Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

JOURNAL OF INFORMATION SYSTEM AND TECHNOLOGY MANAGEMENT (JISTM)
www.gaexcellence.com/jistm

GLOBAL ACADEMIC EXCELLENCE

MIXED REALITY (MR) MODEL BASED ON VISUAL INTERACTION (VI) DESIGN PRINCIPLES FOR DEAF LEARNERS: A SYSTEMATIC LITERATURE REVIEW (SLR)

Ermiera Shafika Mokhtar[1], Nurulnadwan Aziz[2]*, Siti Zulaiha Ahmad[3], Siti Salbiah Hamzah[4], Amad Affandi Supli[5], Azizah Che Omar[6], Anitawati Mohd Lokman[7], Theo Teo[8]

[1]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Terengganu, 23000 Dungun, Terengganu, Malaysia
ermieramokhtar@gmail.com https://orcid.org/0009-0006-7025-4411

[2]Faculty of Business and Management, Universiti Teknologi MARA Cawangan Terengganu, 23000 Dungun, Terengganu, Malaysia
nurulnadwan@uitm.edu.my https://orcid.org/0000-0001-6693-9430

[3] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Perlis, 02600 Arau, Perlis
sitizulaiha@uitm.edu.my https://orcid.org/0000-0001-8529-0171

[4] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Terengganu, 23000 Dungun, Terengganu, Malaysia
salbiah452@uitm.edu.my https://orcid.org/0009-0001-9683-9622

[5] School of Computing and Data Science, Xiamen University Malaysia, 43900 Sepang, Selangor, Malaysia
ahmadaffandi@xmu.edu.my https://orcid.org/0000-0002-5505-2137

[6] School of Multimedia Technology and Communication, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia
co.azizah@uum.edu.my https://orcid.org/0000-0002-3718-2392

[7] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Shah Alam, 40450 Shah Alam, Selangor, Malaysia
anitawati@uitm.edu.my https://orcid.org/0000-0001-9117-5321

[8] Australian Research Centre for Interactive and Virtual Environments, University of South Australia (UNiSA), Australia
Theo.Teo@unisa.edu.au https://orcid.org/0000-0001-7322-8864

*Corresponding Author

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

Article Info:

Article history:
Received date: 12.07.2026
Revised date: 27.07.2026
Accepted date: 06.08.2026
Published date: 15.09.2026

To cite this document:

Mokhtar, E. S., Aziz, N., Ahmad, S. Z., Hamzah, S. S., Supli, A. A., Omar, A. C., Lokman, A. M., & Theo, T. (2026). Mixed Reality (MR) Model Based on Visual Interaction (VI) Design Principles for Deaf Learners: A Systematic Literature Review (SLR). *Journal of Information System and Technology Management, 11* (44), 276-295.

DOI: 10.35631/JISTM.1144017

Abstract:

Although Mixed Reality (MR) technologies have increasingly been explored to support Deaf education, existing studies primarily emphasize technological capabilities rather than the visual interaction requirements and cognitive needs of Deaf learners. This study presents a systematic literature review (SLR), following the PRISMA guidelines, to examine MR applications developed for Deaf individuals between 2015 and 2025. Five academic databases were searched using predefined inclusion and exclusion criteria. Eleven MR applications for Deaf individuals were identified, of which six focused specifically on educational settings and were further analysed to examine their features, interaction approaches, and design limitations. The findings indicate that while existing applications incorporate advanced features such as 3D avatars, gesture recognition, and gamified interaction, none systematically integrates Visual Interaction (VI) design principles to support clarity, consistency, accessibility, and cognitive usability. Furthermore, no MR application was specifically developed for Malaysian Deaf learners. Based on these findings, this paper proposes the Mixed Reality–Visual Interaction Design for Deaf Learners (MRVI-DL), a design framework that integrates MR capabilities with VI principles to support the development of accessible and cognitively appropriate learning environments for Deaf learners.

Keyword:

Human-Computer Interaction, Assistive Technology, Immersive Technology, Mixed Reality, Visual Interaction, Deaf Learners

Introduction

Mixed Reality (MR) has emerged as a promising technology for supporting visual and interactive learning environments for Deaf learners (Samala et al., 2024). MR lets actual and virtual components interact with each other in real time, which is wonderful for Deaf individuals, especially the learners who need visual cues to gain information and communicate (Mokhtar, Omar, & Aziz, 2022). Existing MR applications have demonstrated capabilities such as sign language visualization, gesture recognition, and immersive interaction contextual (Imashev, Oralbayeva, Kimmelman, & Sandygulova, 2022). These features not only keep users engaged, but they also make learning and interacting more effective (Radianti et al., 2020).

However, current studies predominantly focus on technological implementation rather than how visual interaction design can improve accessibility, cognitive processing, and learning effectiveness for Deaf learners. Consequently, there remains a lack of design guidance that systematically integrates Visual Interaction (VI) principles into MR development.

Literature Review

Deaf Learners

According to World Health Organization (2021), an individual is deemed to have hearing impairment or disability when they are unable to hear as well as individuals with normal hearing. There are four phases of hearing loss, which are mild, moderate, severe, and profound. It might injure one ear (unilateral) or both ears (bilateral). Depending on how bad the hearing difficulties are, this condition can make it hard to hear people talking and other loud sounds (WHO,2021). People who are Deaf typically have severe or profound hearing loss, which means they are unable to hear well enough to perceive information through auditory channels. Some individuals who are Deaf might think that having cochlear implants is enough to help them in connecting with the societies, but most of them claim that they rely on visuals, such as sign language, for daily communication. Hence, individuals who are Deaf, especially the Deaf learners, need more effort concerning communication support and learning accommodations to make sure they can fully participate in and access educational settings, especially in school, since traditional teaching and support often do not meet their specific communication needs (Edmondson & Howe, 2019).

