience (GEQ).
(5) **Interview.** A 5–10 minute semi-structured interview probed perceived agency and pacing, clarity/learnability of steps, cultural salience, realism, and improvement suggestions.

4.3.2 Materials and Measurements. Participants used a room-scale HMD with 6-DoF tracked controllers. Guardian/safety boundaries were configured prior to use.

We measure the below:

Procedural knowledge instruments. The MCQ assessed critical parameter knowledge.

Engagement & experience. We administered the Interest Motivation Inventory (IMI) short form immediately post-exposure to assess intrinsic motivation, with subscales targeting interest and perceived competence. The Game Experience (GEQ) capture immersion/flow, competence, positive/negative affect, challenge, and tension, including two dimensions: 1)sensory & Imaginative, 2)positive affect.[30, 47]

ICH awareness. To index awareness, perceived value, and interest in intangible cultural heritage, we used a short form adapted from the ICH Image Scale. This instrument indexes transmission, localization, vitality and association in cultural practices.(See Liu et al. for construct definition and dimensionality.)

Qualitative protocol. A semi-structured interview (5–10 minutes) elicited perceptions of agency, clarity/learnability, cultural salience, and suggested improvements. Interviews were audio-recorded and transcribed.

4.4 Analysis

We adopted a mixed-methods analytic plan. Alpha was .05 (two-tailed); 95% CIs and effect sizes are reported for all comparisons.

Qualitative data. Interview transcripts were analyzed using reflexive thematic analysis with an initial codebook oriented to agency, clarity/learnability, immersion/affect, and cultural salience. Two coders independently coded a subset, discussed discrepancies to refine the codebook, and then one or more coders completed full coding in line with reflexive TA practice; interrater agreement on the double-coded subset was summarized via Cohen's κ. We then conducted a condition-wise framework comparison to surface convergent/divergent themes and negative cases; representative, anonymized quotes illustrate each theme.

Quantitative data. All quantitative data were analyzed using R. Questionnaire responses were analyzed at the dimension level, treating each construct as composed of multiple sub-dimensions. Since the responses were measured on Likert-type scales and did not meet normality assumptions (Shapiro-Wilk test, $p < 0.05$), non-parametric Wilcoxon rank-sum tests were used to compare medians between the two independent groups. For the knowledge test items, which were categorical in nature, group differences in accuracy rates were assessed using chi-square tests of independence. All statistical tests were two-tailed, with a significance level set at 0.05.

5 Results

We report quantitative outcomes for the control condition (VR video) and qualitative themes from post-session interviews. Quantitative instruments included Intrinsic Motivation Inventory (IMI), Game Experience Questionnaire (GEQ), a multiple-choice knowledge test, and a recipe step-order task. Qualitative codes were developed via reflexive thematic analysis focused on RQ1 (procedural/process knowledge representation) and RQ3 (interest, knowledge, awareness), with RQ2 (interaction/navigation) summarized briefly.

5.1 Embodied Doing and Recoverable Errors

5.1.1 Mistakes Become Memory Anchors. Participants generally viewed "doing it yourself" as a key path from "knowing" to "being able to do it." First, the process of error—redo becomes a memory anchor. The VR game group repeatedly described how the low-cost trial-and-error offered by undo/reset functionality "engraves" micro-operations into their physical memory. Typical scenarios included overstuffing, resulting in loose filling, rearranging a plate after tipping it over, and repeated practice after misjudging the timing of blanching. As P2 in the game group reported, "Mistakes help me remember." P10 in the control group stated that they would learn better through a more interactive mode that "After making a mistake once, I know how to adjust". And P7 from the game group stated that "spilled the plate all over the floor...after starting over, I remember the rimming gesture", illustrating "making mistakes is learning" process.

Beyond the interactive learning process enabled by the game, participants suggested adding specific parameters by increasing "interval + outcome cues" would help them to better remember the ICH recipe. Interactive manipulation facilitates the consolidation of key parameters like slice width, packing tightness, and heating time. However, participants such as P10 from the video group and P2 from the game group consistently requested numerical ranges (e.g., 10–15 mm for the width of bitter melon to be cut, or 45–70 s for how long to cook) and outcome cues (color, resistance, and contour) at key points to reduce uncertainty. Hints like "cutting 10–15 mm" or "slightly springy when picked up" would provide more stability. The control group was relatively more likely to complain about the ambiguity of "appropriate/small amount." It's worth noting that a few novices in the kitchen, such as P13 from the video group and P10 from the game group, suggested a three-step rhythm of "video preview → guided practice → free practice" to reduce early errors. This constitutes a negative example of refinement of the main trend, suggesting that prior demonstration and synchronized stepping can more consistently deliver the benefits of embodied practice. (See Figure 5)

5.2 Agency and Pacing

As most participants reported that their core experience of "to what extent do I progress at my own pace, focus on key micro-operations, and practice repeatedly", they also reported that the rhythmic constraints of passive viewing and the need for step synchronization in "watching and doing," illustrating the differences in agency between the two media, as shown in Figure 6.

The video group reported that their pace of learning is constrained by the passive viewing process of the video. Participants in the non-interactive condition generally reported being "led" by the timeline, lacking the ability to adjust speed and perspective, and finding it difficult to pause and replay micro-movements (such as digging out seeds, stuffing,

Fig. 5. Embodied Doing. Interactive VR fosters a recoverable error-repair loop that yields parameter anchors (ranges + outcome cues). This mechanism predicts improvements on procedural/sequence measures rather than declarative MCQs, anticipating our quantitative pattern where item-level MCQs show limited separation while step-sequence metrics are expected to be more sensitive.

and closing the mouth), P3 from the video group stated that "I just followed the video completely. I didn't feel any control." These narratives not only address pacing but also touch upon the feeling of helplessness caused by the fixed camera position: "seeing but not seeing clearly" and "not being able to rewind keyframes." In non-interactive VR, participants wanted to "pause longer at difficult points or repeat a step without having to restart the entire segment," but lacked such mechanisms. In this same vein, the control group frequently expressed requests for "replay/slowdown/multiple perspectives."

