UNIVERSITI TEKNOLOGI MARA

THE USE OF AUGMENTED REALITY (AR) IN ENHANCING ANIMATION LEARNING FOR DEAF AND HARD OF HEARING (DHH) STUDENTS.

MOHAMAD SAIFUDDIN BIN RUSLI

MA

April 2026

UNIVERSITI TEKNOLOGI MARA

THE USE OF AUGMENTED REALITY (AR) IN ENHANCING ANIMATION LEARNING FOR DEAF AND HARD OF HEARING (DHH) STUDENTS.

MOHAMAD SAIFUDDIN BIN RUSLI

Thesis submitted in fulfilment
of the requirements for the degree of
Master of Arts and Design

Faculty of Art and Design

April 2026

CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 04 December 2025 to conduct the final examination of Mohamad Saifuddin Bin Rusli on his Masters of Arts thesis entitled "The Use Of Augmented Reality (AR) In Enhancing Animation Learning For Deaf And Hard Of Hearing (DHH) Students." in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiner recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

Saiful Akram Che Cob@Ab Ghafar
Associate Professor
Faculty of Art and Design
Universiti Teknologi MARA
(Chairman)

Muhamad Fairus Kamaruzaman
Associate Professor
Faculty of Art and Design
Universiti Teknologi MARA
(Internal Examiner)

Noor Hanan Mohd Jafar
Senior Lecturer
Taylor's University
(External Examiner)

PROFESSOR DR HJH ZURAEDA IBRAHIM
Dean
Institute of Postgraduate Studies
Universiti Teknologi MARA
Date: April 2026

AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student	:	Mohamad Saifuddin Bin Rusli
Student ID. No.	:	2020864418
Programme	:	Master of Arts and Design – AD750
Faculty	:	Art and Design
Thesis Title	:	The Use Of Augmented Reality (AR) In Enhancing Animation Learning For Deaf And Hard Of Hearing (DHH) Students.
Signature of Student	:	……………………………………………..
Date	:	April 2026

ABSTRACT

This study investigates the potential of Augmented Reality (AR) to enhance art and design education for Deaf and Hard of Hearing (DHH) students within Malaysian vocational education settings. The research addresses a critical problem: DHH students face significant barriers in art and design classrooms due to the split-attention effect caused by simultaneous visual demonstration and verbal explanation, compounded by limited sign language vocabulary for technical and artistic terminology, and the absence of AR educational tools designed specifically for this population. A comprehensive literature review underpins the study, emphasizing the role of AR in bridging communication gaps and fostering inclusive education through the theoretical lenses of Social Constructivism and Visual Learning Theory. The study employed a qualitative research design, conducting semi-structured interviews with three Special Education Teachers and two AR Experts, supplemented by teacher-facilitated prototype testing with DHH students. Thematic analysis was applied to identify key insights regarding current practices, challenges, and pedagogical strategies. Findings reveal that while educators recognise AR's potential for three-dimensional visualisation and enhanced engagement, purposeful integration remains absent from current practice. Six pedagogical strategies emerged from the synthesis of educator and expert perspectives: Visual-First Design, Mobile-Based Delivery, Pre-Vocational Simulation, Reduced Text Dependency, Interest-Driven Engagement, and Collaborative Development. Preliminary student feedback validated the visual-first approach while indicating demand for expanded interactive 3D content. The study highlights the necessity of developing tailored AR tools that leverage DHH students' documented visual learning strengths while addressing the specific communication and cognitive load challenges they face. Recommendations for future research include experimental studies measuring learning outcomes and expanded investigation across other subject areas and educational levels.

ACKNOWLEDGEMENT

Firstly, I wish to thank God for giving me the opportunity to embark on my Master's journey and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisor, Assoc. Prof. Dr. Zainuddin Ibrahim, for his continuous support, guidance, and invaluable advice throughout this research.

I would also like to express my heartfelt thanks to my second supervisor, Datuk Ts. Dr. Mohd Nor Hajar Hasrol Bin Jono, for his unwavering support and encouragement, which has been instrumental in helping me navigate the complexities of this project.

My deepest appreciation goes to my family, especially my brother, who have been a constant source of strength and motivation. Their understanding, patience, and unwavering belief in my abilities have been a driving force behind this accomplishment.

I am also grateful to my colleagues and friends for their support, and for the stimulating discussions and collaboration that enriched my research experience. Lastly, I extend my thanks to everyone who contributed directly or indirectly to this work, your contributions have been invaluable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviations

AR	Augmented Reality
DHH	Deaf and Hard of Hearing

CHAPTER 1
INTRODUCTION

1.1 Research Background

The rapid evolution of digital technology has fundamentally altered the landscape of modern education, necessitating a departure from traditional, didactic teaching methods toward more immersive and interactive pedagogical models. At the forefront of this technological shift is Augmented Reality (AR), a medium that overlays computer-generated perceptual information including visual, auditory, and haptic data onto the real-world environment. Unlike Virtual Reality (VR), which immerses the user in a completely synthetic environment, AR maintains the user's connection to the physical world while enriching it with digital context (Bilbow, 2021). Although the conceptual origins of mixed reality date back to the 1960s, and the term "Augmented Reality" was coined by Boeing engineer Tom Caudell in 1990 to assist in aircraft assembly, the technology has only recently matured into a ubiquitous consumer tool (Vasarainen & Vetoshkina, 2021). The convergence of advanced computer vision, cloud computing, and the widespread proliferation of high-performance smartphones has transitioned AR from experimental industrial applications to a mainstream technology capable of transforming daily life, healthcare, and specifically, education (Syed et al., 2022).

In the educational domain, AR has revolutionized the learning experience by transforming passive information consumption into active, multi-sensory engagement. Traditional educational environments often rely heavily on text-based and auditory instruction, which can be abstract and difficult for students to conceptualize. AR addresses this by visualizing complex concepts in three dimensions, allowing students to manipulate virtual objects and observe phenomena that would be impossible to replicate in a standard classroom (Majoro, 2021). This capability is particularly vital for inclusive education, where the goal is to provide equitable learning opportunities for students with diverse needs. By offering individualized and flexible learning modalities, AR can bridge the gap between rigid curriculum structures and the unique cognitive or physical requirements of students with special needs (Sayler, 2021).

However, the challenge of inclusion is most acute for the Deaf and Hard of Hearing (DHH) community. Deafness and hearing impairment encompass a spectrum of severity, ranging from mild hearing loss to profound deafness, often categorized by the affected part of the auditory system (Shapiro et al., 2021). For DHH individuals, the primary barrier to education and social integration is communication. The conventional educational ecosystem is predominantly designed for hearing individuals, relying heavily on spoken language and auditory cues. While the DHH community has developed robust communication systems such as Sign Language (e.g., American Sign Language or British Sign Language), lip-reading, and text-based communication, significant gaps remain in accessing information in real-time (Kushalnagar & Vogler, 2020). Assistive technologies such as hearing aids, cochlear implants, and speech-to-text applications have alleviated some of these burdens, yet they often fail to capture the nuance and immediacy of direct communication, leading to potential social isolation and limited access to employment and healthcare (Hyeko, 2021; Dim, 2022).

This is where the intersection of AR and DHH education presents a transformative opportunity. AR technology is uniquely positioned to dismantle communication barriers by providing visual alternatives to auditory information. Recent advancements have demonstrated the efficacy of AR in language acquisition for DHH students, specifically through the use of animated sign language characters and real-time interpretation overlays (Stefánsdóttir et al., 2024). By superimposing sign language interpreters or textual captions directly onto a student's field of view, whether through smart glasses or mobile screens, AR allows learners to access content simultaneously without shifting their focus away from the instructor or the subject matter. This dual-coding approach supports literacy development and helps overcome the challenges DHH students face with written forms of language, which often differ syntactically from sign language (Rusli & Ibrahim, 2022). Furthermore, AR applications in media and entertainment have pioneered accessible design by integrating interpreters into the visual narrative, proving that inclusive design can enhance the experience for all users rather than segregating DHH audiences (Tran et al., 2023; Shovkovyi et al., 2023).

Despite the global proliferation of these technologies, the integration of AR within the Malaysian education system, particularly in Technical and Vocational Education and Training (TVET), remains in a nascent stage. The Malaysian Education Blueprint (2013–2025) explicitly emphasizes the need for ICT integration to foster self-directed learning and improve digital literacy across the nation. However, practical implementation in vocational settings often lacks specific frameworks for students with learning challenges and disabilities. While general adoption of educational technology is increasing in Malaysia, there is a critical scarcity of research addressing how AR specifically supports inclusivity within Malaysian vocational colleges. Most local implementations focus on general technical skill acquisition rather than accessible design for DHH learners.

Consequently, there is a pressing need to explore how AR can be leveraged to democratize access to technical skills for diverse learners in the local context. By bridging the gap between advanced visualization technology and the specific communication needs of the DHH community, AR holds the potential to align Malaysian TVET institutions with global standards of inclusive education. This study seeks to address this gap, examining the efficacy of AR as a pedagogical tool to empower DHH students, ensuring they are not left behind in an increasingly digital workforce.