Sign Language for Deaf Learners

People in Deaf communities all over the world use sign language to converse to each other most of the time. It has its own grammar and vocabulary that are different from those of spoken languages (Bala, 2020). It uses a mix of hand gestures, facial expressions, and body motions to convey meaning. Each Deaf culture has established its own sign language based on the major language used in that group. These languages are not mutually intelligible, even if they have a visual modality (Brentari, 2010). For example, American Sign Language (ASL) is widely used in the US and has had a huge effect on schoolwork all over the world. Meanwhile, in Malaysia, there are two versions of sign language used by the Deaf communities in Malaysia which are Bahasa Isyarat Malaysia (BIM) and Kod Tangan Bahasa Malaysia (KTBM). BIM is a natural sign language used in everyday life, and KTBM is a manually coded version of Malay that was made just for use in schools (Chong, 2018). As for the Deaf Learners, they use BIM for communicating, while KTBM is the language used during learning.

Limitations of MR for Deaf Learners

Reviewing the current immersive technologies for Deaf learners showed that they have several significant issues. To begin with, none of the current immersive technologies developed expressly incorporate VI design principles, as they prioritize functionality over the suitability of the design for Deaf learners learning (Radianti et al., 2020). Second, most technologies are still two-dimensional or only slightly immersive. They rely a lot on videos, flashcards, or simple AR overlays (Kydyrbekova et al.,2023). These designs lack the capacity for much engagement, fail to offer Deaf learners numerous opportunities for learning on their own, and may not make full use of their visual and spatial skills. Third, the growth of immersive systems in Malaysia has been slow and inconsistent, with big gaps in areas other than language and very few healthcare-related applications for Deaf individuals (Glasser, Mason Riley, Weeks, & Kushalnagar, 2019). These restrictions highlight the necessity for a comprehensive MR model tailored for Deaf learners, incorporating VI design principles and material suited to educational objectives.

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

Visual Interaction (VI) Design Principles

Visual Interaction Design (VI) deals with how the visual components mediate, structure and support the interaction between human and technological products such as immersive technologies that include MR or computer systems. VI Design, unlike the traditional interface-centered approaches (Gonzalez, 1995), is based on the concept of interaction as a dynamic process of perception, cognition, feedback and interpretation, rather than a static layout or surface aesthetics. This perspective is based on research in Human – Computer Interaction (HCI) which asks if designers design interfaces, dialogues or interactions. Ultimately putting interaction as the main concern of design.

While VI design is commonly used in interface and user experience design, to date there is no academic paper presenting a formal definition of the term or listing its principles in a standardised way. Instead, VI design principles are derived from its related disciplines, such as HCI, visual design, cognitive psychology, and usability engineering (Norman, 2013; Lidwell, Holden, & Butler, 2010). This interdisciplinary foundation illustrates the practical aspect of VI design, where visual and interactive aspects are integrated to improve usability, accessibility, and user engagement, particularly in complex technology such as MR. The main resources providing a detailed account of principles relevant to VI design principles are summarized in Table 1.

Table 1: Primary Resources

No	Source	Focus Area
1	Norman (2013)	Interaction & Visual Affordance
2	Lidwell, Holden, & Butler (2010)	Visual & Interaction Design
3	Mullet & Sano (1996)	Visual Interface Design
4	Sharp, Rogers, & Preece (2019)	HCI & Interaction Design
5	Garrett (2010)	UX & Interface Layers
6	Johnson (2014)	Cognitive Psychology in Design
7	Shneiderman et al. (2016)	HCI Principles
8	Cooper, Reimann, & Cronin (2014)	Interface & Interaction Design

From the foundational resources in Table 1, a list of VI principles was synthesized. These principles are best practices that help organize visual elements to improve clarity, usability, and user engagement. The sources may emphasize different principles individually, but collectively they provide a coherent framework for designing user interfaces that are both accessible and intuitive. Table 2. Summary of the VI design principles.

Table 2: VI Design Principles

No	Visual Interaction Design Principles	Description	Source
1	Clarity & Legibility	Ensure text, icons, and visuals are readable and distinguishable.	Johnson (2014), Norman (2013)

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

2	Consistency	Maintain uniformity in styles, layouts, and interactions to support predictability and learning transfer	Shneiderman et al. (2016), Lidwell et al. (2010)
3	Visual Hierarchy	Organize visual elements by importance using size, color, or placement.	Ware (2013), Garrett (2010)
4	Feedback	Provide immediate visual responses to user actions include audio, visual, or haptic cues for confirmation or error correction	Norman (2013), Sharp et al. (2019)
5	Affordance & Signifiers	Design elements to suggest how they can be used	Norman (2013), Cooper et al. (2014)
6	Proximity & Grouping	Place related elements close together and use visual similarity (color, shape, size) or enclosures to indicate relationships. Help users easily perceive connections, recognize categories, and navigate to reduce cognitive load	Lidwell et al. (2010), Mullet & Sano (1995)
7	Simplicity	Avoid unnecessary elements that distracted the user focus and focus on essential visual cues and interactions.	Garrett (2010), Johnson (2014)
8	Accessibility	Ensure all users can access and interact with the content. Include consideration for the colors, contrast, and navigation simplicity	Garrett (2010)

In conclusion, the VI design provides a strong theoretical basis for the development of educational systems aimed at visual communication and interaction. VI Design is based on human perception, cognition, and interaction theory, thus enabling the development of accessible, effective, and learner-centered environments. Thus, this systematic literature review (SLR) aims to find out the incorporation of VI in the existing MR for Deaf people, especially the learners.