Regardless of the medium, participants advocated for a step-synced mode with "one-step confirmation, pause/rewind/slow motion, and fast forward to skip waiting" to achieve time control and operation confirmation while doing things: learners across conditions proposed a step-synced mode with pause/skip/slow motion and explicit step confirmations.

While the game group significantly improved subjective agency (capable of grabbing, cutting, placing, and resetting), participants also noted that system pacing remained gated: many steps were "stuck" by the system's rhythm. "I can take initiative at a particular step, but the overall process remains gated" (conceptualized as "agency improves but remains gated"). Consequently, the interactive group also requested branching (allowing for alternate paths) and timeline control (pause/skip/fast-forward). This contrasts with the control group's central complaint of being "paced," forming a continuum, from complete passivity from the control group. to local initiative/global constraint from the game group.

Some participants from both groups also preferred "Preview → Guided Practice → Free Practice." While most participants favored synchronized stepping and immediate control, a minority of novices preferred a segmented approach: first previewing with an expert to establish a "skeleton," then moving into guided practice, and finally free practice to solidify fluency. They viewed this as a balance between "orientation, confidence, and consolidation." This, to some extent, explains why a completely free-flowing pace doesn't benefit everyone, suggesting that we need layered guidance beyond controlled stepping.

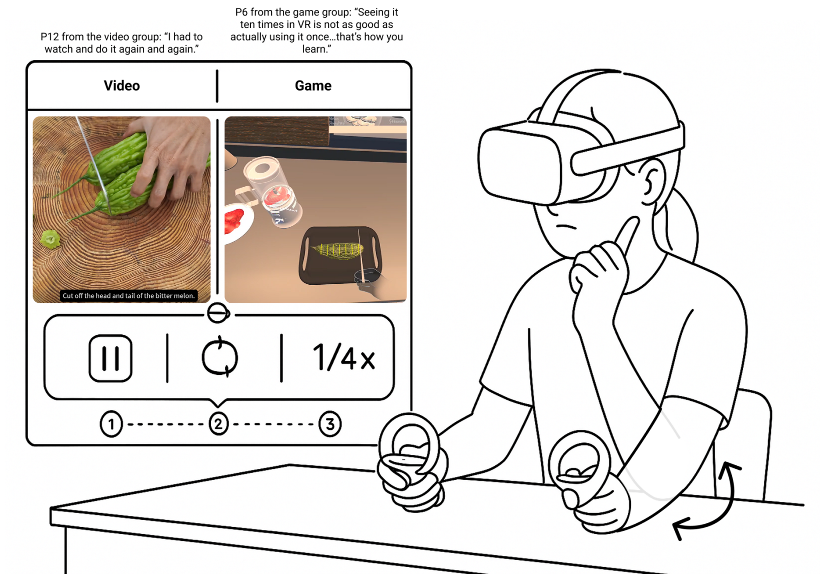

Fig. 6. Agency and Pacing. Learners in both conditions demanded step-synced controls (pause/replay/slow-motion) precisely at micro-operations (e.g., stuffing, blanching). The co-occurrence network links time-control codes to Immersion and Positive Affect, anticipating higher IMI/GEQ scores in the interactive condition, while the weaker linkage to Competence foreshadows non-robust effects on perceived competence.

5.3 Realism & Kitchen Semantics

5.3.1 The physical/dynamic gap is the main bottleneck of the interactome. Participants flagged idealized ingredients, compressed timing, and inconsistent physics (weight, buoyancy, clipping, unstable placement) as breaks in realism that hindered flow and confidence. Several contrasted the "glossy" look with the variability of market produce. Participants expected real-kitchen semantics (hot lids, steam, gloves/tongs) and more faithful appliance controls (knobs vs. sliders), noting that these cues scaffold safe transfer. P2 from the game group reported that "using a slider for the stove instead of a knob feels unrealistic". Robust snapping/placement, friendly undo, and support for authentic alternatives (batch blanching, bowl-first seasoning) were framed as essential for both realism and self-efficacy. "There should be a friendly reset or correction mechanism", as P3 from the game group reported.

5.3.2 Multisensory semantics and the implications of a “real kitchen”. The interactive group placed greater emphasis on "real kitchen semantics" and safety cues: hot pot lids/steam, gloves/tongs, stove knobs, openable and closeable drawers, and other "do-able" utensils and states, which anchored abstract steps to actionable norms (for example, "It's unrealistic for a stove to have sliders instead of knobs"). Concise narration paired with focused visuals was repeatedly cited as helpful: visuals conveyed step order and micro-technique; narration offered rationale and cultural framing. "he voice was like reminders in my ear, and the visuals were very direct", as P1 from the video group suggested. Headset immersion channeled attention to fine manipulations (coring, stuffing), reducing distraction. Several described an increased sense of "taking it seriously." The lack of haptics, heat, and smell constrained tacit cues (stickiness, doneness, aroma), leaving some uncertainty about transfer to real kitchens: "I couldn't feel the stickiness; the steamer looked hot, but I couldn't feel the heat," as P2 from the game group reported.

The two groups have different emphases in their pursuit of "realism": the game group focuses on "being able to make it look real" (physical consistency and instrument semantics), while the video group focuses on "looking real" (camera position, rhythm, and sensory loss). Even so, there are still negative examples and mitigating opinions: some video participants believe that "it's just watching, and the lack of touch warmth is not a big problem", but they also admit that this limits the transition from "understanding" to "being able to do it". Some of the game group participants gave positive comments on the lighting and cleanliness of the scene, while pointing out that "the water collection seemed to appear instantly" and "the interaction of removing the pulp was awkward", which were inconsistent with reality. This shows that the delicate balance between aesthetic appeal and physical reality still needs to be grasped.

