

Development and Evaluation of an Immersive Virtual Reality as a Tool for Hajj Manasik Learning

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Abstract. Conventional Hajj manasik training largely relies on lectures and printed manuals, which often fail to convey the spatial complexity and procedural depth of pilgrimage rituals such as Tawaf, Sa'i, and Wukuf. While several digital applications have been developed to address this limitation, existing tools typically cover only a single ritual and lack grounding in a recognised religious guidance framework. This study develops and evaluates VREduHaji, an immersive virtual reality application that integrates three core Hajj rituals (Tawaf, Sa'i, and Wukuf) within a unified platform guided by Muhammadiyah's official pilgrimage instructions. The application was developed using the 4D model (Define, Design, Develop, Disseminate) and built with Blender and Unity 3D for deployment on the Oculus Quest 2 headset. Evaluation employed a four-tier protocol: black-box functional testing, expert media validation using a Likert scale and Aiken's V coefficient, expert content validation by Islamic studies lecturers, and usability testing via the System Usability Scale involving 40 university students. Black-box testing confirmed 100% functional success across all modules. Expert media validation yielded mean Likert scores of at least 88% with Aiken's V of at least 0.858, and content validation produced scores of at least 93% with Aiken's V of at least 0.86; both were rated highly feasible. The aggregated SUS score was 68.1, meeting the acceptable usability threshold. VREduHaji is technically sound, content-valid, and usable as an immersive manasik learning tool. It offers a religiously grounded and experiential alternative to conventional Hajj preparation.

Keywords: Hajj education; immersive learning; manasik; Muhammadiyah

INTRODUCTION

Hajj requires pilgrims to execute a tightly ordered set of rituals across distinct sites. Learners must understand movement, direction, timing, prayers, and the spatial relationship among the Grand Mosque, Safa and Marwah, Arafah, Muzdalifah, and Mina. Lectures, printed manuals, demonstrations, and physical manasik remain central to preparation, but static explanations alone cannot reproduce the scale, orientation demands, or procedural transitions encountered during pilgrimage. Immersive virtual reality (IVR) is relevant to this problem because a head-mounted display can combine spatial representation, embodied action, and immediate instructional cues in a repeatable environment [1].

Evidence from education research supports cautious use of IVR rather than assuming that immersion automatically improves learning. Reviews across higher education report benefits for visualization, engagement, spatial understanding, and procedural rehearsal, but they also identify inconsistent learning outcomes, weak pedagogical alignment, limited accessibility, and small or homogeneous samples [2]. Meta-analytic evidence indicates that virtual environments can improve learning under suitable instructional conditions [3]. Experimental studies also show a trade-off: stronger presence and positive affect can coexist with greater cognitive load or lower factual learning when salient virtual features distract from the learning task [4]. The Cognitive Affective Model of Immersive Learning therefore treats presence and agency as mechanisms whose educational value depends on instructional design, cognitive processing, and learner characteristics [5].

This design problem is acute in Hajj manasik. The learning task is procedural and spatial, but it is also religiously governed. A convincing simulation is inadequate if the order, wording, or contextual presentation of rituals lacks a stated jurisprudential source. Earlier Hajj-learning systems used mobile augmented reality, interactive multimedia, three-dimensional simulations, and VR [6]. These projects establish technical feasibility, yet many focus on a single ritual or location and provide limited evidence about how religious content was governed and validated.

Interactive media can make ritual instruction more concrete by connecting procedural explanations to visible actions and locations. Sidiq and Mustafidah developed a virtual three-dimensional Hajj simulation [7], while Abdul Rani and Ramli focused on Tawaf simulation under new-normal training conditions [8].

Kabir et al. designed a VR-based Hajj and Umrah experience that allowed users to engage with pilgrimage activities in a virtual setting [9]. Sumardani et al. positioned VR manasik as an accessible training alternative [10]. These systems differ in platform and scope, but they share an attempt to move learners from passive description toward simulated experience.

Augmented reality and multimedia applications provide related evidence. Madi et al. reported an AR mobile application for children learning Hajj [6]. Andyani et al. used VR to introduce the Kaaba to elementary-school students [11]. Utama et al. developed interactive multimedia for Hajj instruction among secondary-school students [12]. Such applications can support visualization and engagement, yet mobile screens and marker-based AR provide a different level of embodiment from head-mounted VR. Immersive VR places visual content around the user and allows controller-based action inside a three-dimensional scene.