Methodology

Systematic Literature Review (SLR) is a well-established secondary research methodology that is used to critically evaluate, assess and synthesize findings from existing primary studies to answer specific research questions (Kitchenham & Charters, 2007). This is a systematic and rigorous approach to identifying, selecting, evaluating and synthesising relevant studies within a particular domain, and provides a comprehensive understanding of the research topic. The main objectives of SLR are to summarize the existing evidence, to identify gaps in the current knowledge, to develop theoretical models, and to guide future research (Okoli & Schabram, 2015).

Furthermore, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for conducting SLR is one of the most widely used and adopted guidelines. PRISMA intends to improve the clarity and transparency of systematic reviews by providing a structured report of objectives, inclusion criteria, review methods and findings (Page et al., 2021). This approach ensures a reproducible and documented review process especially when using academic databases such as IEEE Xplore, ScienceDirect, and Scopus.

PRISMA provides a robust methodology for study selection, involving the definition of inclusion and exclusion criteria, conducting keyword searches, and systematically reviewing pertinent literature (Page et al., 2021).

The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. Five electronic databases (Scopus, Web of Science, IEEE Xplore, ACM Digital Library and Google Scholar) were searched based on pre-defined search strings. We searched for studies published between 2015 and 2025 and included or excluded them based on a priori defined criteria. Eligible studies were then qualitatively analysed for MR applications, design features, implementation gaps and Visual Interaction design elements relevant to Deaf learners. The six main phases that were undertaken across the SLR activities are described in detail below:

Phase 1: Identification

The first phase to be carried out is known as the identification phase. This comprises the formulation of research questions, eligibility criteria, keywords and strings, and the suitable databases. These basic steps were necessary to guarantee a focused and methodological review process. The activities in this initial phase are described in the following subsections.

Identification of Research Questions

The formulation of the research questions at the beginning of the SLR activities is a crucial step with a major impact on the quality, focus and consistency of the entire review process. Booth (2016) has also emphasized that clear research questions help to focus the review, inform the choice of relevant studies, and to ensure consistency in the use of inclusion and exclusion criteria. Well-defined research questions also allow systematic extraction and synthesis of data pointing to expected results. Additionally, structured frameworks such as PICO (Population, Intervention, Comparison, Outcome) may be helpful in formulating research questions that are answerable and comprehensive. The frameworks provide a logical, transparent structure that reduces ambiguity, increases clarity, and supports repeatability and thoroughness of the review process (Richardson et al., 1995). Thus, this research develops three research questions using the PICO framework to guide the SLR process. The research questions generated from the PICO framework are presented in Table 3.

Table 3: Research Questions Based On PICO Framework

No	PICO Elements/ Research Questions	P	I	C	O
1	What are the MR applications available for Deaf individuals between 2015 to 2025?	Deaf individuals	MR applications designed for Deaf individuals	None	A list of MR applications for Deaf individuals developed between 2015 and 2025
2	What are the features and gaps of existing MR	Deaf learners	Features and gaps of MR applications for Deaf learners	None	Identified features and gaps of existing MR applications for Deaf learners

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

	applications for Deaf learners?				
3	What are the components, elements, and principles of VI based on existing MR for Deaf learners?	Deaf learners	Components, elements, and principles of VI based on existing MR for Deaf learners	None	Identified components, elements, and principles of VI based on existing MR for Deaf learners

Identification of Eligibility Criteria

To ensure the relevance and quality of studies or research selected for review and analysis, a set of predefined eligibility criteria were formulated, including inclusion and exclusion criteria. These criteria were critical in defining the scope of the review process and filtering the studies, to ensure that only studies that are aligned with the research objectives were selected for review (Kitchenham & Charters, 2007). The application of clear eligibility rules enhances the consistency, transparency, and replicability of the review process. Table 4 depicts a list of inclusion and exclusion criteria.

Table 4: Eligibility Criteria

No	**Inclusion Criteria**		**Exclusion Criteria**	
1	Population	Studies with only Deaf or total hearing loss or profound hearing loss participants	Irrelevant Population	Studies that focus exclusively on other types of disabilities (e.g., visual, cognitive impairments) or other degrees of hearing impairment
2	Technology Focus	Studies on MR technologies	Non-MR Technologies	Studies focused solely on AR, VR, or XR without MR context
4	Publication Type	Research articles, conference papers and academic proceedings	Other publication types	Theses, dissertations, patents, posters, or unpublished manuscripts
5	Language Publication	English	Language Barrier	Other than English
6	Time Frame	2015 to 2025 (10 years)	Out of Time Frame	Out-of-the-year range provided
7	Databases	Scopus, IEEE Xplore, Web of Science, ACM Digital Library and Google Scholar (Supplementary Searches)	Other Databases	Other than the mentioned databases

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

Identification of Keywords and Databases

For this SLR activity, a systematic and exhaustive search strategy was designed to retrieve relevant and high-quality studies. The strategy used a combination of database-specific query structures, Boolean operators, and carefully selected keywords to optimize coverage and precision (Booth, 2016). The search was based on the core concepts of "Mixed Reality" and "Deaf", complemented with synonyms and related terms to broaden the disciplinary scope. In the preliminary phase, initial searches were piloted and iteratively refined to enhance the sensitivity and specificity of the search process. The keywords of "Education" and "Visual Interaction" were not added due to the limitation numbers of findings to ensure the richness of results.