1.2 Motivation for this Work

The theme of the study is based on the fact that there is an unlimited range of opportunities for the community of Deaf and Hard of Hearing (DHH) including education, entertainment, and social interaction through the use of AR technology (Fernandes et al., 2023). Still, even though significant progress has been made in technological innovations and social inclusiveness, the DHH individuals still face many problems on the level of information, education and media that are at the same level with the hearing individuals. Such a scenario naturally stunts both professional and personal growth while also increases the level of social shyness. The advent of AR technology offers the experts a unique chance to deal with the problems at the root. By superimposing digital information into the real world through AR, the HHH will help them to interact with their surrounding in a better way, thereby, making it more accessible and inclusive. For example, AR makes learning more engaging through its visual and interactive features and by excluding auditory information only (Köse & Güner-Yildiz, 2021). In entertainment, AR can be an important factor for a more inclusive media world, which DHH audience can build up the feelings of being part of the story just like hearing people do, because of the sign language integration or subtitles that can be highly visible and clear.

Moreover, the hypothesis of using AR as a real-time sign language translation tool would be a phenomenal invention that goes a long way in equalizing the playing field between DHH people and the hearing world (Awwad et al., 2021). This could considerably reduce the feeling of loneliness and helplessness, which are the most striking symptoms of hearing circumstances and make people feel as if they are part of the community. The basic reason of the research lies in the belief that technology is supposed to remove barriers and make the world a united place according to (Bibri et al., 2024). The study of the AR potential to boost the DHH community accessibility and inclusiveness is the objective of this work. This work sets the base for the future of a tech-empowered DHH community.

1.3 Problem Statement

The fundamental challenge addressing the educational landscape for the Deaf and Hard of Hearing community is not merely one of access to information but rather the mode and efficacy of instructional delivery. While inclusive education policies have placed DHH students within mainstream and vocational settings, the pedagogical strategies employed in these environments often remain rigidly auditory in nature. This disconnect is particularly acute within the specialized domain of Art and Design education. Unlike theoretical subjects that may rely heavily on textbooks which are accessible through reading, creative disciplines such as animation, graphic design, and visual arts require a unique blend of technical demonstration, abstract conceptualization, and immediate critique. The current educational ecosystem fails to provide adequate support for DHH learners in these creative fields, leading to a significant gap in skill acquisition and professional readiness compared to their hearing peers.

The primary issue lies in the inherent nature of Art and Design pedagogy which relies heavily on the simultaneous presentation of visual and verbal information. in a typical animation or design class, an instructor will demonstrate a software technique or a drawing method on a screen while simultaneously explaining the theoretical rationale behind the action. For a hearing student, processing this visual and auditory input happens concurrently and seamlessly. However, for a DHH student, this creates a cognitive phenomenon known as the split attention effect. The student must look at the interpreter to understand the explanation, then look at the screen to see the demonstration, and then look back at the interpreter. By the time their gaze returns to the screen, the critical moment of the demonstration has passed. This constant visual toggling results in cognitive overload and fragmented learning, making it nearly impossible for DHH students to grasp complex, time sensitive technical skills in animation and design.

Furthermore, the linguistic gap in creative education presents a formidable barrier. The specialized terminology used in animation and design education encompasses abstract concepts such as "squash and stretch," "rule of thirds," or "chromatic aberration." These technical terms often lack direct equivalents in standard Sign Language. Consequently, interpreters who are not subject matter experts may resort to fingerspelling these terms or using simplified gestures that fail to convey the nuance of the artistic principle. This lack of precise technical vocabulary in the instructional delivery prevents DHH students from mastering the professional jargon necessary for the industry. The absence of a standardized, visual based lexicon for design concepts means that DHH learners are often excluded from the deeper theoretical understanding required to excel in creative professions, relegating them to merely copying techniques without understanding the underlying artistic logic.

Although Augmented Reality technology has been touted as a solution for accessibility, the current state of AR development reveals a significant deficiency regarding applications tailored for the creative education of DHH learners. Existing AR solutions for the Deaf community are predominantly focused on basic communication utilities, such as speech to text translation or general navigation assistance. While these tools are valuable for daily social interaction, they are wholly insufficient for the complex demands of Art and Design education. A simple captioning overlay does not solve the problem of visual distraction in a studio class, nor does it help visualize abstract 3D motion concepts. There is a distinct lack of AR integrated learning support that is specifically designed to teach creative skills. Current literature and practice have largely ignored the potential of AR to act as a direct pedagogical bridge in the arts, focusing instead on STEM subjects or general literacy.

This gap is further exacerbated by the design of existing educational technologies which often prioritize audio cues or text heavy interfaces that do not align with the visual spatial learning strengths of the Deaf community. DHH individuals often possess enhanced peripheral vision and a strong capacity for processing visual information, yet standard educational software rarely leverages these strengths. In the context of animation education, where understanding movement, timing, and spatial relationships is paramount, the lack of visually centric AR tools represents a missed opportunity. The problem is not that the technology does not exist, but that it has not been configured to address the specific pedagogical needs of DHH art students. There is a scarcity of research on how animated, visually enhanced AR content can be used to demonstrate abstract design principles directly within the student's field of view, thereby eliminating the need to look away at an interpreter and reducing the cognitive load.

Moreover, the exclusion of DHH students from quality Art and Design education has profound long term implications for their professional inclusion. The creative industries are increasingly reliant on digital technology and complex software proficiency. By failing to provide accessible, high quality instruction in these areas, the education system effectively bars DHH individuals from entering high growth careers in media, advertising, and entertainment. The problem is therefore two fold: a pedagogical failure in the classroom caused by the split attention effect and linguistic barriers, and a technological failure in the market to provide specialized AR tools that cater to the unique requirements of creative skill acquisition.

Consequently, this research identifies a critical void in the intersection of AR technology, special education, and the creative arts. The problem this study seeks to address is the absence of a dedicated, AR integrated learning framework that supports DHH students in overcoming the specific communication and cognitive hurdles present in animation and design education. Without the development of specialized AR applications that utilize visual overlays, sign language integration, and animated demonstrations of abstract concepts, DHH students will continue to be marginalized within the creative disciplines. This study argues that generic accessibility tools are insufficient for the nuance of art education and that a targeted approach using visually enhanced AR is necessary to ensure equitable learning opportunities and to unlock the creative potential of the DHH community.

1.4 Research Objectives

i) To examine the current application of Augmented Reality (AR) within art and design education for Deaf and Hard-of-Hearing (DHH) students.

ii) To analyze the challenges and limitations associated with implementing AR-based learning tools for DHH students in art and design contexts.

iii) To propose pedagogical strategies that can effectively enhance AR-based learning experiences for DHH art and design students.

1.5 Research Questions

i) How is Augmented Reality (AR) currently applied within art and design education for Deaf and Hard-of-Hearing (DHH) students?

ii) What specific challenges and limitations arise when implementing AR-based learning tools for DHH students in art and design contexts?

iii) What pedagogical strategies can effectively enhance AR-based learning experiences for DHH art and design students?

1.6 Significance of Study

The study on Augmented Reality (AR) for Deaf and Hard of Hearing (DHH) individuals in Malaysia that is particularly focused on animation has a tremendous significance (Rusli & Ibrahim, 2022). The study fills an important niche in inclusive technology and education by examining how AR can boost learning, communication, and engagement for DHH individuals who typically have to face the hurdles of information and education resources acquired. On the one hand, this study has considerable contribution to making inclusive education in Malaysia sustainable. Through the exploration of the efficacy of AR-infused animation for DHH learners, the study helps the development of sophisticated educational resources that meet a range of learning styles. Through applying interactively and imagery content, AR can be used to make learning easier, engaging, and effective for DHH students (Alias et al., 2023). As a result, greater academic success and personal growth are likely to be achieved.

Moreover, the research has a great impact on enhancing the sense of belonging and equality for DHH people in Malaysia (Moeller et al., 2024). Information and communication access is the foundation of participation in social, cultural, and economic activities. Through AR technology this research aims to overcome communication and comprehension barriers of non-hearing individuals as well as enable them full participation in the society that will eliminate the gap between the hearing and not hearing worlds. Besides, this research also has impact on the field of technology innovation and creation in Malaysia (Adnan, 2022). This research aims at investigating the AR technology usage and appropriateness among the DHH population, especially in animation, which is important in creating enhanced and suitable AR solutions for different areas, beyond education, including entertainment, healthcare, and workforce training. This stimulates technological advancement and economic development and competition on a global digital arena too. Ultimately, this study brings policy and advocacy implications for promoting accessibility and inclusion of DHH individuals in Malaysia (Tan et al., 2023). Research findings serve as the basis for the investment in inclusive technologies and the development of intervention programs that cater to the different capacities of participants. Because by knowing that AR-enhanced animation is an important integration tool for the curriculum and digital systems on a systemic level, the research suggests that the DHH people should be put first.

1.7 Limitation

Even though the investigation on AR for Deaf and Hard of Hearing (DHH) students in Malaysia contributes to advancements in technology and education, the study is affected by limitations that prevent a clear interpretation and conclusion that can be generalized (Rusli & Ibrahim, 2022). Sample bias is a significant constraint (Monroe et al., 2022). This study specifically refers to Malaysian DHH people; hence, the recruitment of a representative sample is an issue due to the heterogeneity in this community regarding hearing loss levels and communication preferences. Furthermore, as a qualitative inquiry, this study relies on a small sample size to achieve depth of understanding. This approach introduces limitations regarding the subjectivity of the researcher in data interpretation and restricts the statistical generalizability of the findings to the wider DHH population.