5.4 Cultural Salience: Action Masking vs Narrative Uptake

We observed a clearly differentiated trajectory under the two media conditions: the action load of interactive VR creates "action masking" at key steps, making cultural information easy to overlook, while the narrative continuity of VR video is more conducive to "narrative absorption".

5.4.1 Action Masking. In the interactive condition, participants generally reported being completely absorbed by the task itself, diluting their understanding of the intangible cultural heritage/Hakka context due to the task load. As P3 from the game group reported that "When doing the task, my attention was more focused on the task in front of me... I absorbed the narration more limitedly." Most people from the game group "didn't know stuffed bitter melon was a Hakka dish/intangible cultural heritage; the experience hardly conveyed any clear information about 'intangible cultural heritage,' so my perception hasn't changed much." As the participants from this group suggested that this "obscuration" doesn't reflect a lack of interest in culture, but rather a misalignment between presentation and timing. Several participants proactively suggested embedding lightweight, "on-the-spot" prompts (information cards/tidbits pop-up, or NPC guidance) at key steps to connect cultural points within the context of the process: "Information cards/tidbits pop-up after completing the steps (concisely highlighting the Hakka and intangible cultural heritage background)." Direct expressions of "still unaware/unsure this is Hakka intangible cultural heritage" also appeared in the coding sheet and transcriptions, as 11 also stated that "I didn't know it was a Hakka dish...my perception hasn't changed much."

5.4.2 Narrative Absorption. In contrast, the continuous narrative and multimodal explanation of VR videos are easier to "see and hear", thus forming value recognition and respect. In general, the video group suggested that the video mentioned the significance of Hakka cuisine as an intangible cultural heritage, which made me realize that it's not just any home-cooked dish, but a craft with historical value. P6 from the video group stated that "feel like watching videos in VR allows me to focus more...it helps me to remember." and P4 stated that "the VR glasses...use a very large panel, which creates a strong visual impact" to see the cooking process more immersively. Several participants experienced a change in their attitudes after "clarifying that it's intangible cultural heritage/why it's intangible cultural heritage". P3 from the video group stated that "I used to think Hakka cuisine was just an ordinary home-cooked meal, but this time I learned that stuffed bitter melon is an intangible cultural heritage," and P1 reflected that "I never thought...such a common dish could be considered...intangible cultural heritage. I was surprised."

5.5 Game Experience Effects on Players

To compare the effects of VR video and VR game interventions across multiple constructs measured with a Likert scale, we conducted Wilcoxon signed rank tests due to the paired and nonparametric nature of the data. Three primary constructs were evaluated: Immersiveness, Interest & Motivation, and Cultural Awareness, along with their respective subdimensions.

5.5.1 Interest & Motivation (IMI). As shown in Figure 7, analysis of the Intrinsic Motivation Inventory revealed that participants in the game group reported higher Interest (median = 5.6, IQR = 5.2–6.0) compared to the video group (median = 4.6, IQR = 4.4–5.0), and this difference was statistically significant (Wilcoxon rank-sum test, $p < 0.05$). Perceived Competence did not differ significantly between groups (game median = 4.6, IQR = 4.3–5.0; video median = 4.5, IQR = 4.0–5.0; p = 0.219, ns). The increase in interest reflects the motivational pull of interactivity and narrative-driven tasks. However, the lack of difference in perceived competence suggests that both modalities offered a similar level of challenge and clarity regarding task requirements. The improvement in immersion and positive emotions is consistent with the subjective reports of "first-person close-up + controlled stepping"; however, the sense of competence is not significant, which is consistent with the explanation in the discussion that "single exposure + lack of touch/heat/smell makes it difficult to form stable self-efficacy."

5.5.2 Game Experience (GEQ). As shown in Figure 8, the game group scored higher on Sensory & Imagery (median = 5.6, IQR = 5.2–6.0) than the video group (median = 4.8, IQR = 4.6–5.0; $p < 0.05$), and on Positive Affect (game median = 5.7, IQR = 5.4–6.0; video median = 4.8, IQR = 4.6–5.0; $p < 0.05$). It demonstrated a clear advantage of VR game over VR video in both Sensory & Imaginative Engagement and Positive Affect. The significant improvement in sensory and imaginative engagement suggests that VR game successfully strengthen participants' perceptual immersion. Similarly, the higher Positive Affect under the VR game condition reflects a more emotionally rewarding experience.

5.5.3 Cultural-Heritage Awareness. As shown in Figure 9, cultural Awareness analysis showed significant differences in three of the four sub-dimensions. Transmission (game median = 5.6, IQR = 5.2–6.0; video median = 4.6, IQR = 4.2–5.0; $p < 0.05$), Vitality (game median = 5.3, IQR = 5.0–5.6; video median = 4.7, IQR = 4.4–5.0; $p < 0.05$), and Association (game median = 5.7, IQR = 5.4–6.0; video median = 4.6, IQR = 4.4–5.0; $p < 0.05$) were significantly higher in the game group. Localization did not differ significantly (game median = 4.7, IQR = 4.5–5.0; video median = 5.2, IQR = 5.0–5.4; p = 0.919, ns). It revealed significant improvements in Transmission, Vitality, and Association for the VR game condition, while Localization showed no difference. The non-significant difference in Localization probably suggests that both modalities were equally effective or equally limited in illustrating how cultural practices adapt to new contexts. "Action masking" makes it easier to miss local narratives during the moment of action, explaining the lack of prominence of localization. However, the interface strategy of "embedding cultural elements at key steps" has the potential to improve this dimension. The discussion also pointed out that the generation of a sense of place relies on on-site context and co-presence, requiring the activation of local cues in situations such as the kitchen, the market, and the museum.