Query construction was optimized for full terms (e.g., "Mixed Reality" and "Deaf") versus acronyms (e.g., "MR") that are highly polysemous and often returned a high volume of irrelevant results. Additionally, related but different terms such as "Augmented Reality", "Virtual Reality" and "Extended Reality" were intentionally excluded to maintain a focused scope on MR specific interventions and applications for the Deaf community. Then, to ensure inclusiveness and terminological accuracy in identifying the target population, a variety of lexical variants was used, such as "deaf", "hearing impaired", and "hearing disability". Booth (2016) showed that using a wider vocabulary in database searching reduces the chances of missing relevant studies because of differences in terminology.

The next step was to select the academic databases based on their relevance to the computing, education and assistive technologies fields and their indexing quality. Scopus and Web of Science were given priority due to their comprehensive bibliometric indexing, especially for interdisciplinary and peer-reviewed research (Gusenbauer & Haddaway, 2020). In the early stages of the search, the number of studies that specifically targeted MR for Deaf individuals were limited. Therefore, the scope was broadened by incorporating IEEE Xplore, ACM Digital Library and Google Scholar.

Kitchenham (2007) supported the decision of including IEEE Xplore by emphasising that the database is suitable for conducting systematic reviews in technical and engineering related fields. ACM Digital Library was selected for its large collection of user-centered and interaction design research highly relevant to the focus of this review (Wohlin, 2014). In addition, Google Scholar was utilized as an additional source to find grey literature, conference papers, theses, and emergent research not indexed in conventional databases (Higgins et al., 2019), thus enhancing the coverage of the review. A detailed list of keywords, Boolean operators and search strings used in each database can be found in Table 5. The screening process is described in the following sections.

Table 5: Keywords And Databases

Databases	Strings
Scopus Web of Science IEEE Xplore ACM Digital Library	("Mixed Reality") AND ("Deaf" OR "Hard of Hearing" OR "Hearing Impaired" OR "Hearing Impairment" OR "Hearing Loss" OR "Hearing Disability" OR "Deafness" OR "DHH" OR "Deaf and Hard of Hearing" OR "Profound Hearing Loss" OR "Total Hearing Loss")

Google Scholar	

Phase 2: Screening

The screening is the second phase of the SLR activity. During this phase, all records obtained from the initial search were preliminarily evaluated by reviewing their titles and abstracts for their relevance to the research objectives. This step was conducted following the inclusion and exclusion criteria, giving special attention to the studies that addressed the MR technologies developed for the Deaf. Records were excluded if they fulfilled any of the following criteria:

- The study did not involve MR as a core technological component,
- The targeted population did not include Deaf or totally hearing loss or profound hearing loss individuals, or
- The study fell outside the intended scope, focusing solely on Augmented Reality (AR) or Virtual Reality (VR) applications rather than MR-specific implementations.

The first screening phase was used to exclude clearly irrelevant studies, thus reducing the size of the dataset and ensuring that only potentially eligible studies proceed to the next phase of full-text evaluation. The results of this screening process are presented in Table 6. Additional information for the eligibility criteria and the reasons for the selection of the studies is discussed in the next sections.

Table 6: Screening Results

Database	Total Records Retrieved	Records after Inclusion and Exclusion Criteria
Scopus	42	20
Web of Science	20	15
IEEE Xplore	15	11
ACM Digital Library	338	82
Google Scholar	4220	648
Total	4635	776

Phase 3: Selection

The third phase is the election phase. It included full text eligibility assessment of studies identified at initial screening. At this stage a total of 776 articles were selected for detailed review. During this phase each article was critically evaluated for the relevance, methodological rigor and contribution to the research objectives, the application of MR designed for Deaf individuals.

In addition, a pre-determined set of inclusion and exclusion criteria was strictly followed to maintain quality and consistency. Studies were excluded if they (i) were outside the scope of MR technology, (ii) did not specifically focus on the Deaf or Deaf learners, and (iii) did not offer enough detail on the design components, elements, and principles of MR for the Deaf. Moreover, during this stage, 765 articles were excluded due to duplication, not matching the research scope, or lack of academic reliability. After applying all the eligibility criteria and removing duplicates and irrelevant content, only 11 studies fulfilled the final inclusion criteria. The basis for the next stage of the SLR, namely the inclusion and data abstractions, was made up of these 11 studies.

Phase 4: Inclusion and Data Abstraction

In this last phase of SLR, 11 studies were selected for qualitative analysis and detailed interpretation, all of which met the inclusion criteria. These studies represent a concentrated body of recent research on the development of MR technologies designed to meet the specific needs of Deaf people. All papers were carefully reviewed to extract meaningful insights and synthesize relevant data to inform the theories and approaches of this study.

Furthermore, to ensure consistency and academic rigor, the selected studies were systematically classified and assessed based on their fit with the core research questions as defined in the PICO framework. These questions were focused on three main aspects which are (i) existing MR for Deaf individuals from 2015 to 2025, (ii) gaps and features of the existing MR for Deaf learners, and (iii) design components, elements, and principles of VI based on existing MR for Deaf learners.

The whole process of review, starting from initial identification, screening, assessing eligibility and inclusion, is shown in Figure 2, which follows the PRISMA 2020 standardized flow diagram format. This clear and systematic approach improves the validity, reproducibility, and credibility of the review findings, providing a sound basis for subsequent model development.