The limitations of this study regarding technology are engendered by problems of accessibility and usability (Henni et al., 2022). While AR technology can make information more accessible to the DHH community, it encounters challenges such as device compatibility, internet connectivity, and interface design. Likewise, technical issues such as battery life and processing power may hamper the user experience of AR-enhanced animation, potentially affecting the validity of the study results. Another issue is the ecological validity of the experiment design. Unsupervised trials or simulations may not adequately represent the real-life situations DHH students experience in Malaysia (Almurashi et al., 2022). Factors like classroom dynamics and socio-cultural conditions are critical issues that determine the applicability of AR technology, requiring caution when generalizing research outcomes.

Moreover, the research faces cultural and linguistic limitations (Baker et al., 2020). Malaysia is unique due to its multiethnic and multicultural background. Developing AR-augmented animations that align with the diverse cultural preferences and sign language variations of these groups poses challenges in translation and localization. Finally, the study is bound by strict ethical considerations regarding access to minors. Conducting research with DHH students in schools requires rigorous adherence to ethical protocols, parental consent, and institutional permissions, which limits the researcher's ability to access participants freely and impacts the scope of data collection.

1.8 Assumption

This research is based on several assumptions that form the basis of research objectives and framework (Shwartz & LeCun, 2024). It is of utmost importance to look critically at these assumptions to ensure the upholding of the research quality. For example, the AR study claims that the technology is able to offer opportunities and better education to the deaf students in Malaysia. This view is anchored on the knowledge that AR provides visual, interactive, and immersive experiences that are customized to effectively address the learning problems and communication style of the DHH group. On the other hand, these factors could be overlooked such as technology availability, ease of use, and culture adaptation, which are important to the success of AR implementation and the inclusion of the DHH people in Malaysia. Nevertheless, the program considers AR-enhanced animation and provides educational material that has been designed for including the culture of DHH in Malaysia. This hypothesis demonstrates the inclusion of sign language interpretation, subtitles, visual cues, and mixed reality to the language and culture requirements of different DHH communities in Malaysia (Alpat, 2022). This linguistic diversity of the DHH community in terms of various language proficiency, sign language dialects, and cultural background makes it challenging to create a universal AR content, which can be inappropriate for some DHH members. Adjustments should therefore be made to ensure linguistic correctness and cultural appropriateness.

In addition, the study assumes that DHH people in Malaysia have adequate technological infrastructure and resources to work competently with the augmented reality animations (Venkatesan, 2024). This assumption inferred a fair availability of AR-enabled devices, internet connectivity, and technological support services across the entire Malaysian territory. Nevertheless, the lack of technology, digital literacy and financial resources will result in the unequal distribution of AR application among the DFH community with the underprivileged and undermined groups being left behind (Heyko, 2021). Another feature that is taken into account is the research methodology, which is a valid and reliable measure of the effectiveness of AR-enhanced videos in DHH people in Malaysia. It also means that these instruments, methods of sampling and data analysis techniques which are relevant to the observation of learning results, participation by participants and experiences of the deaf and hard of hearing community. However, some methodological limitations such as sample bias, ecological validity, and mis-measurement can undermine the authenticity and generalizability of the study. This necessitates authentic diligent validation and triangulation of data sources.

1.9 Ethical Committee

This research is rich in ethical issues, which must be weighed carefully so that participants' rights, health, and dignity are not abused (Bos, 2021). Ethical challenges of this study are associated with the issues of informed consent, privacy and confidentiality, cultural sensitivity, accessibility, and potential risks and benefits related to the AR technology. First, informed consent, which plays a paramount role in research with human participants, including those who have a hearing disability, must be addressed. Researchers should certainly detail thoroughly the aims, procedures, risks, and benefits of the study for participants and give them full liberty to decide if they want to take part (Xu et al., 2020). The diversity in the communication capacity of the

DHH population demands that research must be presented suitably, like sign language, written text, or visual representations, so that the community members can put those information into good use. Moreover, consent of guardians or caregivers will be mandated for DHH children or those with cognitive disability who could not be able to decide on their own.

Privacy and confidentiality are always an important factor of ethics, and experiments that involve sensitive personal data or information are not excluded (Cilliers and Viljoen, 2021). Researchers should incorporate measures that will protect participants' personal and health information, including the usage of AR software and feedback. It would cover data anonymization, data storage and transmission security, as well as get explicit consent for data collection, usage and sharing. Furthermore, the participants have the right to know how data will be collected and kept safe from the researchers. The ethical problem, which is most critical in research of the diverse community, whether they are DHH of Malaysia or of other groups, is cultural sensitivity and inclusiveness (Chaubey & Kuknor, 2024). Researchers should take note of cultural codes, traditions, and ethics of the DHH community that has a language diversity and a specific way of speaking. They may aid in this through partnerships with DHH grassroots organizations, interpreters and community liaisons to ensure that the recruiting, research and intervention ways are culturally appropriate. There is also a need for researchers to be aware of any potential cultural biases or power imbalances that could affect the interactions and interpretations inside the research location.

Additional to accessibility, ethics in researching people with disabilities is another issue, especially of those with hearing impairment (Hofmann et al., 2020). The scientists should ensure that the equipment used in the research is accessible, simple to comprehend, and effective. The task can take the form of developing new ways of transmitting information that are inclusive as well, e.g. sign language interpretation, subtitling, and written transcripts, and physically accessible venues and user-friendly technology platforms for those who are hearing-impaired. Moreover, the study should comprise the advantages and disadvantages of the technology to DHH Malaysians, which can arise in both directions. The pros of AR technology as far as increasing the accessibility, communication, and learning processes cannot be ignored, but it is accompanied by challenges of technological barriers, sensory overload, and unintended consequences.

1.10 Thesis Scope

The study is multidimensional and consists of technologies, education, access to services, and social inclusion (Yilmaz, 2021). Furthermore, it examines the effectiveness of AR-based animation in facilitating learning, engagement, and communication within the localized Malaysian DHH scene. The research covers the educational aspect of how AR techniques can be utilized in individualized learning settings for DHH students. Drawing on Reeves et al. (2021), this paper specifically investigates the influence of AR-enhanced animation on learning outcomes and understanding within the context of art and design education, rather than attempting to cover all academic levels. Furthermore, the research will help in the detection of whether and how AR might be considered a utility for inclusive teaching practices and an environment for learning that fits the traits of the DHH.

Moreover, the research scope covers the cultural and linguistic aspects of AR technology in Malaysia (Majid et al., 2021). This is done through figuring out how the language and the cultural backgrounds of DHH individuals from different backgrounds can be included in AR-fueled motion pictures. This research focuses on the barriers and enablers to the application of AR technology for the deaf community, which can be related to technology access, digital literacy, and social and cultural constraints. However, the investigation also focuses on larger societal consequences of AR technology for hearing-impaired people in Malaysia, namely, social inclusion, communication accessibility, and empowerment (Venkatesan, 2023). This research sheds light on how those actualised in augmented-reality animations facilitate communication, interaction, and participation of DHH people in social, cultural, and economic contexts, and how to promote fairness, diversity, and equality in Malaysian society.

1.11 Thesis Outline

Chapter one introduces the research by providing comprehensive background information on the challenges faced by Deaf and Hard of Hearing (DHH) students in art and design education. This chapter outlines the research problem, clearly defined research objectives, significance of the study, scope, assumptions, limitations, ethical considerations, and provides an overview of the entire thesis structure. Chapter two presents a thorough literature review examining augmented reality technology in educational contexts, with specific focus on its application for DHH learners. This chapter explores various types of AR technologies, educational, cultural and linguistic implications of technology integration, and current research on AR in accessibility. It establishes theoretical frameworks including interpretivism and visual learning theories, while addressing gaps in existing literature regarding AR-enhanced animation. Chapter three details the research methodology, beginning with philosophical foundations and explaining the qualitative research approach. It comprehensively covers research design, sampling techniques, participant recruitment, instrumentation, data collection procedures, interview protocols, and data analysis methods. This chapter also addresses research validity, reliability, generalizability, ethical considerations, and importantly. Chapter four presents the analysis and results, featuring the AR prototype demonstration with its sign language integration and visual communication features. And examines the influence of AR content features on learning outcomes for DHH students in Malaysia. Chapter five offers a comprehensive discussion of findings, connecting results to theoretical frameworks, addressing research objectives, exploring implications for educational practice, suggesting recommendations for future research, and concluding with the potential of AR technology to transform inclusive education for DHH individuals in Malaysia.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Chapter two begins with a comprehensive literature review that focuses on the role and function of AR technologies within the art and design education of the hearing-impaired young learners. It is a study on the types of AR technologies in use, highlights the issues and strategies in teaching art and design and analyzes the effect of AR in improving education. This review will act as a scaffold for the research by offering theoretical frameworks, empirical studies, and critical discussions that emerge from the body of knowledge.

2.2 Augmented Reality for Education

2.2.1 Playful Learning

The incorporation of AR in the educational sphere has to a great extent transformed the educational technology by bringing in interactive and immersive experiences that keep students excited and address different learning styles (Adnan, 2020). One of the most common ways in which AR is used in education is through playful learning where the joy and fun of play is coupled with educational content and goals. This combination of fun and learning through AR induces students' interest and also leads to deeper comprehension and memory of knowledge. Through AR playful learning brings in the aspects of play- curiosity, exploration, and challenge- into the learning process, making education a pleasant experience. AR combines a three-dimensional space with a virtual object and real-time information, giving a different type of setting for exploration and learning. This approach takes advantage of the intrinsic curiosity in students and helps them to experiment with different concepts and ideas in a very direct way. Through gamification of learning outcomes, AR can transform boring educational material into fun quests, which will be both effective and entertaining, thus increasing the efficiency of the learning process.