This study develops VREduHaji, an IVR application that combines Tawaf, Sa'i, and Wukuf within one Oculus Quest 2 environment. The application uses three-dimensional scenes, controller-based navigation, audiovisual guidance, ritual counters, and directional cues. Its instructional content follows Muhammadiyah pilgrimage guidance and undergoes review by Islamic-studies experts. The study asks how an integrated application can represent the three rituals while maintaining functional and religious-content validity, and whether the resulting product meets expert-feasibility and user-usability criteria.

The study uses the 4D development model and evaluates the product through four separate tiers: black-box functional testing, media-expert validation, Islamic-content validation, and System Usability Scale (SUS) testing with 40 university students. This layered protocol distinguishes software operation from media quality, content accuracy, and perceived ease of use. Such separation follows the wider IVR literature, which recommends evaluating instructional design and interaction quality rather than treating technological novelty or presence as sufficient evidence of educational value [13]. SUS interpretation is anchored in empirical usability research showing that scores should be read comparatively and with attention to the tested user group and system context [14].

METHODS

Research design

The study used Research and Development with the 4D model: Define, Design, Develop, and Disseminate. The model was selected because it provides a direct sequence from needs analysis to product specification, implementation, expert review, user testing, and distribution. The unit of development was the integrated VREduHaji application. Evidence for the article was consolidated from the staged development of the Tawaf, Sa'i, and Wukuf modules. The overall research design and development stages are illustrated in Figure 1.

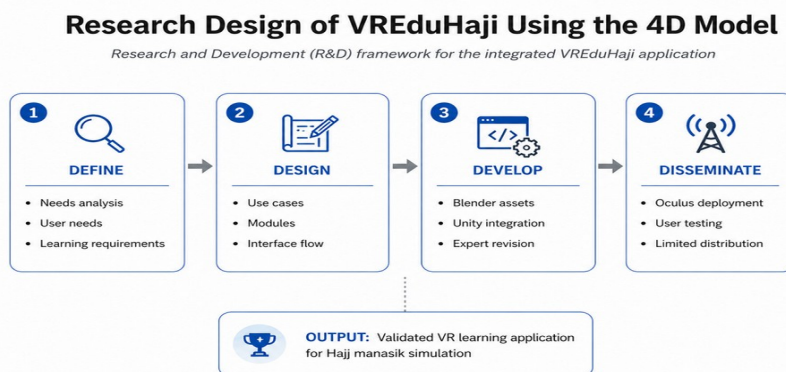


Figure 1. Research Design

The Define stage identified the learning and product requirements. The analysis reviewed conventional manasik practices and earlier digital applications. It found three central needs: spatial representation of ritual locations, procedural guidance during simulated action, and a clear religious reference for instructional content. Earlier internal development had produced separate Tawaf and Sa'i functions, while the Wukuf sequence and Muhammadiyah-aligned guidance remained incomplete.

The target users were Muslim learners and prospective pilgrims who needed introductory or supplementary manasik practice. University students were selected for the usability study because they could provide structured feedback after direct use of the headset. The application was not designed to issue religious rulings, certify pilgrim competence, or replace authorized instructors.

The Design stage translated the requirements into use cases, activity flows, scenes, and interface components. The main menu provided access to the three focal modules and supporting pages for instructions, material, application information, sound control, and exit. Each ritual module contained a distinct interaction flow. The Tawaf module placed the user in a three-dimensional representation of the Grand Mosque facing the Kaaba. Directional guidance supported counter-clockwise movement, while a lap counter recorded completed circuits. The module also provided audiovisual and textual material about Tawaf and the Kaaba environment.

The Sa'i module represented movement between Safa and Marwah. Directional arrows guided the user through the route, and a counter recorded completed passages. Pop-up information and prayer guidance connected movement to the procedural explanation. Reset and return controls allowed users to repeat the simulation or leave the scene. The Wukuf module represented Arafah with a desert environment, tents, routes, and Jabal Rahmah. Users could navigate with the controller, follow directional signs, open introductory material, and access prayer and worship guidance. Audiovisual content presented the sequence of Wukuf based on Muhammadiyah guidance, including prayer, remembrance, supplication, and seeking forgiveness. The design included movement controls, media controls, audio, and a reset function.

Three-dimensional assets were modeled and prepared in Blender. Unity 3D was used to assemble scenes, configure lighting and materials, implement navigation and interactions, manage audio and video, and connect the modules through the main menu. The application was built for the Oculus Quest 2. Controller input supported locomotion, button selection, object interaction, and ritual-specific actions.