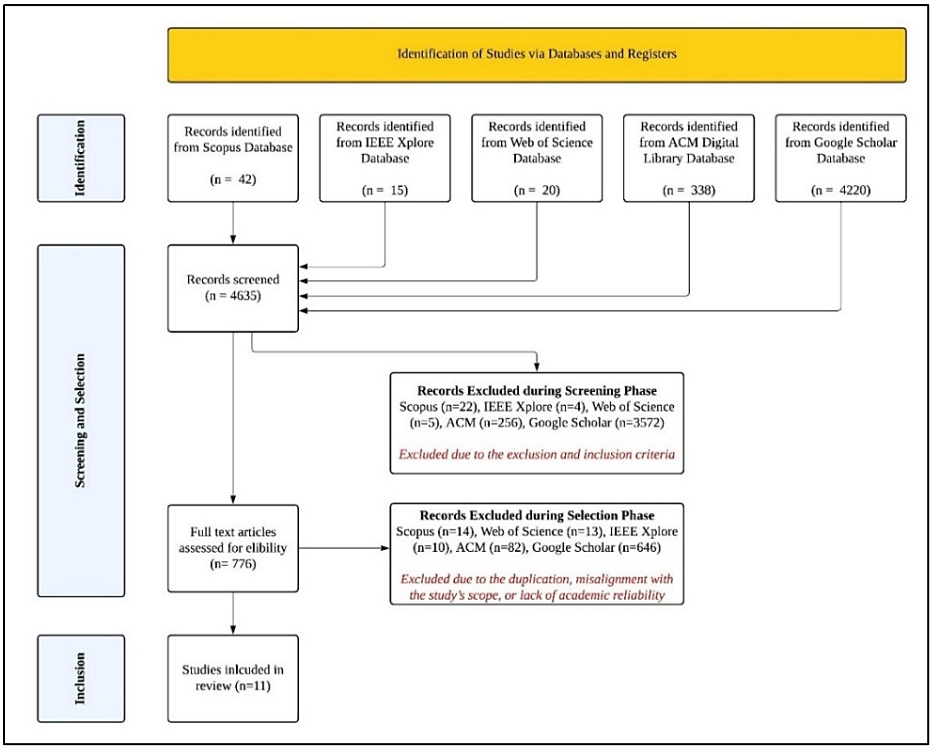

Figure 1: Data Abstraction and Analysis

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

Result and Discussion

This section discusses the results of the SLR process to answer the defined research questions. The review identified eleven MR applications targeting Deaf users. The purpose of this study is to explore educational design and for this reason only six studies that were explicitly centered on teaching and learning contexts were selected for detailed qualitative analysis. From these studies, interaction features, usability limitations and Visual Interaction design components were identified. The results were discussed in detail as follows:

Existing MR for Deaf Individuals (2017 – 2025)

Although the review initially aimed to cover studies from 2015 to 2025, only publications from 2017 to 2025 met the inclusion criteria and were deemed relevant. This period marks a notable advancement in the development of MR technologies, particularly in their application to accessibility and inclusion. During these years, innovations such as gesture recognition, AI-powered avatars, and cost-effective immersive hardware have enabled the creation of MR systems tailored to the communication needs of Deaf users (Radianti et al., 2020). Specifically, MR applications have started integrating features like sign language interpretation, holographic gestures, and visual prompts that align with the visual-centric communication style of Deaf individuals (Imashev, Oralbayeva, Kimmelman, & Sandygulova, 2022). Table 7 depicts the lists of existing MR for Deaf individuals available between 2017 to 2025.

Table 7: Existing MR for deaf individuals (2017 – 2025)

No	Citation	Application Name	Context of Use	Target Group
1	Adamo-Villani & Anasingaraju (2017)	Holographic Signing Avatars for Deaf Education	Educational for Math Learning	Deaf learners, parents, and teachers
2	Atanan, Sombunsukho, & Boonlue (2017)	E-Classroom	Language & literacy learning	Deaf learners
3	Correa et al. (2018)	MR Sign Language Therapy Tools (Coloring & Domino)	Education sign language learning	Deaf learners
4	Glasser, Mason Riley, Weeks, & Kushalnagar (2019)	MR Speaker Identification	Accessibility support	Deaf individuals
5	Hirabayashi, Fujikawa, Yoshimura, & Fujisawa (2019)	Japanese MR Learning Equipment	Education sign language learning	Deaf learners
6	Waldow & Fuhrmann (2020)	Avatar Collaboration in MR	Collaboration systems	Deaf individuals
7	Yang (2022)	Holographic Sign Language Interpreter	Educational interpreter	Deaf learners
8	Davis (2022)	PokerFace Mask Prototype	MR captioning	Deaf individuals
9	Kydyrbekova et al. (2023)	MR App Interaction Design	Kazakh Sign Language MR	Deaf learners

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

10	Wen et al. (2024)	MR Sign Language Teaching App	Immersive SL learning	Deaf learners & hearing users
11	(Chen et al., 2025)	AI Avatars with Sign & Voice in MR	Deaf-hearing communication	Deaf individuals & hearing users

Based on Table 7, it is evident that while significant advancements of immersive technology, particularly MR, many of the existing MR focus more on the content delivery than on the underlying design principles that ensure effective interaction and accessibility. On top of that, it is also revealed that most existing studies have concentrated on creating or enhancing learning environments to improve the educational experiences of Deaf learners. These MR systems primarily aim to facilitate visual learning, support sign language comprehension, and provide interactive experiences that help students engage with abstract concepts or curriculum-based content. Similarly, this research seeks to design a MR model specifically tailored to enhance the learning experiences of Deaf learners. The following subsections discuss the design challenges and opportunities for Deaf learners can be addressed in greater depth.

Gaps and Features of Existing MR for Deaf Learners

From the broader pool of MR applications identified for Deaf people, a subset of systems specifically designed for educational purposes was extracted and analyzed. These MR applications aim to support language acquisition, cognitive development, classroom engagement, and visual-based learning, aligning more directly with the visual communication preferences of Deaf learners. Out of the 11 MR previously listed, six studies were directly applicable to formal or informal learning contexts. The narrowed focus allows for a more in-depth analysis of the features and gaps which were summarized in Table 8.