AR's ability to merge play with education addresses one of the fundamental challenges in teaching, which is student engagement (Maas & Hughes, 2020). Traditional methods of teaching have a hard time holding students' attention, especially those who are not reached through the traditional methods. Nevertheless, the interactive nature of AR and the novelty of its digital experiences yield a high level of student engagement and motivation. The more students engage with the learning materials viewed in an AR format, the more they get involved in the process, and consequently, develop a positive attitude towards education. Playfulness of the AR entertain and also improve learning outcomes greatly (Baabdullah et al., 2020). Through 3D visualization of abstract notions, students can grasp how these concepts work and gain a clearer understanding, making them easy and comprehensible. For instance, in humanities and geometry or physics subjects, students can actually touch or manipulate the shapes, forces, and phenomena in real-time and can immediately see the results of their actions. This type of personal and immediate learning improves understanding and affects memory greatly, since students tend to remember experiences that involve their emotions and cognition better.

AR can be tailored to provide differentiated and personalized learning experiences, the type that makes each student feel unique (Tetzlaff et al., 2021). By using AR applications, educators can customize materials, adjust the degree of difficulty level and provide individualized feedback to ensure that all students experience a challenging but achievable learning experience. This individualized approach not only targets students of different levels of understanding, but also gives them freedom to control their learning process; they are able to explore different topics at their own pace and according to their liking. Although students experience AR mostly on their own, AR also gives students plenty of chances to work with others and be social. With AR applications for several users, students are able to collaborate as a team and solve problems, accomplish tasks or navigate AR environments. This teamwork in playing with AR not only strengthens the student's social skills like communication, negotiation, and cooperation but also serves to make the learning process interesting by allowing students to learn from each other, share discoveries and collectively surmount the problems. The advantages of AR in promoting playful learning are significant, however, there are some issues that must be taken into account by educators and developers. Access to AR technology and digital divide can result in excluding students from having these enriching learning experiences (Baabdullah et al., 2022). Moreover, the creation of high-quality AR content that is informative and exciting entails considerable expertise and resources. Teachers must be well equipped to incorporate AR technology into their teaching methods and also balance it with other teaching strategies to make sure students have a holistic education.

2.2.2 Kinesthetic Learning

In educational psychology, one of the primary learning styles identified is kinesthetic learning, which entails learning through physical activities instead of listening to lectures or watching demonstrations (Dmitrichenkova et al., 2020). Tactile or kinesthetic learners process their information best when they are actively involved in the process, such as by participating in hands-on activities, moving around, or work with their hands. This learning style emphasizes on a connection between physical activity and cognitive processing where motion is suggested to play an important role for learning, especially for children who are likely to find sitting in a sit-and-listen kind of school environment challenging. Kinesthetic approach, in turn, presupposes that students learn better when they are physically engaged in the learning process. This can include, for example, getting involved in a lab experiment, an enactment, a model, and a handwriting exercise. Moving endlessly helps both the process of comprehension and memorization for kinesthetic learners (Alkhabra et al., 2023). People who like doing things than just watching will find it necessary to interact physically with material for them to learn well.

According to the theory behind kinesthetic learning, both multiple intelligences theory and experiential learning theory that acknowledge bodily-kinesthetic intelligence and the importance of experiences in the learning process support it (May-Varas et al., 2023). In Gardner's Multiple Intelligence theory, bodily-kinesthetic intelligence is one of the ways people understand and learn the world, showing, then, that for some, physical activities are the main mode of processing information. In the same way, experiential learning theory by David Kolb states that experience is the essence of learning and learning comes after concrete experiences and observation. Kinesthetic learning provides numerous advantages especially in fostering engagement, retention and motivation among students. Physical activities that are associated with the taught material could make lessons more creative and fun, consequently increasing students' chance to remember information. Kinesthetic activities offer an opportunity to those students who may encounter difficulties in the conventional learning environment through the means of another modalities (Cabual, 2021). In addition, weaving movement into learning can develop better focus and relieve stress which contribute to a healthier, more vibrant learning environment.

The introduction of kinesthetic learning in education is the responsibility of the educators to be creative and flexible (Rini et al., 2020). There can be strategies such as role-playing, arts creation, science experiments, model building, or inclusion of educational games that involve movement. Technology, which includes VR and AR has been extended to kinesthetic learning, providing students with three-dimensional models or virtual simulations they can immerse themselves in. The strategies suit the kinesthetic learners and diversify teaching methods benefiting all students by accommodating different learning styles. Kinaesthetic learning can be used in different areas of education, and therefore it boosts understanding and engagement (Rini et al., 2020). In science, students learn by actually doing experiments through which they acquire theoretical knowledge and apply it to everyday phenomena (Altmeyer et al, 2020). In regards to mathematics, hands-on manipulatives such as blocks and interactive software allow students to understand abstract ideas via physical interaction. In the language arts, doing the scene from a book, or writing physically with the pen and paper can make the learning process be more alive and less abstract.

Along with its merits, kinesthetic approach to teaching produces some problems (Alzahrani, 2020). However, educators may face time, curriculum, and resource constraints that can make it challenging to incorporate active learning. Moreover, care should be taken concerning the timing of kinesthetic activities so that they support learning objectives and, in fact, bring a deeper meaning to the learning process. Evaluating learning outcomes from kinesthetic activities necessitates careful thinking because the traditional methods of testing may not appropriately measure the depth of knowledge acquired through these types of activities. The future of kinesthetic learning is exciting, and new technologies available in VR and AR are bringing in innovative ways of interaction with such learners (Alzahrani, 2020). The relevant technologies can mimic real-life situations, give students immersive learning environments, and deliver interactive, hands-on tasks that were impossible or difficult before. As educational practices transform to feature individualized learning experiences, kinesthetic learning is expected to play a key part in satisfying various learning preferences and necessities.

2.3 Deaf and Hard of Hearing

2.3.1 DHH in individual and collaborative work

The integration of DHH individuals to the employment arena and the school setting need a detailed comprehension of the challenge and the opportunity that face both individual and collective work environment (Marchetti et al., 2024). These challenges are surmountable as these are aspect that can be used to view the resilience and adaptive strategies of DHH individuals, as well as the potential for more inclusive practices. In the sphere of on-self work, DHH persons experience many problems mainly in the area of accessing information and communication. Conventional modes of information sharing through auditory instructions or announcements are not an option for DHH individuals, which can cause misinterpretations and information loss. It implies that the methods of information delivery should be adapted, for example, written instructions, or the provision of the sign language interpreters, captioning services, etc. to ensure equal access to information. However, DHH individuals frequently encounter barriers to professional development resources and participation in online forums or online discussions, which are crucial in today's digital workplaces. The technology that will be exploited for the adaptation will be video relay services and text-to-speech software to fill in the gaps so that DHH people will be fully and autonomously involved in their work. The loneliness of DHH individuals in work settings in an organization can be as profound (Heyko, 2022). With the exclusion of several casual interactions, which hearing people fail to notice, DHH subjects may miss out on job opportunities or the sense of partnership in the same working space. On the downside, the isolation can also be a source of extremely strong concentration and focus, turning the disadvantage into an absolute strength. Due to the experience of having to develop creative problem-solving skills and the ability to adjust to actual situations, people with hearing disabilities often contribute valuable perspectives and solutions to the workplace.

For DHH individuals, the challenges in a collaborative work setting are intensified because verbal communication is a key component of a team meeting (Olwal et al., 2020). Meetings, discussions, and other conversations can lead to the exclusion of DHH community members from full participation. Nevertheless, these obstacles create the chance for teams to adopt more inclusive communication style of communication. The teams can create more effective communication with the members of the DHH by visual aids, written summaries, and ensuring the presence of sign language interpreters. One of the most fundamental challenges in collaborative environments is that the bias unconsciously thinks hearing means communication skills. As a result, DHH people can be undervalued in terms of their contributions to the team, or they could simply be overlooked for leadership roles. In this, the crucial step is to give the worth to the diverse communication styles and to acknowledge the unique views and abilities that DHH people possess. The chance for DHH people to demonstrate their relative advantages in a team work directly depends on the openness of organizations to create non-discriminatory work environments (Dibben & Wood, 2024). This is more than providing technological and accommodations supports; it also includes creating a company culture that is welcoming and respectful of people with disabilities. In this kind of setting, Deaf and hard-of-hearing individuals can excel, bringing all their abilities and viewpoints to the table.

Technology enhances the chances of DHH people in both private and group occupations (Fossen & Sorgner, 2022). The development of augmented reality, speech-to-text software, and video conferencing platforms integrated with captioning services did not only redefine the way Deaf and hard of hearing individuals interacted at work. These technologies allow communication and support the autonomy and independence of DHH individuals; hence, facilitate their ability to excel in their workplaces. Futhermore, the implication of these technologies in the workplace can help employees with disabilities all around. Stronger communication, ease of getting information, and more focus on visual and written formats can improve the way that everybody interacts, while underlining the idea that accommodating for DHH people is more than a universal improvement. The road toward making all workplaces and educational settings accepting of DHH individuals is a continuous one. It takes a communication from all parties to accept and address the unique set of challenges that DHH people face, using technology and adaptations that support their inclusion, and treating the diversity of their ideas as a benefit (Renken et al., 2021). This process will enable organizations and educational institutions to fulfill their legal and ethical obligations in this regard and have a diverse and enriched community.