5.5.4 Procedural Knowledge Quiz. As shown in Figure 10, a chi-square test on multiple-choice question accuracy revealed that most questions showed no statistically significant differences between VR video and VR game conditions ($p > 0.05$). Although the VR game group tended to have higher correct rates for some items, these differences did not reach statistical significance. In qualitative tests, participants viewed the resumable trial-and-error process of "making a mistake—resetting—redoing" as a memory anchor, and more often mentioned "parameter range + result clues" (such as thickness, tightness, color/resistance) as aiding recall and transfer. This may explain why the individual differences in MCQ questions were not significant, while real-world operational/parametric indicators may be more sensitive.

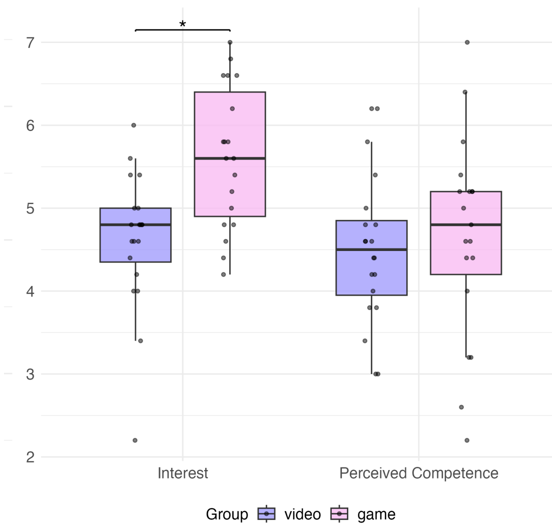

Fig. 7. The results of Interest Motivation Inventory. Significance levels are indicated with * for $p \leq 0.05$.

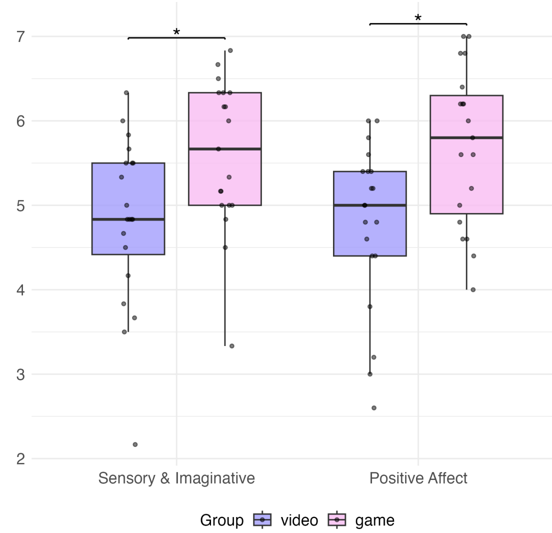

Fig. 8. The results of Game Experience. Significance levels are indicated with * for $p \leq 0.05$.

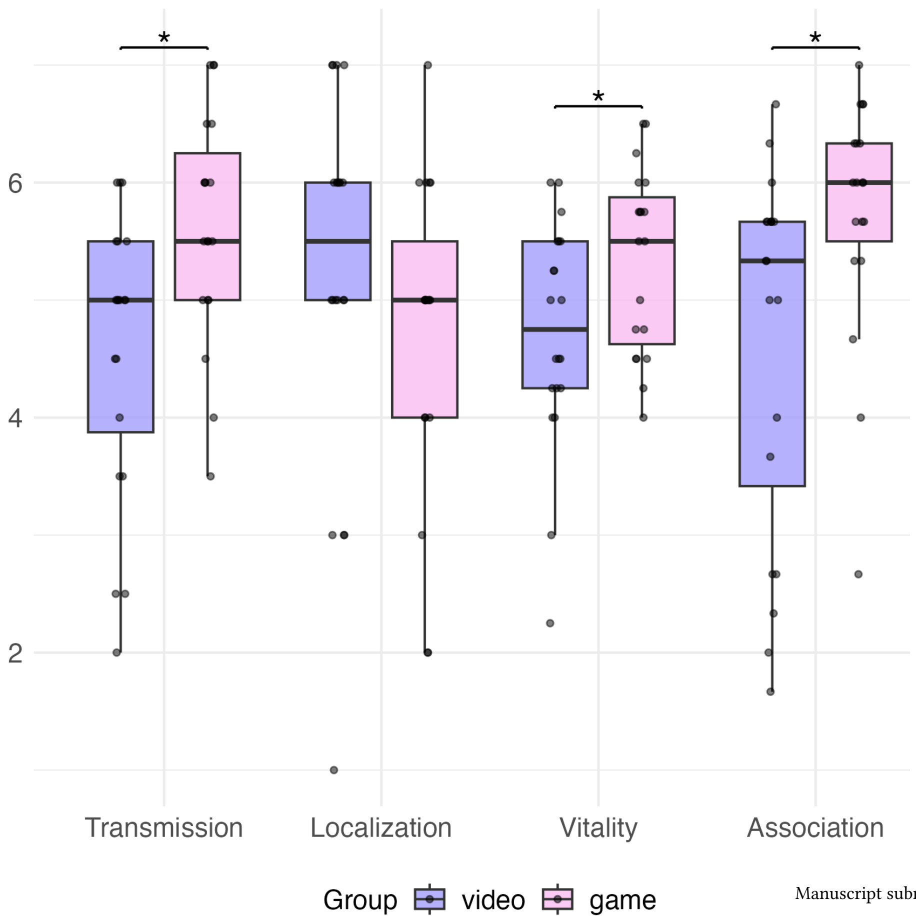

Fig. 9. The results of Cultural Awareness. Significance levels are indicated with * for $p \leq 0.05$.