Table 8: Gaps and features of existing MR for Deaf learners

Study No	Citation	Features	Contribution	Gaps	Integration of VI Design Principle
1	(Adamo-Villani & Anasingaraju, 2017)	3D hologram avatar + speech translation via AR glasses	Provides avatars to translates spoken English to Signed English to support the Deaf learners to understand Mathematics learning contents	• Limited accessibility support • Minimal sign language integration • High cognitive load for complex tasks	No
2	(Atanan, Sombunsukho, & Boonlue, 2017)	MR screen simulations, AR overlay,	Provide MR classroom design for Deaf learners to learn Science	• Lack of consistency in interface design	No

		gesture recognition	through Thai Sign Language	• Limited accuracy in gesture recognition • No adaptive difficulty • Not personalized for different proficiency levels	
3	Correa et al. (2018)	MR + gamified learning	Supplemental language skills learning and therapy support outside clinic—designed for use at home with therapist/parent guidance	• No personalized learning path • Limited gesture or motion interaction • Insufficient guidance for learners • Potential technical complexity for classroom use	No
4	Hirabayashi, Fujikawa, Yoshimura, & Fujisawa (2019)	HoloLens, hand tracking	MR-based sign language and katakana training device	• Minimal integration with curricula • Limited engagement tracking • No real-time feedback on gestures	No
5	Yang (2022)	HoloLens, interactive feedback	User experience with holographic sign language interpreter	Limited flexibility for learner pace	No
6	Kydyrbekova et al. (2023)	3D avatars, quizzes, interactive tasks	MR interface design recommendations	Limited user customization	No

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

As shown in Table 8, the existing MR applications are based on state-of-the-art technologies, such as holographic avatars, gesture recognition, and immersive environments, but most of the systems are more focused on technological novelty than usability and suitability of the design for the Deaf learners.

For example, Atanan et al. (2017) report interface inconsistency and limited gesture recognition accuracy, problems that could have been avoided with consistent visual affordances and feedback mechanisms. Likewise, Yang (2020) and Kydyrbekova et al. (2023) focus on user experience and interface recommendations. However, there is no systematic inclusion of VI principles in the design or evaluation process. Another limitation that is mentioned time and again in the table is the dearth of personalization and adaptability. Several studies such as studies by do not accommodate the learners' pace, proficiency levels or individual visual preferences. This is a crucial gap from a Deaf-centered design perspective because Deaf learners vary in linguistic background, sign language proficiency, and visual processing strategies. The lack of adaptive visual interaction mechanisms suggests that current MR systems are predominantly using a one-size-fits-all model rather than a learner-centered model. In summary, Table 8 effectively shows that existing MR systems for Deaf learners are technology-driven but design-theory-poor, especially in visual interaction. The identified gaps which are limited accessibility support, lack of personalization, insufficient feedback, high cognitive load, and absence of explicit VI integration which highlight the needs of MR model that integrate the VI design principles for the Deaf learners. Moreover, none of the reviewed MR systems was designed specifically for Deaf learners in the Malaysian context. Therefore, the following section is dedicated to the characterization of the design elements and components that constitute the basis for the development of the proposed MRVI-DL model.

Design Components and Element of Existing MR for Deaf Learners

There are six studies that were selected due to providing explicit and extractable details on the design components and elements relevant to the MR for Deaf learners. Despite differences in research focus, technological setup, and learning context, the studies collectively address a broad spectrum of design components and elements which can be classified as technological environments, sign language presentation methods, interaction mechanisms, feedback delivery, learning modes, user roles, application structures, and embedded learning theories. These varied contributions provide a comprehensive foundation for identifying and extracting the common design components required for constructing the MRVI-DL model, as summarized in Table 9.

Table 9: Design Components and Elements of MR For Deaf Learners

Study	Design Components	Design Elements
1	Holographic Sign Language Avatar (Full body)	3D full-body rigged avatar, life-like motion, Signed English signs, prosodic markers/modifiers
	Speech to Signed Conversion	Uses Microsoft Speech SDK + custom SRGS file
	Math-Focused Sign Content	K–6 animated math sign database
	Classroom Integration	Real-time teacher speech translated to holographic sign
	AR Display System	Meta 1 see-through glasses; 360° head tracking; real-world hologram integration

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

	Development Platform	Unity 3D engine
	Hardware	Meta 1 SDK (AR glasses, cameras, mic/speakers)
2	TSL Video-Based Learning	TSL signer video overlays, Smartboard, Tablets
	Gesture Recognition and Control	Camera-Based Gesture Input
	Visual Feedback	Real-Time Visual Matching
	Sign Repetition and Recognition	Practice & Response Tasks
	Vocabulary-Based Learning	Posters, Mobile AR interface, science keywords
	Tutorial	Onboarding Instructions
	Self-Paced Learning	Individualized Progression
	MR Equipment Interface	Smartboard, Mobile Devices, AR posters
	Looping Sign	Repeated Sign Animations via Video Loops
	Flash Cards	Printed AR cards (object flashcards) + camera scanning via mobile device
3	Domino Games	Tangible Domino Blocks, Tablet Camera, Marker Recognition
	Visual Feedback	Sentence highlighting, color-coded results, on-screen animations
	Error Highlighting	Incorrect color change, mismatched sentence structure indicator
	Therapist-Informed Content	Level-based system, therapist-in-the-loop design
	Vocabulary-Based Learning	Image-word domino blocks, sentence construction tools
	Match and Pair Tasks	Noun-adjective pair tasks, contextual visuals
	Self-Paced Learning	Tablet-based control, level choice, repeat option
	Customization Option	Configurable content blocks, adjustable difficulty
	Progress Tracking	Log system, interaction tracking, session summaries
	MR Equipment Interface	Tablet, AR markers, printed dominoes
4	Gesture Recognition	Gesture input via HoloLens
	Gesture-Based Control	Gaze-gesture interaction
	Head gaze	Gaze tracking
	Tangible Interaction	AR Flashcard
	Visual Feedback	Real-time AR response
	Multimodal Feedback	Multi-sensory (gesture + gaze + visual)
	Animated / Looping	Looping sign animation
	Vocabulary-Based Learning	Word-sign association
	Sign Repetition	Repeatable AR triggers
	Self-paced learning	Independent pacing
	Flash cards	Physical + digital flashcards
	MR Equipment	HoloLens, Tablet
5	Holographic Sign Language Avatar	Animated 3D avatar
	Avatar Framing Options (Full-body vs Half-body)	Avatar framing
	Gesture Control	Drag, rotate and resize
	Multimodal Feedback	Tutorial + UI + avatar
	Looping animation	Continuous sign animation