2.3.2 Collaborative learning

Collaborative learning, with its focus on group activities, shared knowledge creation, and mutual support among students with Deafness and hearing loss, creates both possibilities and challenges for those in education and work settings (Buxton, 2023). Communication difficulty, team dynamics construction, and equal participation through accommodation are some challenges that the bilingual members face in the group learning setting. In group learning environments, where oral communication plays a significant part, communication may become a challenge for people with a hearing deficiency. Lack of facilitators like sign language interpreters, real-time captioning or visual aids, hearing impaired students may be unable to participate in group discussion, creative thinking or teamwork. However, this is a common effect among the members of DHH who are likely to experience the pain of being excluded and devaluing of their self-worth by their peers. In addition, one of the most probable sources of miscommunication is in the activities where communication is mostly oral (Swart et al., 2022). By lacking any system of linguistic communication and visual clues, DHH people may find it hard to follow the complex discussions, share their ideas in proper way, etc. This could make the students insecure about their abilities to contribute fruitfully in group tasks and, therefore, they may become more passive learners.

Such scenarios can be avoided when DHH people and their peers apply numerous strategies to boost communication, inclusiveness, and learning cooperatively (Paatsch & Toe, 2020). Individuals who are DHH must be the advocates for the competencies they require to be involved in cooperative learning activities. Examples of the services could include sign language interpreters, captioning services, or using of assistive listening devices for better communication accessibility. DHH people will have chances to take part in inclusive learning opportunities thanks to the advocacy. The leveraging of visual communication tools, for example written material like notes, diagrams, and visual representations of concepts, helps in understanding and enables collaboration in group learning. By using these visual aids, DHH people and their peers communicate with each other and this makes it possible for them to explain context or clarify during group discussions. Establishing communication avenues in the right way, the whole team members will have a chance to participate in group activities. DHH individuals and their peers can come to an understanding on communication norms, akin to yielding space in speech, communicating via visual signs or using written platforms to support discussions (Heyko, 2021). Developing an inclusive team culture for collaborative learning is imperative to ensure mutual respect, empathy, and help from all group members. DHH peers and individuals can work together to create a supportive atmosphere in which diversity of outlook is appreciated, communication barriers are pre-emptively addressed, and facilitations are made to ensure equal access to learning opportunities.

Even though there are the difficulties, the group learning brings the benefits about the communication between DHH individuals like peer support, knowledge sharing, and social interaction (Lin & Huang, 2020). In collaborative learning environments DHH individuals can gain from their peers, give out their expertise, and work together in projects that facilitate mutual learning and understanding. Collaborative learning activities also foster social skills, communication skills, and teamwork abilities of DHH individuals so that they can thrive in their educational and professional lives. Collaborative learning also links DHH individuals as they work together with the objective of overcoming common challenges as well as ensuring success. Collaborative learning experience is where DHH individuals can grow meaningful relationship with other people and ultimately build supportive networks as well as sense of belonging in their educational communities (Martin & Borup, 2022). This aspect of comradery is fundamental to producing positive academic and social results for DHH people and consequently enhancing their quality of life.

Technology is a must in the development of inclusive co-operative learning situations for persons with hearing impairment (Fernández-Gavira et al., 2021). An example of technologies that enhance amicable learning environment are video conferencing platforms with captioning features, documents editing tools, and online forums. Technology gives DHH people a chance to interact in cooperative learning activities on the same basis as others hearing or not. Among other things, technology gives technological tools to DHH people such as online tutorials, interactive learning, or multimedia presentations, resulting in a variety of learning approaches (Ibrahim, 2022). The integration of technology into collaborative learning environments will help teachers to develop inclusive and accessible learning experiences that can adapt to all students' needs including those with impaired hearing.

2.4 Types of AR-Enhanced Technologies for Teaching Hearing Impaired Students

AR has been highly recognized as one of the best education tools in the world, which basically enhance visual learning and increase understanding level (Huang et al., 2021). AR can activate real possibilities for teaching students who are hearing-impaired, as it provides visual and interactive aids that are adjusted to various learning styles. Different types of AR technologies have been invented for the purpose of training hearing impaired children. Each of them possesses particular features and the range of application. The biggest obstacle that deaf students face is communication, which is especially tricky when sign language interpreters are not available. The IP technology is used in sign language recognition and translation apps for the purposes of recognizing gestures and translating them into words or texts right away (Papastratis et al., 2021). These apps create a medium for these students to relate better with their peers, teachers, and colleagues just so that they can bridge communication barriers and hence be inclusive in educational setups.

Mobile devices with rich and interactive features, like AR, are taking advantage of Augmented Reality to produce lessons that involve hearing-impaired students in activities like explorations and experiments with their hands (Elliot, 2020). This technology provides opportunities for pupils to interact with three-dimensional models, virtual environments, and objects they can manipulate in real time; hence, learning of abstract concepts in subjects such as science, mathematics, and geography become more effective. Interactive visualizations and simulations provide a way for visually depicting and interacting with complex concepts to the students with impaired hearing (Krasavina et al. 2022). By the AR technologies such as a captioning and subtitling tools, the written text captions or subtitles are overlaid on the real world scenes, videos, and presentations; therefore, the hearing impaired students can more fully comprehend the spoken information. Such tools might be useful in school classrooms, where teachers deliver lectures, show videos or multimedia presentations. Such captioning and subtitling mechanisms make sure the hearing-impaired students get the same level of comprehension and academic achievement, when it comes to understanding the spoken word.

Interactive storybooks and learning games are all about merging the best of traditional storytelling with the latest AR technologies, resulting in high-engagement and cool learning for deaf students (Gray & Dunn, 2024). With the help of these AR enabled technologies, students get the opportunity to interact with the characters, environments, and game situations, which makes the learning apposite and lively. Along with the use of stories, interactive storybooks and learning games give hearing-impaired students the chance to progress in crucial language skills, which could include vocabulary acquisition, comprehension, and expressive communication. The interactive aspect of these experiences makes the students actively participate in the content, developing critical thinking skills and problem-solving approaches as they overcome difficulties and take key decisions in the plot or game. Moreover, storybooks and learning games are also interactive, which help in stimulation of creativity and imagination. Hearing-impaired students get chance to explore new worlds by interacting with new characters and concepts (Marojo, 2021)). Acquired from these activities, students can be exposed to a comprehensive knowledge of literature, storytelling, and the arts along with the latest digital literacy and technical literacy.

VR and AR interactive learning media have revolutionised education by creating an immersive learning environment for the hearing-impaired students that is required by everyone (Creed et al., 2024). Such platforms help structure virtual classrooms in which students can engage with digital content via virtual objects and simultaneously work as a team. The application of both visual and tactile aspects in teaching allow for deaf students to learn how to understand and use educational materials in ways that they would not in traditional learning environments. Furthermore, the usage of VR and AR opens doors for teachers to design instructional materials as per the need of the hearing-impaired students. These materials are unique to the style as well as preferences of learning. This level of personalization create involvement and participation among the hearing-impaired students that enable them to take charge of their own education and empower them to achieve more (Majoro, 2021). Generally, VR and AR classroom platforms indicate great advancement in inclusive education, giving new prospects for learning, collaboration, and academic achievement to hearing impaired students.

For each of the AR enhanced technologies used, there are particular benefits and application areas of teaching students with hearing impairments (Köse & Güner-Yildiz, 2021). Language recognition apps and translation to sign language promote communication and social relationships, visual simulations, and interactive visualizations deepen understanding of abstract concepts, captioning and subtitling tools guarantee equal access to spoken content, interactive storybooks and learning games stimulate language development and critical thinking, virtual reality and augmented reality classroom environments create an immersive and interactive learning environment.

2.5 Challenges Faced in Art and Design Classes for Hearing-Impaired Students

Art and design courses have their own challenges for the hard of hearing learners due to the use of verbal commands, sound feedback, and teamwork (Zhuo et al., 2024). Students who have hearing impairment may experience difficulties in art and design due to the expressive and visual qualities of these disciplines. Tactile instruction provides the basis in art and design education, in which, during the class, the instructors explain the process, provide feedback, and comments. Yet, for hearing-impaired students, these verbal interactions create insuperable communication obstacles. The instructions written or by means of the visual demonstration may be of some help, but they usually lack the immediacy and clarity of the real- time accurate verbal communication. As a result, the hearing impaired students could probably find it difficult to completely grasp the subtleties of verbal instructions, thus it could lead to difficulties in following directions, asking questions, and participating in classroom discussions. Additionally, the use of spoken language tends to be a source of loneliness and discouragement to hearing-impaired learners as they feel they are not part of the group discussions (Nkosi, 2022). Overcoming these communication challenges requires educators to use different communication methods, like sign language interpreters, captioning services, or visual aids, so that deaf students can follow the material taught, and comfortably engage in the learning process. Through providing priority to inclusiveness and accessibility in art and design education, educators can create such a learning environment which is supportive and fair for all the learners that have different hearing status.

In art and design classes, auditory feedback is a key part of the creative process, giving vitally important advice on techniques, materials and the art form itself (Kang & Jackson, 2021). Yet, it is the fact that deaf students struggle with getting auditory feedback that hinders them from maximum engagement with the material and learning artistic skills. Likewise, deaf students may find it difficult to hear the sound of a brush on a canvas or truly appreciate the more intricate aspects of music, which can affect their artistic understanding of texture, rhythm and tone. With the absence of auditory feedback, visually impaired learners will feel disengaged from the creative process and will be less confident in their capabilities. They will have poor abilities to revise their work and make educated artistic choices, which can result in a feeling of incompetence and frustration. Moreover, the loss of auditory feedback could lead to a shrinkage of the crafts and the media which the hearing-impaired students are willing to experience, curbing their artistic growth and expression (Stephens & Yenika-Agbaw, 2022). To overcome these difficulties, the educators can employ alternative modes of feedback and instruction where these visual and tactile experiences come first. Another example is using visual tools during demonstrations, giving written feedback on the artwork, or making students to handle the materials. Educators can include the above methodologies in their teaching to make sure that hearing-impaired students get ample chances to explore the creative process and acquire artistic skills along with everyone else in the classroom which is both inclusive and supportive.