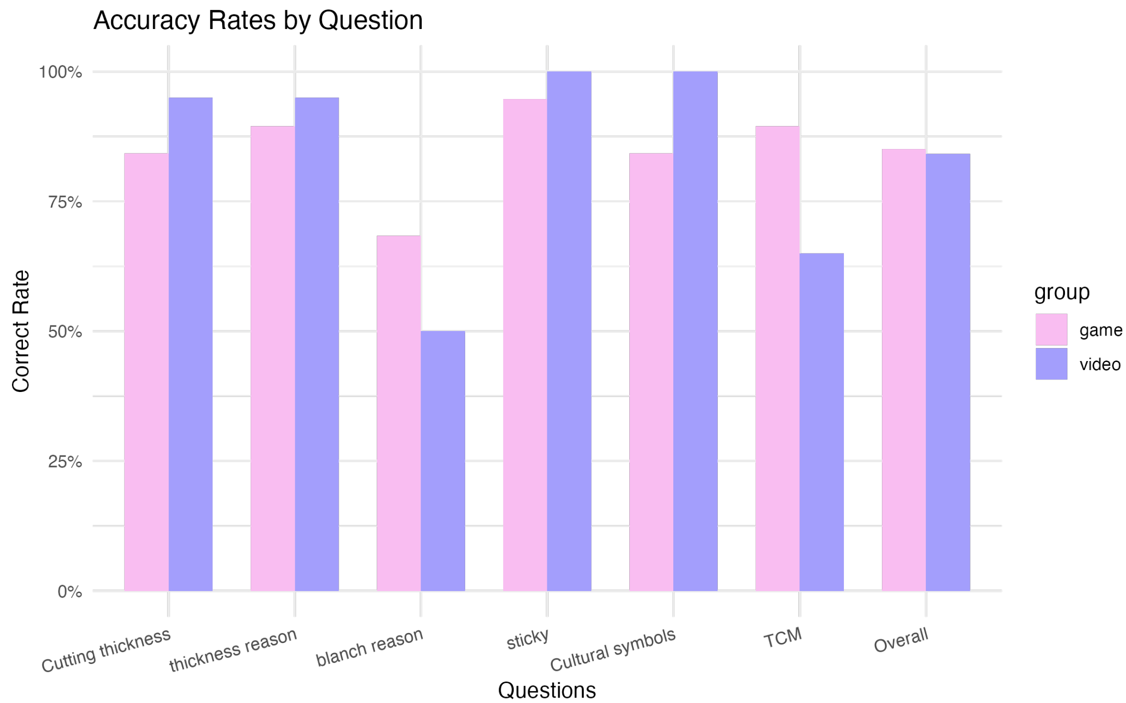

Fig. 10. The results of accuracy rates with no significance.

6 Discussion

Our goal in this study was to examine how an embodied VR cooking game can encode and communicate process-rich, tacit culinary know-how (RQ1), how people actually engage with those mechanics in situ (RQ2), and whether such engagement changes interest, knowledge, and awareness of ICH (RQ3).

6.1 From watching to enacting ICH

Our findings show that the interactive VR condition—where participants enacted micro-techniques and could make recoverable mistakes—produced markedly higher sensory/imaginative engagement and positive affect than a matched VR video. Interview accounts linked durable "know-how" to action, pacing control, and friendly error recovery (e.g., undo/respawn). Together, these results support the claim that process-rich ICH is best represented by media that close the perception–action loop rather than by observational visuals alone [2, 65]. They extend prior immersive-heritage work that used interaction to scaffold situated technique learning (e.g., conservation tasks) by translating that logic to culinary ICH, where time–temperature windows, quantity ranges, and texture cues constitute the grain of expertise [2, 65]. In contrast to 360° heritage tours that heighten presence yet remain observational, our results highlight error-tolerant, feedback-rich loops (e.g., step-synchronous timers, on-step quantity feedback) as mechanisms for building enactable routines rather than passive recall [65]. This representational stance is aligned with embodied/grounded cognition, which posits that memory and understanding are shaped by modal simulation and situated action [? ?].

A clear boundary also emerged: without haptics, heat, or smell, participants lacked tacit cues (e.g., stickiness or doneness). HCI studies show that adding olfactory and thermal feedback can increase presence and improve decision fidelity in food/VR settings, suggesting a feasible augmentation path that preserves safety and tractability in lab deployments [46, 54].

6.2 Local Identity and Situated Belonging

Quantitatively, the strongest cultural-awareness gain was on Association; qualitatively, participants reframed an "everyday" dish as worthy heritage. We interpret this as identity alignment: enacting techniques alongside a culturally grounded narrative positioned learners not only as observers but as inheritors. This echoes intercultural AR work showing that well-timed, in-situ cues and role-taking can scaffold belonging and mutual recognition [**?**]. At the same time, Localization did not differ between conditions, indicating that place-making is partly dependent on context and community co-presence—implicating deployments in kitchens, markets, or museums where site-specific associations can be activated [65]. In the broader media ecology, platform studies of Douyin/TikTok document how short-video cultures scale ICH visibility and pride while risking spectacle and flattening; our results suggest a complementary pipeline where short video sparks curiosity and VR anchors identity through hands-on rehearsal [53, 77].

6.3 Competence, Motivation, and the Role of Multisensory Feedback

Despite higher interest and affect, perceived competence did not differ between conditions. Framed by self-determination theory (SDT), this pattern implies that while autonomy needs were supported (interactivity, pacing), competence may require longer practice horizons, richer sensory feedback, and criterion-referenced successes—conditions a single session cannot fully provide [**? ?**]. Meta-evidence on VR/simulation training similarly finds robust boosts to motivation and near-term knowledge, with skills and confidence sensitive to task fidelity, feedback, and dosage [8]. Consistent with this, participants requested knife damping, pour/tilt physics, lightweight haptics/thermal cues, and granular replay—all mapping to established design levers for tacit judgment in food contexts [46, 54].

6.4 Design Implication

Our study of Hakka Kitchen highlights several design implications for developing game-based immersive applications aimed at transmitting intangible cultural heritage (ICH). While grounded in the specific case of cooking stuffed bitter melon, these insights extend to other culinary and non-culinary ICH practices, such as traditional crafts, performing arts, and rituals.