Development proceeded iteratively. Each scene was first tested inside Unity, then built for the headset. Functional defects were corrected before expert review. Expert feedback informed changes to interface readability, navigation, audiovisual clarity, instructional sequence, and the religious material presented in the Wukuf module.

The Disseminate stage consisted of deploying the build on Oculus Quest 2 devices and conducting user trials. The study used a bounded dissemination strategy: the application was shared with evaluators and university-student participants rather than released publicly. This scope allowed the researchers to collect usability evidence before broader implementation.

Participant and Evaluators

Functional testing involved designated testers who executed the defined scenarios across the application. Media validation involved lecturers in Informatics Engineering Education with expertise in learning media and software. Content validation involved lecturers in Islamic studies, including Islamic education and Qur'anic studies, who assessed ritual accuracy and instructional suitability. User testing involved 40 second-semester university students who were enrolled in the Ibadah Muamalah course.

Instruments

Black-box testing used scenario-based checks for installation, launch, menu navigation, controller response, media playback, sound controls, ritual interactions, counters, reset controls, scene transitions, and application exit. A scenario passed when the observed response matched the specified response.

The media-validation questionnaire used a four-point Likert scale. Items covered instructional design, visual communication, navigation, interaction, software reliability, ease of operation, and the suitability of the development tools. The content-validation questionnaire also used a four-point scale and assessed learning objectives, sequence, depth, clarity, interactivity, communicative quality, and consistency between material and ritual guidance.

Usability was assessed with the ten-item System Usability Scale. Participants rated each statement on a five-point scale. For odd-numbered items, one was subtracted from the response. For even-numbered items, the response was subtracted from five. The adjusted scores were summed and multiplied by 2.5, producing a score from 0 to 100. The mean score represented perceived usability for each development stage.

RESULTS AND DISCUSSION

Product

VR EduHaji produced a single headset application with a shared home interface and integrated ritual scenes. Users could select Tawaf, Sa'i, or Wukuf; read or watch supporting material; control audio; return to the main menu; and exit the application. Ritual-specific functions included a Tawaf lap counter, Sa'i route guidance and passage counting, and a Wukuf environment with worship guidance, prayers, audio, and navigation toward Jabal Rahmah. The user interface of VR Haji is shown in Figure 2, the learning material display is shown in Figure 3, and the in-game experience is shown in Figure 4.

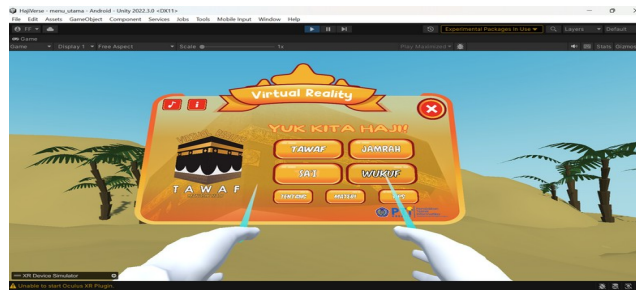


Figure 2. User Interface VR Edu Hajj

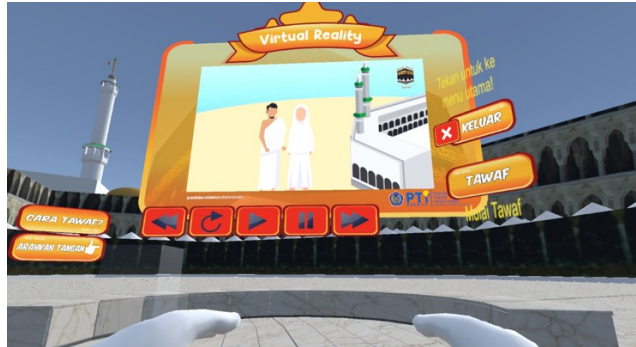


Figure 3. Learning materials

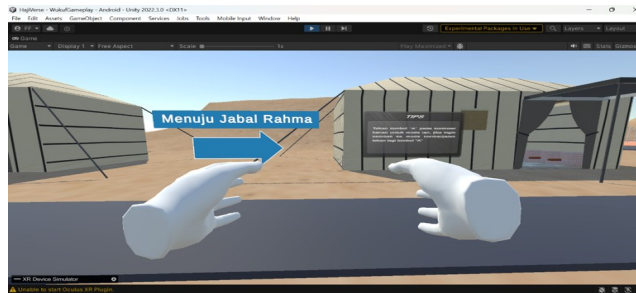


Figure 4. In game experience

The final product supported first-person interaction through Oculus Quest 2 controllers. The combination of three-dimensional environments and guided action distinguished the application from a video-only presentation. It also reduced fragmentation by placing multiple rituals within the same interface.