Collaborative projects or group works are often involved in art and design classes (Cheng et al., 2022). On the other hand, participating in these social events can be difficult for hearing-impaired students because of the communication barriers. Most hearing-impaired students find it hard to engage actively in collaborative discussions, provide feedback to their peers, or contribute to group projects if there are no effective communication methods such as sign language interpreters or captioning services. Such confusion, misconception, and sense of loneliness can actually derail the collaborative learning process (Alias & Ramly, 2021). To overcome these obstacles, educators need to establish an inclusive atmosphere where all students are appreciated and supported, while also providing accommodations and alternative communication methods which hearing-impaired learners can use to participate in group activities and contribute to the collective learning.

Yet, hearing-impaired learners may be restricted in getting instructional materials that use audio signals or oral explanations only (Bian & Ji, 2021). Without subtitles, captions, or visual aids, hearing-impaired students might not understand the material covered in the classroom. Lack of access to instructional resources can prove to be the hindrance in the learning process, and the student might end up having difficulty in understanding the content. To solve this problem, educators need to ensure that the materials for instruction are accessible to hearing impaired students through captioning, subtitling, or alternative formats of visualization. Teachers would be able to avail the necessary instructional materials to support hearing impaired students to create the inclusive and equitable learning environment in art and design classes. Art and design education in most cases encompasses cultural and social contexts, developing students to examine various viewpoints, identities, and experiences in their expression through their works (Sya et al., 2022). Many hearing disabled students meet with additional social and cultural blocks, especially if the curriculum does not sufficiently reflect their life, experiences, and point of view. Through lack of inclusive and culturally adequate content, the hearing-impaired students can end up feeling marginalized or disconnected from the artistic community, which, in turn, can cause their belonging or identity as artists to suffer.

To deal with the hurdles that the hearing impaired students experience in art and design classes, educators and institutions can introduce different steps to foster inclusiveness and accessibility (Worsley & Bar-El, 2022). Embedding visual and tactile instruction methods as visual demonstrations, tactile models or hands-on activities could give a hearing impaired student a better learning experience and could be an alternative source of instruction and feedback. By ensuring the accessibility of communication supports, including sign language interpreters, captioning services, and assistive listening devices, hearing-impaired students will be able to overcome communication barriers and be fully included in class discussions and group activities. Designing a nurturing and equitable educational environment where individual efforts and experiences are recognized can build a feeling of home in hearing impaired students. Teachers can interact with hearing-impaired learners, promote peer support, and honor diversity in art during art practice. Proposing the inclusion of accessibility standards and policies as part of art and design education can guarantee accessible instructional materials, resources, and facilities for all learners including those who are hearing impaired (Rossi, 2023). Through emphasizing accessibility, teachers and institutions can achieve more inclusive learning settings where hearing impaired students can expand their academic and artistic scope alongside the other learners.

2.6 Strategies for Teaching Art and Design Classes with AR Technologies

Utilizing AR technologies such as AR for teaching art and design creates enviable chances for educators to impart learners with interactive and immersive lessons (Burns, 2023). The integration of AR with art and design education is beneficial as it can improve students' engagement, help them to work with their hands, and stimulate their creativity and inventiveness. To benefit from the capabilities of AR technologies in teaching art and design classes, educators need to use a range of tools that match the expectations and abilities of the students. This brings about the use of AR technologies in the teaching and learning of the various artistic techniques and processing by including interactive demonstrations and tutorials. Through the augmenting of digital instructions, animations, and visual prompts onto physical objects, AR applications afford students with their hands-on learning experiences that are tangible and interactive (Fan et al., 2023). Students are able to get a detailed direction and they can also be given feedback as they move through the artistic tasks, which ensures practice and experimentation through their own hands. Those practical sessions, on the other hand, are beneficial in this way because they provide multisensory learning, the learning targets are strengthened through active participation, and at the same time, they facilitate a better understanding of the subtleties of the artistic ideas. Additionally, these AR tutorials are interactive which promotes student autonomy and creativity making it possible for students to showcase their artistic talent in fun and supportive classes.

Virtual art galleries and exhibitions displayed by AR technology is an innovative tool for showcasing student artworks and for the audience to be discovering and interacting with them in the 3D space (Tan, 2021). With VR applications, AR can digitalize student art and create interactive 3d virtual exhibitions that allow a closer look at each work. The virtual galleries allow students to broadcast their work to a broader audience, get criticisms, and get appreciated for their artistic efforts. Secondly, virtual exhibitions facilitate dialogue about art and design concepts and themes which lead viewers to interact more critically with the artwork and contemplate its deeper meanings. Using AR technologies to create virtual art galleries and exhibitions, teachers are able to increase the visibility and impact of students' pieces at the same time as providing them with beneficial opportunities for creative expression and artistic growth. Besides, carrying out collaborative projects and group critiques by AR technologies will certainly change the way students in art and design handle each other. Through the utilization of AR applications, educators can develop virtual collaborative work environments where students can work together simultaneously, even though they may be from different locations. By these platforms students are able to show off their work, give peer-to-peer feedback, and engage in group conversations on artistic concepts and techniques. Through the provision of collaboration, communication, and critical thinking skills, AR technologies enhance the feeling of community and team spirit among students, thereby encouraging them to support and learn from each other (Tang, 2024). In addition, AR collaborative spaces in real-time can improve productivity and efficiency as students can work collaboratively resulting in the achievement of their shared goals.

Infusing AR into art history and theory classes transforms students' interaction with historical artworks and the ideas behind them (Perich, 2023). Through the utilization of AR apps, teachers are provided with the tools at their disposal to produce engaging and interactive activities that help to connect past and present. Digital applications lay-on digital reconstructions, animations, and multimedia content upon physical artifacts and historical sites, allowing students to experience art history more interactively and more meaningfully (Njai, 2021). Through AR, the students can experience a historical event, analyze the artifacts from various viewpoints or deepen their understanding of the artworks in the terms of cultural and social contexts in which the artworks were created. AR allows teachers to take AR to the lessons in art history and theory making the students understand the artistic movements, styles and cultural contexts, thinking critically, and appreciating the vast human creativity across time.

AR technologies provide educators with a platform to offer tailored learning experiences that are suited to every student's requirements and desires (Donally, 2022). Educators are capable of creating AR apps that correspond to the knowledge level, learning style and interests of students that provide instruction, feedback and help to students as they advance in the curriculum. The use of augmented reality (AR) in personalized learning allows teachers to engage students in own education, enhance their creativity and reach their academic achievements at their own speed. The teachers or educators must have in mind accessibility and inclusivity when employing AR in their art and design classes so that all learners can actively participate in the learning system (Jesionkowska et al., 2020). Teachers need to establish respective accommodations like captioning, subtitling and alternative communication methods for exclusively hearing impaired students and other students with different learning disabilities. Moreover, the teachers should design the AR apps with user-friendly interfaces and simple navigation to avoid the circumstances where the learners cannot get access and so they are able to learn

2.7 Roles of AR Technologies in Enhancing Art and Design Lessons

AR technologies have become the most important element for the improvement of art and design lessons as these technologies provide new tools and media that turn simple exercises into interesting and practical ones (Chen et al., 2020). With AR technologies students earn involvement and chances to demonstrate their creative potentials and try out things without real life examinations. By means of variety of applications, the AR technologies offer the art and design education with several vital tools. With AR, as a first, it serves as an ideal tool for visualization of abstract ideas and complex concepts in art and design. Digital information is processed in this way, and thus AR apps enable students to be able to interact with 3D models, explore virtual world, and manipulate objects in the real life (Latsyshyn et al., 2020). This combined experience of visual and touch results in better understanding of the subject by the students, retaining the information in their short-term memory, and strengthening their long-term memory. As an illustration, AR, can be applied to demonstrate the significance of the difference in lighting of a sculpture or offer virtual tours of distinctive works of architecture that link students to artistic styles and ideas in a practical and interactive way.

Similarly, an AR system can be developed to incorporate the students' individual demands and preferences (Baabdullah et al., 2020). Educators could create AR applications which not only adapt to the character of students, their skill levels, learning styles, and interests, but also provide individualized instruction, feedback, and assistance as the students are progressing. Such active learning contexts introduce students to the process of their individual development, artistic facet and creative potential development. For instance, AR apps could use interactive tutorials, quizzes and games that would be personalized to the student’s learning goals and passions, which would allow them to direct their own learning as such. In addition, students get a chance of forum collaboration as they have tools and platforms to exchange, talk about and evaluate their work immediately (Syed et al., 2022). In group collaborative AR environments, students are given to opportunity to work together on projects, to offer feedback to each other, and to be involved in talks about artistic techniques and concepts as a group. Such collaborative moves foster communication skills, critical thinking, and problem solving abilities as students converse to attain the same objectives and creatively resolve problems together. For example, students can utilize AR apps to brainstorm and work jointly on virtual sculptures and paintings, exchange their ideas, receive feedback from the audience in real-time in the same space. This will form a culture that is team-oriented among the students.