6.4.1 Expert Knowledge as Design Drivers. Expert interviews play a critical role in shaping our design decisions, as discussed in Section 3.2. Many forms of ICH—such as weaving, calligraphy, or pottery—require skills that are difficult to master, demand extensive practice, or rely on tacit professional knowledge. Expert practitioners are uniquely positioned to identify these critical learning points, enabling designers to translate them into appropriate game mechanics or feedback systems that support player learning. We suggest future immersive ICH games should therefore treat practitioner insights not only as cultural content to be represented, but as design specifications that directly inform the design of game mechanics, hints, and error-responsive feedback.

6.4.2 Embodied Interaction for Tacit Knowledge Transfer. Our game leveraged natural hand interactions, audiovisual feedback, real-world physics and environment to approximate embodied practices. These interactions provided meaningful sensorimotor engagement that enhanced the embodied learning of the cooking process while simultaneously deepening the player's immersion in the game. Yet players highlighted shortcomings when audiovisual fidelity was lacking (e.g., absence of real pouring sounds, no visual cue of steam, or no blanching color change). Even small discrepancies between simulated and real-world cues were reported to reduce immersion and diminish engagement.

For intangible cultural heritage, the demand for high realism is not simply a matter of visual polish but stems from the embodied nature of knowledge itself. Skills in cooking and in analogous practices depend heavily on multisensory integration: color cues signal progress, the amount of applied force influences the outcome, and tactile resistance guides technique. When these perceptual anchors are missing, ICH transmission risks being reduced to partial or superficial knowledge transfer. Moreover, players often approach VR with an expectation of faithful real-world simulation, particularly when the interactions are explicitly designed to mirror real-life scenarios. When the virtual environment fails to provide the expected sensory realism, players experience disappointment and disengagement.

Therefore, we suggest future VR ICH systems to carefully align embodied interactions with high-fidelity sensory realism across the virtual environment, physics, and core interactions. In the case of culinary ICH, for example, visual color changes should be faithfully represented to present procedural information. Beyond vision and sound, the experience can be enriched with lightweight olfactory and thermal cues (e.g., the aroma of steaming food, subtle warmth radiating from a pot), which heighten presence and reinforce decision-making fidelity [46, 54].

6.4.3 Engagement Strategies for ICH Learning. A recurring challenge in serious games is that their educational orientation often comes at the expense of engagement and enjoyment. Prior studies note that serious games can lead to reduced player motivation and lower willingness to persist through tasks compared to purely entertainment-focused games [14][38]. This tension between instructional depth and playful engagement is particularly pronounced in heritage contexts, where cultural accuracy and authenticity are prioritized but may result in experiences that resemble tutorials rather than games.

In our design, we sought to mitigate this tension through a set of engagement strategies–Progress Indicator, Unlocking Cultural Narratives, and Achievement Badge, as discussed in section 3.3.5. These elements supported sustained engagement without diluting the cultural and procedural authenticity of the experience. However, post-play feedback revealed that a few participants still perceived the system as "less like a game" and "not very enjoyable." To address this, future iterations could expand the repertoire of playful mechanics. For example, Chef Lin could evolve into a fully embodied NPC capable of dynamic interaction, or the cooking tasks could be extended into cooperative multiplayer modes that foster collaboration, or competitive formats where players prepare dishes and receive scores from virtual tasters. Such approaches would increase playfulness while reinforcing cultural learning. Importantly, however, these designs must balance playfulness with cultural authenticity to ensure that playful mechanics enhance rather than trivialize ICH knowledge. For broader ICH applications, playful engagement should be rooted in the embodied practices of each tradition. Playful mechanics can be designed to amplify the mastery embedded in the practice itself, thereby creating both engaging gameplay and meaningful cultural transmission.

6.4.4 Feedback Mechanisms as Scaffolds for ICH Learning. Another central implication from our design is the importance of feedback mechanisms in supporting the transfer of tacit knowledge within intangible cultural heritage (ICH). In Hakka Kitchen, we implemented layered feedback, including confirmation and rejection audio, targeted reminders for critical errors, and narration that reinforced key knowledge only after players corrected their mistakes. Participants reported that these mechanisms made learning more memorable. Because many ICH practices are traditionally acquired through cycles of trial, error, and adjustment, we suggest designers of VR ICH experiences treat feedback as scaffolding—guiding players through the learning process by making errors informative rather than punitive.

6.5 Limitation and Future Works

6.5.1 Attention Allocation. We included Chef Lin's narratives to enhance players' awareness of intangible cultural heritage. However some participants reported being so focused on completing each stage of the cooking task that they did not fully attend to Chef Lin's audio narration. This reflects a common tension in interactive learning environments: when cognitive load is directed toward task execution, narrative or cultural context delivered in parallel may be overlooked. Prior work in multimedia learning highlights this split-attention problem [7][45], where learners struggle to integrate multiple streams of information simultaneously.

We attempted to mitigate this issue by triggering narrations immediately after step completion—when players had no competing tasks or time pressure—but this strategy was not always sufficient. This suggests that the issue may not only be about split attention during action, but also about how players prioritize goals in a task-oriented environment. As a result, the effectiveness of our narrative design in fostering cultural awareness may be underestimated since some players likely engaged more with procedural tasks than with the cultural storytelling.

Future work should explore design solutions to re-balance attention between procedural tasks and cultural storytelling. One possible direction is to augment the role of Chef Lin by giving him a virtual body and enabling real-time interaction with players. Instead of passively listening to disembodied narration, players could engage with Chef Lin as a visible mentor who gestures, demonstrates, or reacts to their performance while telling the cultural stories. This embodied presence could capture players' attention more effectively and reduce the tendency to deprioritize narrative in favor of task execution.