Functional Testing

Black-box testing recorded successful operation for all tested components. The application launched on the target device, displayed the main menu, accepted controller input, opened the ritual scenes, played the required media, updated counters, reset simulations, returned to the home scene, and exited as specified. No tested scenario was recorded as failed. Functional success was therefore 100%.

This result supports technical readiness under the tested configuration. It does not establish error-free operation on other headsets, operating-system versions, or prolonged sessions. The test also reflects predefined scenarios rather than unrestricted exploratory use.

Expert Validation

Media experts evaluated instructional design, communication and visual quality, and software operation. Across development stages, mean Likert feasibility scores were at least 88%. In the Wukuf-enhanced version, two media experts assigned a combined score of 86 from a possible 96, equivalent to 89.58%. The corresponding mean Aiken's V was 0.858. Aspect-level coefficients were 0.915 for instructional design, 0.872 for visual communication, and 0.787 for software.

The software aspect received the lowest coefficient. Item-level feedback and scores pointed to navigation ease, interaction consistency, comfort, and the realism of visual elements as areas for refinement. These findings align with the user score: the application was usable and feasible, but not frictionless for all first-time users.

Islamic-studies experts assessed the clarity, sequence, depth, and suitability of the ritual material. The Sa'i-centered stage obtained a 93% Likert score and a mean Aiken's V of 0.86. In the Wukuf-enhanced stage, content validation reached 100%, with Aiken's V equal to 1.00. Both stages fell within the highest feasibility category used by the study.

The Wukuf module's content was strengthened by explicitly referring to Muhammadiyah guidance. It described Wukuf as a core Hajj ritual and presented an ordered set of worship activities, including prayer, remembrance, supplication, and seeking forgiveness. The module provided selected prayers in text and audio formats. Expert validation supports the internal suitability of this content for the stated framework. It does not resolve jurisprudential differences outside that framework.

Usability Testing

The first group of 20 students produced a mean SUS score of 64.0 for the Sa'i-centered version. The second group of 20 students produced a mean score of 72.125 after the addition and refinement of the Wukuf module. The equal-weighted aggregate across 40 users was 68.1.

The increase between stage means should not be interpreted as an effect of the Wukuf module because the stages involved different participants and no controlled comparison. The aggregate score provides a concise summary of perceived usability across the two development samples. It indicates that participants could use the system, while the distance from higher SUS bands suggests remaining barriers in onboarding, control familiarity, and interface consistency.

Table 1 summarizes the overall usability testing results across both development stages, including the number of participants, the mean SUS score obtained in each stage, and the aggregate usability score from all 40 participants. The table provides a concise overview of the evaluation outcomes and supports comparison of usability performance across the two tested versions of VREduHaji.

Table 1. Result of all testing

Evaluation	Evaluators/ participants	Measure	Result	Interpretation
Functional testing	Designated testers	Black-box pass rate	100%	All tested functions passed
Media validation	Media experts	Likert feasibility	≥88%	Highly feasible
Media validation	Media experts	Aiken's V	≥0.858	High to very high validity
Content validation	Islamic-studies experts	Likert feasibility	≥93%	Highly feasible
Content validation	Islamic-studies experts	Aiken's V	≥0.86	Very high validity
User testing	40 students	Aggregated SUS	68.1	Acceptable, with room for improvement

Discussion

VREduHaji met the four feasibility criteria used in this study. The application executed every predefined scenario, media experts rated its instructional and technical design highly, Islamic-studies experts judged its content valid within the stated Muhammadiyah framework, and students reported acceptable usability. The evidence supports deployment as a supplementary manasik medium under supervised learning conditions. It does not establish educational superiority over lectures, manuals, videos, or physical practice.

The integrated structure responds to fragmentation in earlier Hajj applications. Previous systems demonstrated AR, multimedia, three-dimensional simulation, and VR for Hajj, Tawaf, the Kaaba, or general manasik instruction [9]. VREduHaji places Tawaf, Sa'i, and Wukuf within one interface and interaction model. This continuity matters because procedural learning depends on connecting what to do with where and when to do it. The design is consistent with international IVR research that identifies spatial visualization, repeated practice, and active interaction as plausible strengths of immersive environments [15][16].