In addition, AR technology provides experiential learning through the creation of interactive and immersive experiences that visually provide a solid example of the art and design principles (Panciroli et al, 2023). AR applications enable students to visit virtual exhibits of fine art, cultural artifacts and architectural landmarks and to get an idea about the development of painting styles, artistic movements and cultural backgrounds. These contact learning moments broaden students' art history and theory knowledge, which stimulates critical thinking and develops their understanding of artists across the globe who have been the source of talent since the beginning of time. For instance, students can use AR apps to visit art galleries and museums virtually, interact with artworks, learn about the artists, and the time in which the artworks were created. Besides that, AR technologies assist in assessment and feedback through creation of tools and platforms for the evaluation of student work and giving feedback on time (Haleem et al., 2022). Educators can utilize AR applications to evaluate students' development, register their performance, and provide immediate feedback on their artistic undertakings. Through the help of these assessment tools educators can recognize students' strengths and weaknesses, adjust their teaching to the requirements of individual students and thus support the development of their creative skills. Such as, teachers can utilize AR apps to compile digital portfolios, display students' work, and give multimedia feedback that includes annotations, voice recording, and visual cues which in turn fosters feedback process and reflection and strengthens self-change.

2.8 Effectiveness and Benefits of AR in Teaching Hearing-Impaired Students

AR is one of the most influential tools in education and, specifically, in addressing the demands of hearing-impaired students (Fernández Batanero et al., 2022). Through a layer of digital content on the physical world, AR technology provides the unique benefits that improve the quality of learning for these students. AR has numerous advantages in teaching the deaf students in terms of accessibility, engagement, comprehension and communication. One of the key advantages of AR in education of the hearing impaired is that it helps to increase accessibility. The traditional teaching method mainly depends on oral communication, which may hinder hearing-impaired students greatly. AR technology enables alternative ways of communication through visual and tactile cues, which are easier for such students to understand (Köse & Güner-Yildiz, 2021) . Through the addition of the digital content in the physical environment, AR gives hearing impaired students a medium of auditory instructions, explanations and feedback that is appropriate to their individual learning needs. This accessibility gives the hearing-impaired students similar opportunities like other students to take part in class activities, read through course materials, and interact with the teaching staff and fellow students on equal basis.

In addition, AR technology bolsters engagement and motivates the hearing-impaired students (Rusli & Ibrahim, 2022). The experience of AR is deeply interactive and immersive, which traps students' attention and excites their interest, causing a higher level of engagement. AR techniques can turn the invisible into the visual and make learning for hearing-impaired students more interactive and memorable. For instance, AR simulations can be designed to enable students to browse scientific principles, historical events, and artistic techniques in a virtual reality setting, providing experiential learning opportunities that facilitate understanding and memorization (Remolar et al., 2021). Such heightened involvement causes improvements in learning results and sparks a passion for learning among hearing-impaired students; this not only keeps them interested in learning but also influences them to explore new topics and pursue their academic interests with excitement. Furthermore, AR technology promotes understanding and retention by the use of multisensory learning environments. It is the fact that visual and tactile cues are the primary ones among the hearing impaired. Therefore, AR gives the perfect means for the transmission of complex concepts and ideas through. To meet the needs of students with varying learning styles and preferences, the AR applications for hearing-impaired students integrate visual imagery, auditory cues, and engaging elements (Fan et al., 2020). Therefore, the students will have a better grasp of the topic. For instance, AR simulations may show scientific phenomena, historical events and mathematical concepts in an illustrative and interesting way for hearing-impaired students to understand abstract ideas with clarity. It is multisensory approach that supports hearing impaired students to process information and consolidate knowledge. Consequently, they become more skillful to process and memorize the information, which they can subsequently apply in different circumstances.

In addition, the use of AR also stimulates communication and interaction between the deaf students (Stinson et al., 2020). In normal classroom, there are several lectures, group activities, discussions, which enable impaired students to be more involved in and reduce their active participation. AR tech creates a new model of communication that enables hearing-impaired students to join in team activities as well as work in collaboration with each other, removing the barriers of social interaction. AR applications offer a virtual working environment, virtual meeting rooms and interactive platforms, where deaf students can jointly work on projects, exchange ideas and communicate instantly with their peers (Buxton, 2023). It increases a sense of belonging among hearing-disabled students and at the same time promotes positive relationships and interaction skills that are crucial for academic and professional success. Additionally, AR technology provides personalized learning experiences that are custom-tailored to the unique needs and preferences of hearing-impaired learners. Via AR applications the students' skill levels, learning styles and interests could be taken into account, offering individualized teaching, feedback and support (Alam, 2023). For example, AR simulations can provide engaging sessions of instructions, tests, and challenges that cater specifically to each student's personal learning objectives and preferences, facilitating the progression of hearing-impaired students at their own pace and making them comfortable in the quest of academic pursuits. This exclusively tailored approach to learning equips hearing-impaired students with self-directed learning abilities and helps them reach their academic aspirations.

2.9 Barriers and Limitations of AR Implementation in Art and Design Education

Although AR offers substantial possibilities for the improvement of art and design courses, its incorporation into education may be accompanied by barriers and limitations, which instructors and institutions should take into account (Takrouri et al., 2022). The challenges can come as technical issues to pedagogical ones and they may make the notion of implementing AR into the curriculum inept and untenable. If affordability and accessibility of AR technology are the major obstacles to AR adoption in art and design subjects among students, they should be carefully considered. The procuring or purchasing of AR applications and devices can be costly, especially for those institutions with lean budgets (Pearce, 2020). Moreover, the current spending for the software updates, maintenance and technical support will raise the expenditure of adoption of AR. As a result, some schools have the challenge of getting funds to buy AR technology that impedes them from using the technology in arts and design education.

In addition, AR is limited to certain technical barriers that constrain the AR implementation in art and design education (Jesionkowska et al., 2020). AR apps depend on a strong hardware and software infrastructure and support to provide smooth and complete user experience. On the other hand, compatibility problems, linkage issues, and hardware restrictions may act as the hindrance to the quality of AR technology in educational environments. For instance, old hardware might not be able to run the latest AR apps, and that can lead to poor user experience and the displeasure by both students and teachers. Besides, constant interruption from unreliable internet connection will affect AR applications that depend on cloud services or steaming content, making the process more difficult (Takrouri et al., 2022). Also, educational institutions have to be prepared to provide teachers with trainings and professional development so that they can efficiently use AR technology in teaching and learning. Nevertheless, there may be teachers who will not have the information, competence and experiences to integrate AR into their teaching practice (Akram et al., 2022). The lack of adequate training and support might cause educators to have problems with effective mastery of AR applications, creation of beneficial learning materials, and design of exciting AR lessons for their students. Also, including AR to an existing instructional algorithm means that a careful planning and transitioning process is required which may need extra time and money that teachers usually do not have.

However, one more hindrance to AR put in art and design education is lack of standardized content and curricula guidelines (Kerr et al., 2020). Whilst the use of AR is possible in a variety of applications and platforms, there is still no common method for blending AR and teaching curricula. Therefore, educators will most likely face the problems of the choice of appropriate AR tools and opportunities that are consistent with the learning objectives and instructional goals. Additionally, the lack of established content and guidelines for the curriculum brings into question the cooperation and provision of knowledge among teachers, consequently making it difficult for educators to come up with a common approach for AR introduction in art and design. Moreover, ethical challenges and privacy issues concerning AR technology create an additional barrier for its implementation in art and design education (Christopoulos etal., 2021).

AR applications, by default, always gather and process huge data volumes which consist of individual information or users' data, consequently, this issue is why privacy and security are raised. Educators have to consider the ethical issues related to students' privacy, consent and data protection with augmented reality in learning environment. In addition, teachers must make sure that the immersive, accessible and respectful AR environments, which contain no stereotypes, biases and discriminatory content that extend discrimination are created.

2.10 Best Practices and Recommendations for AR Integration in Art and Design Classes

The inclusion of AR in art and design classrooms gives impulse to increased creativity, engagement, and learning outcomes (Yousef, 2021). For successful implementation, they can apply best practices and recommendations that exploit the power of AR technology in art education. First, teachers should relate AR integration with the learning targets and instructional goals. Through the setting of specific goals, educators could select AR tools and activities that will help students acquire specific art and design competencies. As an example, teachers can choose graphical applications that put up digital grids and guide lines in the real situations to let students learn and practice the basic of perspective drawing. Moreover, educators should carry out right trainings and assistance for students and colleagues so that they must have good proficiency of AR technology (Laciok et al., 2020). It is also imperative that we offer users with AR application and technique-based workshops, tutorials, and tools to give them a more comprehensive understanding of the AR tools and the techniques to use them proficiently and effectively. In addition, creating a culture of invention and exploratory experimentation stimulates students' thinking to treat AR technology as a creative tool and encourages educators to use AR in educational modules wisely.

Teachers need to develop AR activities that develop active learning and student-centered teaching (Jesionkowska et al., 2020). Rather than the role of only passive consumers of content, students play an active role of explorers, experimenters, and creators with the application of AR technology. This will be demonstrated by the introduction of AR scavenger hunts with interactive simulations in which students have to come up with their own solutions, make choices and use their creative skills in a real-world context. Students' curiosity, critical thinking, and creativity can be fostered by facilitating the active learning application of AR. Moreover, teachers are required to use AR technology in order to provide individualized learning that is aligned to the students' unique needs and preferences. With AR applications, learning can be tailored, students with different skills, learning styles and interests can be accommodated and instructions, feedback, and support can be provided (Mystakidis et al., 2022). For instance, teachers can apply AR applications in providing adaptive tutorials, assessment, and challenges with individualized recommendations. Due to taking into account modes of learning of each individual, AR integration creates a learning environment where everyone has an equal opportunity to shine in art and design.