6.5.2 Hint Usage Variability. Participants varied in how often they used the optional hint system, which introduced uneven levels of scaffolding across the sample. For some, frequent reliance on hints may have reduced cognitive effort and supported more accurate procedural execution, while others who avoided hints risked missing procedural knowledge about the dish and had to rely on trial-and-error or common sense to progress. This variability complicates interpretation of knowledge outcomes, as differences may partly reflect how much instructional support participants chose to access rather than the inherent affordances of the immersive and interactive VR system.

Future studies should more systematically examine the role of hints by manipulating their availability or timing—for example, making them always available, always withheld, or adaptively triggered based on performance. Logging and analyzing hint usage patterns could also clarify whether hints primarily reduce frustration, transmit deeper cultural knowledge, or simply act as optional aids without strong impact on learning.

6.5.3 Study Design. Our evaluation was conducted in a single lab-based session, with dependent measures collected immediately after exposure. While this design allowed for controlled comparisons between the interactive VR cooking game and the non-interactive VR video control, it did not capture long-term retention, transfer of knowledge to real kitchens, or sustained cultural awareness over time. For example, although both groups showed immediate gains in procedural knowledge, it remains unclear whether these differences would persist, diminish, or widen over weeks or months. Similarly, cultural awareness and motivational effects may evolve differently outside of the lab context, particularly when players encounter related practices in their everyday lives. Moreover, the short exposure duration and immediate testing window limited opportunities for consolidation, and the factual detail–oriented quiz items may not have fully captured the embodied and conceptual benefits of interactive learning.

Future research should employ longitudinal designs to assess durability and transferability of learning. This includes testing whether embodied VR practice supports better long-term procedural knowledge, deeper cultural appreciation, or real-world cooking uptake compared to passive VR video viewing. Complementary measures that probe conceptual understanding and transfer, beyond factual recall, would also provide a fuller picture of learning outcomes. Field studies in real-world kitchens could further reveal how lab-based outcomes translate into authentic settings and whether embodied interaction produces more sustainable impacts than observational formats.

6.5.4 Control Design. We used a VR video as the control condition to isolate the role of interactivity while keeping procedural content constant. However, this design carries two limitations. First, although we selected footage that closely mimicked a chef's viewpoint, mismatches in angle and framing remained compared to a true first-person perspective. Such discrepancies may have introduced perceptual bias, as participants in the control condition could interpret procedural steps differently than if they had viewed them directly from the chef's eyes. Future control videos could be captured using head-mounted or stereoscopic equipment worn by the chef to ensure a more authentic alignment of perspective, thereby reducing perceptual mismatches and strengthening the validity of cross-condition comparisons.

Second, watching a seamless, error-free demonstration may inflate immediate procedural knowledge scores for the control group, as participants observe an ideal execution without the possibility of making mistakes. By contrast, interactive gameplay exposes participants to trial-and-error, which is theorized to foster more durable learning through embodied error-based practice [48]. This raises the possibility that our design underestimated the added value of interactivity when judged only by short-term outcomes. Future longitudinal studies should test whether the initial knowledge advantage of passive video viewing persists or diminishes over time compared to interactive practice, thereby clarifying whether VR's trial-and-error learning supports more durable retention.

6.5.5 Demographics. Our participant sample consisted of individuals aged 20–30 years, all of Chinese background, mostly undergraduates or above, with considerable variation in regional origin and durations spent overseas. At the level of internal validity, the demographic similarity across both the VR game and VR video (control) groups means that our comparisons between conditions are not biased by differences in age, education, or cultural background. However, at the level of external validity, this homogeneity constrains the generalizability of our findings.

Limited Education Representation. Our participant sample was largely composed of undergraduates or above. Higher education has been consistently identified as a strong predictor of cultural participation and interest across diverse contexts [26]. Consequently, our participants may have entered the study with elevated baseline interest or engagement, potentially amplifying the game's apparent effectiveness or masking differences visible in broader populations. For example, less-educated groups might display lower baseline familiarity with intangible cultural heritage (ICH) and therefore exhibit stronger relative knowledge gains, or alternatively, they might engage less with narrative framing due to differences in prior exposure to heritage discourses.

Limited Cultural Background Representation. The all-Chinese participants limit the generalizability of our findings to cross-cultural audiences. Prior research in cultural psychology demonstrates that cultural background strongly shapes how individuals interpret, value, and engage with heritage practices [31][60]. Within this shared context, Chinese participants may have found Chef Lin's narratives more engaging because of shared cultural scripts and culinary traditions. However, even within a homogeneous cultural background, several participants questioned whether stuffed bitter melon should be considered an "authentic" Hakka dish, noting that they had encountered it in other regions or viewed it as an everyday common dish. This perception may have dampened their interest in learning, suggesting regional variation and personal food histories can influence how cultural narratives are received.

Including participants from non-Chinese cultural backgrounds could reveal different dynamics. For instance, those unfamiliar with the dish might perceive Chef Lin's stories as novel and thus more engaging, while others may struggle to connect with embedded cultural scripts, resulting in diminished interest and reduced awareness of the heritage message.

Future studies should recruit participants with more varied educational backgrounds and from different cultural contexts. Expanding to less-educated groups and non-Chinese participants would help reveal whether engagement, knowledge, and awareness outcomes generalize across broader populations and provide insight into how cultural familiarity or distance influences learning in VR-based ICH experiences.

6.5.6 Applicability Across Traditions. Since our study focused on a single culinary practice—stuffed bitter melon, its findings are limited in generalizability to other culinary traditions and intangible cultural heritage practices. Culinary practices vary widely in complexity, required tacit knowledge, and cultural symbolism, and it is not yet clear whether the same design choices would transfer seamlessly to other dishes or to non-culinary forms of intangible cultural heritage. To broaden the scope, future work could develop multi-dish curricula that cover a variety of recipes, allowing for comparisons across dishes with different technical and symbolic demands. This would enable testing which interaction, feedback, and narrative strategies are robust across contexts, and which require domain-specific adaptation, thereby strengthening the generalizability of immersive game-based representation of ICH.