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295

	Tutorial: Hand Coach and Onboarding	Onboarding UI
	Sign Repetition and Self-paced learning	Repeatable flashcard
	Avatar Manipulation (Resize, Rotate, Move)	3D Avatar, Resize/Rotate Tools,
	MR Equipment	Smartphone AR App
	Speech-to-Sign Pipeline (Prototype)	Backend processing
6	Avatar-based Sign Demonstration	3D animated avatar
	Full or Half Body	Avatar Framing
	Gesture Recognition & Assessment	Gesture Feedback Visuals, Sign Accuracy Indicators
	Visual Feedback	Animated avatar
	Tutorial	Pre-training screen
	Looping Animation	Continuous motion
	Vocabulary-Based Learning	Category-word pairing
	Sign Repetition	Self-triggered observation
	Self-Paced Practice Mode	Independent learning
	MR Equipment Interface	Head-mounted display

Table 9 depicts the identified design components and elements across six selected studies based on the studies identified in Table 8 previously. In contrast, the analysis of VI design principles revealed notable gaps as none of the existing MR for Deaf learners integrates the VI design principles into their design and development process. Based on the identified design gaps, this study proposes MRVI-DL, a design framework that integrates Mixed Reality technologies with Visual Interaction design principles to support accessible, learner-centred, and cognitively appropriate learning environments for Deaf learners. Unlike previous MR applications that primarily emphasise technological functionality, MRVI-DL provides systematic design guidance for future educational MR development.

Future Works and Recommendations

The results suggest several avenues for future research. First, the design of future MR systems should systematically incorporate Visual Interaction design principles to increase usability, accessibility, and cognitive support of Deaf learners. Secondly, there should be adaptive and personalized interaction mechanisms to respond to different learning needs. Finally, future development should consider localisation, especially in the Malaysian education context by incorporating the local curriculum, BIM and KTBM to increase the educational relevance and adoption.

Conclusion

In this systematic literature review, 11 MR applications developed for Deaf individuals were identified and six educational applications were selected for further analysis. These applications demonstrate great technological advancement, but none systematically applies Visual Interaction design principles to facilitate interaction that is accessible and learner centred. The review also points to the lack of MR systems specifically designed for Malaysian

Deaf learners. The results are the foundation of the proposed MRVI-DL framework which combines MR capabilities with Visual Interaction principles to guide the future design of educational MR applications for Deaf learners.

Acknowledgements:	The authors wish to thank Universiti Teknologi MARA (UiTM) for the resources and support provided for this research. We are grateful to colleagues and peers for their valuable insight and constructive feedback which greatly improved the quality of this paper.
Funding Statement:	This research received financial support from Ministry of Higher Education (MOHE) Malaysia through the Fundamental Research Grant Scheme (FRGS) by the code FRGS/1/2023/ICT10/UITM/03/1. The funding body had no role in the design of the study, data collection, analysis, interpretation of results, or the decision to publish this manuscript.
Conflict of Interest Statement:	The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have contributed to this work and approved the final version of the manuscript for submission to the International Journal of Information System and Technology Management (JISTM)
Ethics Statement:	Ethical research standards were followed throughout the study. The studies with human participants were reviewed and approved by Universiti Teknologi MARA (UiTM) Terengganu, approval number 09/2024. Prior to data collection all participants provided informed consent. Participation was voluntary and confidentiality and anonymity were assured to the respondents. The data were used solely for academic purposes.
Author Contribution Statement:	All authors contributed substantially to the development of this manuscript. The conceptualization, methodology, and overall supervision of the study were carried out by Ermiera Shafika Mokhtar. Nurulnadwan Aziz was involved in the collection, analysis and interpretation of the data. Siti Zulaiha Ahmad helped draft the literature review, helped draft the manuscript and helped critically revise the manuscript. All authors have read and approved the final version of the manuscript prior to submission.

References

Adamo-Villani, N., & Anasingaraju, S. (2017). Holographic signing avatars for deaf education. In E-learning, e-education, and online training (pp. 54–61). Springer. https://doi.org/10.1007/978-3-319-52836-6_8

Alan Cooper, A., Reimann, R., & Cronin, D. (2014). About Face: The essentials of interaction design. Wiley.

Atanan, Y., Sombunsukho, S., & Boonlue, S. (2017). E-future classroom: A study mixed reality learning environment for deaf learners in Thailand. International Journal of Environmental and Science Education, 12(10), 2291–2315.

Bala, A. (2020). Sign language and its linguistic structure: A global perspective. Routledge.

Ben Shneiderman, B., et al. (2016). Designing the user interface. Pearson.