Religious grounding adds a second layer of validity that general educational-VR frameworks rarely address. In manasik education, content accuracy includes the provenance, sequence, and context of ritual guidance. VREduHaji states its Muhammadiyah reference and subjects the material to Islamic-studies review. This decision makes the instructional position inspectable and maintainable. It also limits interpretation appropriately: validation supports consistency with the selected framework, not universal agreement across all jurisprudential traditions.

The findings fit the broader literature's distinction between immersion and learning. IVR can create presence and agency, but these mechanisms produce educational value only when interface demands and sensory detail support the intended task [5]. Parong and Mayer found that immersive science instruction can produce motivational benefits without automatically maximizing test performance [4]. Makransky, Terkildsen, and Mayer likewise reported greater presence but less learning in an immersive laboratory simulation [5]. These results explain why VREduHaji's functional success and expert feasibility should not be treated as evidence of knowledge gain. The present study evaluates the product, not comparative learning effectiveness.

The SUS score of 68.1 indicates usable but still improvable interaction. Empirical SUS research cautions against interpreting a single score as an absolute pass–fail judgment; scores depend on the product class, users, and testing conditions [14]. Here, many participants were first-time or inexperienced headset users, so controller familiarity may have raised perceived complexity. The media experts' lower score for the software aspect points in the same direction. A brief controller tutorial, guided practice before ritual instruction, consistent button placement, clearer reset and exit states, larger text, and less visual obstruction should reduce first-use friction.

Comfort and cognitive load require equal attention. Reviews of HMD-based learning report that cybersickness, navigation difficulty, equipment constraints, and extraneous detail can reduce the value of otherwise engaging simulations [17]. VREduHaji should therefore add adjustable locomotion speed, snap turning, teleport movement, seated mode, subtitles, high-contrast text, and visible boundaries. Instructional prompts should appear at the moment of action and avoid competing audio, text, and visual signals. These changes follow the CAMIL account of learning in IVR, in which presence and agency must be balanced against cognitive demands[5].

The virtual scenes also simplify field conditions. They do not reproduce crowd density, heat, fatigue, accessibility barriers, route changes, or operational decisions faced during pilgrimage. The Sa'i version sometimes placed pop-ups behind nearby geometry, and the Wukuf environment did not fully match the current physical setting. These limits are acceptable for introductory spatial and procedural rehearsal only when instructors explicitly discuss differences between simulation and practice. Periodic content and scene review is needed because both religious guidance materials and the physical organization of pilgrimage sites can change.

External validity remains limited. The 40 participants were university students from one institution and may be more comfortable with digital systems than many prospective pilgrims. International reviews repeatedly identify narrow samples and short evaluations as weaknesses in IVR education research [13]. Future studies should include first-time pilgrims, older adults, users with glasses, participants susceptible to motion sickness, and people with mobility or sensory limitations. A controlled pretest–posttest design should compare instructor-led manasik with instructor-led training supplemented by VREduHaji. Outcomes should include procedural recall, route sequencing, errors during physical simulation, delayed retention, confidence, cybersickness, and task completion time. Only such evidence can determine whether the application improves learning and for whom.

VREduHaji is best used before or alongside instructor-led manasik. An instructor can introduce the ritual and its religious basis, allow learners to practice inside VR, then debrief errors and questions. This sequence retains scholarly and pastoral guidance while using VR for spatial rehearsal. Shared sessions can also allow observers to follow the headset view on an external display and discuss the user's decisions.

Institutions adopting the application should treat content governance as an ongoing process. Religious experts should review updates whenever prayers, narration, sequence, or visual representation changes. Software versioning should record which content revision is included in each build. Technical testing should be repeated after Unity, headset firmware, or interaction-library updates.

CONCLUSION

This study developed VREduHaji, an immersive Oculus Quest 2 application integrating Tawaf, Sa'i, and Wukuf within a common learning environment. Blender and Unity 3D supported the creation of three-dimensional scenes, controller interactions, audiovisual guidance, counters, and directional cues. The Wukuf material followed Muhammadiyah pilgrimage guidance and underwent Islamic-content review.

All predefined black-box scenarios passed. Media experts assigned feasibility scores of at least 88% and Aiken's V values of at least 0.858. Content experts assigned scores of at least 93% and Aiken's V values of at least 0.86. Forty students produced an aggregated SUS score of 68.1. These results establish functional readiness, expert-assessed validity, and acceptable perceived usability under the tested conditions. VREduHaji should be described as a feasible supplementary learning medium, not yet as a proven substitute for conventional manasik. The next research stage should test learning and performance outcomes against an appropriate comparison group, involve prospective pilgrims across age groups, and improve accessibility and first-use interaction.

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