7 Conclusion

Our study demonstrates that representing intangible cultural heritage through interactive procedures rather than static content fosters deeper sensory engagement and cultural awareness. By actively enacting the steps of a traditional dish, players not only acquire procedural know-how but also experience the embodied cultural meanings embedded in the practice. This suggests that VR's capacity to model interaction and feedback can enrich how intangible traditions are transmitted to broader audiences, extending beyond the limits of videos or text. More broadly, immersive and interactive representations hold promise for strengthening public appreciation and safeguarding of diverse ICH practices across domains.

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Table 1. Participant demographics by condition. Values are M (SD) or counts.

Group	n	Age $M(SD)$	Female	Male	Bachelor's	Master's	High school	0 h	0–3 h/wk	3–7 h/wk	≥7 h/wk	Cooking freq M	Prior VR M	Motion sickness M
Interactive VR game	18	26.2 (3.4)	13	5	8	10	0	4	9	2	3	3.4	2.2	2.4
VR video (control)	20	22.7 (1.9)	12	8	13	6	1	3	8	4	5	3.4	2.6	2.6

A Appendix

A.1 Participants Demographics

A.1.1 Demographic Summarization.

A.1.2 Detailed Demographic Table.

Table 2. Participant roster with self-reported demographics by condition.

Condition	ID	Age	Gender	Education	Cultural background	Weekly gaming	Cooking frequency	Prior VR use†	Mot
VR game	1	25	Male	Master's	Wuxi, Jiangsu	≥7 h/wk	3×/week	2	
VR game	2	25	Male	Master's	Wuxi	0–3 h/wk	4×/week	1	
VR game	3	28	Female	Master's	Zhengzhou, Henan	0 h	3×/week	3	
VR game	4	30	Female	Master's	Suzhou	0 h	6×/week	2	
VR game	5	27	Male	Bachelor's	Anhui	≥7 h/wk	1×/week	3	
VR game	6	28	Female	Bachelor's	Wuxi native	0 h	1×/week	1	
VR game	7	22	Male	Bachelor's	Anhui	≥7 h/wk	5×/week	1	
VR game	8	37	Female	Bachelor's	Shanxi	0–3 h/wk	2×/week	1	
VR game	9	27	Female	Bachelor's	Xi'an, Shaanxi	0–3 h/wk	2×/week	1	
VR game	10	24	Female	Bachelor's	Guangdong	0 h	3×/week	2	
VR game	11	22	Female	Master's	Huangshan, Anhui	≥7 h/wk	2×/week	4	
VR game	12	24	Female	Master's	Fuzhou, Fujian	3–7 h/wk	3×/week	4	
VR game	13	23	Female	Master's	Hakka and Henan	3–7 h/wk	1×/week	3	
VR game	14	27	Female	Bachelor's	Tianjin	0–3 h/wk	2×/week	4	
VR game	15	24	Male	Master's	Henan and Shandong	0–3 h/wk	3×/week	2	
VR game	16	28	Female	Master's	Shenzhen, Guangdong	0–3 h/wk	6×/week	2	
VR game	17	24	Female	Master's	Sichuan	0–3 h/wk	6×/week	6	
VR game	18	23	Female	Master's	Guangzhou	3–7 h/wk	1×/week	3	
VR video	7	25	Female	Bachelor's	Dalian, Liaoning	0–3 h/wk	4×/week	2	
VR video	2	22	Female	Bachelor's	Beijing	3–7 h/wk	2×/week	1	
VR video	4	22	Female	Bachelor's	Suzhou, Jiangsu	0–3 h/wk	4×/week	2	
VR video	6	23	Male	Bachelor's	Nanjing, Jiangsu	3–7 h/wk	3×/week	1	
VR video	8	22	Female	Bachelor's	Wuxi, Jiangsu	0–3 h/wk	3×/week	3	
VR video	9	21	Male	Bachelor's	Beijing	0–3 h/wk	0×/week	1	
VR video	10	23	Male	Bachelor's	Wuhan, Hubei	0–3 h/wk	2×/week	2	
VR video	11	21	Male	Bachelor's	Beijing	0–3 h/wk	5×/week	4	
VR video	12	23	Female	Master's	Henan	3–7 h/wk	6×/week	3	

Condition	ID	Age	Gender	Education	Cultural background (translated)	Weekly gaming	Cooking frequency	Prior VR u
VR video	13	21	Female	Bachelor's	Beijing	3–7 h/wk	3×/week	3
VR video	14	22	Male	Master's	Beijing native	≥7 h/wk	4×/week	3
VR video	15	22	Female	Bachelor's	Shandong (Lu cuisine)	≥7 h/wk	3×/week	6
VR video	16	23	Female	Master's	Qingdao, Shandong	0–3 h/wk	3×/week	2
VR video	17	23	Male	Bachelor's	Beijing	≥7 h/wk	4×/week	2
VR video	18	21	Female	Bachelor's	Beijing	0–3 h/wk	3×/week	2
VR video	19	21	Male	Bachelor's	Beijing	≥7 h/wk	3×/week	3
VR video	20	24	Female	Master's	Tianshui, Gansu	3–7 h/wk	2×/week	1
VR video	21	23	Female	Master's	Beijing	0 h	3×/week	1
VR video	22	21	Male	Bachelor's	Hunan	0 h	2×/week	4
VR video	23	23	Female	Bachelor's	Wuxi, Jiangsu	0–3 h/wk	3×/week	6
VR video	24	22	Male	High school	Zhejiang	≥7 h/wk	4×/week	3
VR video	25	23	Female	Bachelor's	Beijing	0 h	3×/week	2
VR video	26	24	Female	Master's	Beijing	≥7 h/wk	4×/week	6
VR video	27	22	Male	Bachelor's	Zhejiang	3–7 h/wk	5×/week	6

†Higher values indicate more frequent prior VR use (self-report). ‡Higher values indicate greater motion-sickness susceptibility (self-report).