Booth, A. (2016). Searching for qualitative research for inclusion in systematic reviews: A structured methodological review. Systematic Reviews, 5(1), 74. https://doi.org/10.1186/s13643-016-0249-x

Chen, S., Cheng, H., Su, S., Patterson, S., Raja Kushalnagar, R., Huang, Y., & Wang, Q. (2025). Customizing generated signs and voices of AI avatars: Deaf-centric mixed-reality design for Deaf-hearing communication. Proceedings of the ACM on Human-Computer Interaction, 9(2), 1–31.

Chong, C. L. (2018). Sign language education in Malaysia: BIM and KTBM perspectives. Malaysian Journal of Communication, 34(2), 45–60.

Claes Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies. In Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering (pp. 1–10). https://doi.org/10.1145/2601248.2601268

Correa, D. P. A., Mejía, J. P., Lenis, A. M., Camargo, C. A., & Navarro-Newball, A. A. (2018). Building alternative methods for aiding language skills learning for the hearing impaired. In Colombian conference on computing (pp. 192–200). Springer.

Davis, J. (2022). PokerFace mask: Exploring augmenting masks with captions through an interactive, mixed-reality prototype (Master's thesis). Dartmouth College.

Diane Brentari, D. (2010). Sign languages: A linguistic introduction. Cambridge University Press.

Don Norman, D. A. (2013). The design of everyday things (Rev. ed.). Basic Books.

Edmondson, S., & Howe, J. (2019). Exploring the social inclusion of deaf young people in mainstream schools using their lived experience. Educational Psychology in Practice, 35(2), 216–228.

Garrett, J. J. (2010). The elements of user experience. New Riders.

Glasser, A., Mason Riley, E., Weeks, K., & Raja Kushalnagar, R. (2019). Mixed reality speaker identification as an accessibility tool for Deaf and hard of hearing users. In Proceedings of the 25th ACM symposium on virtual reality software and technology (pp. 1–3). ACM.

Gonzalez, C. (1995). Visual design of interaction, dialog, or interface? ACM SIGCHI Bulletin, 27(1), 12–13.

Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Research Synthesis Methods, 11(2), 181–217. https://doi.org/10.1002/jrsm.1378

Helen Sharp, H., Rogers, Y., & Jennifer Preece, J. (2019). Interaction design: Beyond human–computer interaction (5th ed.). Wiley.

Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (Eds.). (2019). Cochrane handbook for systematic reviews of interventions. Wiley.

Hirabayashi, N., Fujikawa, N., Yoshimura, R., & Fujisawa, Y. (2019). Development of learning support equipment for sign language and fingerspelling by mixed reality. In Proceedings of the 7th ACIS International Conference on Applied Computing and Information Technology (pp. 1–6).

Imashev, A., Oralbayeva, N., Kimmelman, V., & Sandygulova, A. (2022). A user-centered evaluation of the data-driven sign language avatar system: A pilot study. In Proceedings of the 10th International Conference on Human-Agent Interaction (pp. 194–202).

Johnson, J. (2014). Designing with the mind in mind. Morgan Kaufmann.

Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering.

Kydyrbekova, A., Kenzhekhan, A., Omirbayev, S., Oralbayeva, N., Imashev, A., & Sandygulova, A. (2023). Interaction design of the mixed reality application for Deaf children. In International Conference on Human-Computer Interaction.

Lidwell, W., Holden, K., & Butler, J. (2010). Universal principles of design. Rockport Publishers.

Mokhtar, E. S., Omar, A. C., & Aziz, N. (2022). Proposed design principles of Malay sign language mobile application for hearing-impaired alpha generation. In 2022 IEEE 12th International Symposium on Computer Applications and Industrial Electronics (ISCAIE) (pp. 233–240). IEEE.

Mullet, K., & Sano, D. (1996). Designing visual interfaces. ACM SIGCHI Bulletin, 28(2), 82–83.

Okoli, C., & Schabram, K. (2015). A guide to conducting a systematic literature review of information systems research.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & Moher, D. (2021). The PRISMA 2020 statement. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Papadopoulos, T., Evangelidis, K., Kaskalis, T. H., Evangelidis, G., & Sylaiou, S. (2021). Interactions in augmented and mixed reality: An overview. Applied Sciences, 11(18), 8752.

Paul Milgram, P., & Fumio Kishino, F. (1994). A taxonomy of mixed reality visual displays. IEICE Transactions on Information and Systems, 77(12), 1321–1329.

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers & Education, 147, 103778.

Richardson, W. S., Wilson, M. C., Nishikawa, J., & Hayward, R. S. (1995). The well-built clinical question: A key to evidence-based decisions. ACP Journal Club, 123(3), A12–A13.

Rokhsaritalemi, S., Sadeghi-Niaraki, A., & Choi, S. M. (2020). A review on mixed reality: Current trends, challenges and prospects. Applied Sciences, 10(2), 636.

Samala, A. D., Rawas, S., Criollo-C, S., Bojic, L., Prasetya, F., Ranuharja, F., & Marta, R. (2024). Emerging technologies for global education. SN Computer Science, 5(8), 1175.

Waldow, K., & Fuhrmann, A. (2020). Addressing deaf or hard-of-hearing people in avatar-based mixed reality collaboration systems. In IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) (pp. 594–595). IEEE.

Wen, H., Xu, Y., Li, L., Ru, X., Wu, Z., Fu, Y., & Wang, X. (2024). Enhancing sign language teaching: A mixed reality approach. In 2024 IEEE International Conference on Systems, Man, and Cybernetics (SMC) (pp. 740–745). IEEE.

World Health Organization. (2021). Deafness and hearing loss. WHO.

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 11 Issue 44 (September 2026) PP. 276-295
Yang, F. C., Mousas, C., & Adamo-Villani, N. (2022). Holographic sign language avatar interpreter. Computer Animation and Virtual Worlds, 33(3–4), e2082. https://doi.org/10.1002/cav.20