Apart from that, teachers need to create teamwork and cooperation among students by adding AR tasks that advocate cooperative learning and teamwork (Chen et al., 2020). Collaborative AR projects contribute to the development of the collaborative skills of students as they work as a team to solve problems, share their ideas and create artifacts by using the digital tool of AR. For instance, students can collaborate on designing virtual art installations, crafting multimedia presentations, or creating interactive storytelling applications using AR apps (Hernandez-de-Menendez et al., 2020). Teamwork, communication and interpersonal skills are developed in virtual environments as a result of the interaction between AR and people. Through this process, students are equipped with skills to handle issues in academic and professional life. Furthermore, teachers should examine and assess the effectiveness of AR integration in the classes of art and design to influence instructional decisions that will result in better student learning outcomes (Mystakidis et al., 2022). With the help of students' feedback, performance data analysis and reflective teaching practice, teachers can detect teachers' strengths, point out what they need to work on and indicate new approaches to AR. Similarly, the design of AR activities with the inclusion of formative and summative assessments helps educators to measure the comprehension, skills, and progress of students, furnishing crucial information about the influence of AR technology on teaching results.

2.11 Visual Communication and Animation

Multimedia objects such as video and animation are crucial for the design of the value proposing relevant AR experiences concerning DHH students. Graphics, images, and animations are forms of nonverbal communication used in the transmission of information, and since this audience mostly rely on sight to get information, then visual communication is useful to them. Indeed, interaction raises this to another level, taking non-moving images and converting static content into animated materials that can be engaging and informative when in animation. This is important especially in learning environments where most conventional teaching approaches are heavily based on sound-information delivery systems which in fact puts the DHH individuals at a disadvantage (Smith & Allman, 2020). For instance, ideas such as using animated sign language interpreter or 3D models in learning can improve the understanding and recall of lessons by the students making education based applications of AR more engaging and effective. Narrative skills, such as animation, can help deal with gaps in understanding especially where the topic is difficult to expound on easily. It has been established that using animation in the provision of information improves the chances to segment complex knowledge and to provide viewers with stimulating and engaging content (Mirzaei et al., 2020). In the fields of art and design education, applications of augmented reality including complex visual and animated descriptions enable DHH students to learn techniques as well as theories with the help of step by step animation. Using animated overlays and visual feedback during AR enhances the learners' comprehension levels of artistic practices; invitational participation, and creativity with regards to the barriers of learning associated with the stuck formats.

2.12 Synthesis of Literature and Research Gaps

While the preceding sections have explored the multifaceted roles of AR in education, a critical synthesis of the recent literature (2020–2024) reveals specific trends and notable gaps. The majority of current studies focus on general education or STEM subjects, with limited attention paid specifically to Art and Design education for the hearing-impaired in the Malaysian context. Table 2.1 summarizes key recent studies, highlighting their focus and findings, which inform the direction of this research.

Table 2.1
Synthesis of Key Literature (2020–2024)

Author(s) & Year	Context /Sample	Key Findings	Relevance to Current Study
Adnan (2020)	General Education	AR facilitates "Playful Learning," increasing engagement through gamification and curiosity.	Supports the strategy of using AR to make art history and theory less abstract.
Köse & Güner-Yildiz (2021)	Special Education (DHH)	AR enhances accessibility via visual cues and sign language integration.	Validates the "Types of AR" (translation/visuals) needed for DHH students.
Baabdullah et al. (2022)	Educational Technology	Highlighted the "Digital Divide" and infrastructure challenges in AR adoption.	Informs the "Challenges" theme regarding resource constraints in schools.
Creed et al. (2024)	Immersive Tech (VR/AR)	VR/AR creates immersive environments that allow for safe experimentation and personalized learning.	Supports the "Role of AR" in providing a risk-free environment for artistic practice.
Marchetti et al. (2024)	DHH Employment/ Education	DHH individuals face isolation; technology is crucial for autonomy and collaborative inclusion.	Highlights the need for AR not just for learning, but for social inclusion in group art projects.
Tang (2024)	Collaborative Design	AR collaborative spaces improve team spirit and peer-to-peer feedback mechanisms.	Directly links to the "Strategies" of using AR for group critiques in design classes.

2.12.1 Research Gaps

Despite the robust body of knowledge regarding AR in general education, significant gaps remain. Firstly, while studies like Creed et al. (2024) and Tang (2024) discuss immersive technology, there is a scarcity of qualitative research specifically exploring the lived experiences of hearing-impaired students in Art and Design courses in Malaysia. Most existing studies are quantitative or focus on STEM (Science, Technology, Engineering, Mathematics), failing to address the unique subjective and creative needs of art education where visual nuance is paramount.

Secondly, while the literature identifies technical challenges (Baabdullah et al., 2022), there is limited discussion on how these technical barriers specifically intersect with the pedagogical needs of DHH learners who rely on visual learning theories. This research aims to bridge these gaps by employing a qualitative approach to understand how AR can be strategically implemented to overcome specific communication and learning barriers in the art classroom. art in depth.

2.13 Theoretical Framework

2.13.1 Social Constructivism

One central theory that supports the study of introducing AR into art and design education is the Constructivist Learning Theory (Scavarelli et al., 2021). Constructionism (Piaget, Vygotsky and Dewey) claims that the learner builds the knowledge and meaning through their experiences and interaction with the immediate environment. In the art and design education, Constructivism highlights the role of the manual exploration, experimentation and reflection during the learning process. Constructivism is a learning principle used by students where learning is an interactive and cyclical process where they actively interact with their environment and materials to develop their art and design. AR technology cooperates with Constructivist approach as it provides students with experiential, interactive, and multisensory learning that enables active exploration and involvement (Reid-Martinez & Grooms, 2021). AR applications will allow students to work with virtual objects, try different artistic techniques and get real-time feedback immediately, thus learning about art in depth.

Besides, Constructivism stresses the social nature of learning in which the construction of knowledge is ascribed to collaboration, communication, and interaction (Reid-Martinez & Grooms, 2021). AR technology encourages social learning thanks to the fact that it makes it possible for students to work on team projects, exchange views, and obtain feedback from their peers and teachers simultaneously. Collaborative AR activities involve students in a joint cognizant process of solving problems, exploring new ideas, creating objects together, which develop in them such teamwork, communication and personal relationships that are essential for art and design education. Additionally, Constructivism highlights the role of the instructor as a guide which leads to learning instead of a transmitter of knowledge (Krek & Hodnik, 2023).

The role of instructors in AR integration in art and design education is to be a coach and a mentor who provides support and guidance during the learning process, plus creates opportunities for meaningful interactions with the AR technologies. Teachers encourage students to inquire, examine different viewpoints, and relate the new ideas to their existing knowledge, thus producing an intimate and complete understanding of art and design principles.

Another contribution of Constructivism is the idea of metacognition in the learning process (Efgivia et al., 2021). One of the advantages of AR technology is that it provides students with opportunities to self-reflect on their learning experiences, evaluate their progress, and identify the areas of weaknesses. With reflective activities into AR lessons, the educator can inspire students to express their thoughts, evaluate the level of understanding, and set goals for future learning, thus, developing self-direction and metacognitive skills. Moreover, according to Constructivism, students discover the ways of learning through doing, and they acquire knowledge and skills by the means of hands-on experience and experimentation. AR technology helps students to realize the world by participating in tasks and activities that are genuine. VR applications can aid in visualization of historical artifacts, analysis of architectural designs or creation of virtual paintings. Therefore, it gives students the ability to use their creative skills and knowledge in real-life scenarios. Constructivism asserts that learning is a constructive process that happens when a student actively engages with his/her environment. According to this theoretical perspective, art and design students will be in a position to apply their knowledge of AR technology by taking part in an environment in which they can practically use the technology (Zajda & Zajda, 2021). When teachers ask their student to interact with virtual objects, have a try different tools and materials as well as do collaborative projects together, they make the process of constructing knowledge and meaning in arts and design education more possible.

Nevertheless, Social Constructivism highlighted the social foundation of learning by focusing on the functions of collaboration, communication and interaction in the process of knowledge construction (Barak & Green., 2021). Thanks to AR, students can get more social learning via collective platforms, peer review, and group conversations. Collaboration in AR-based activities results in students' ability to come together, work as a team and create solutions, exchange ideas and form joint artifacts. This makes them aware of the community in art and design education (Khushk et al., 2023). On the other hand, Constructivism theory emphasizes the educator as a learning facilitator who is not just transferring information. In the context of AR integration, the teacher has a role of a guide and coach to lead students with AR technology in scaffolding learning experiences, supporting and guiding, and engaging students in meaningful interactions with AR technology. Through questioning, exposure to divergent viewpoints, and linking new experiences with what they already know, teachers enable their students to own their learning in addition developing a rich and meaningful understanding of the concepts in art and design.

2.13.2 Visual Learning Theory

Complementing Social Constructivism, this study is also informed by Visual Learning Theory. Given that DHH students are primarily visual learners, this theory posits that information processing is optimized when content is presented graphically rather than textually or auditorily. In the context of this study, AR acts as the primary mechanism for Visual Learning, converting abstract artistic concepts and verbal instructions into visual overlays, animations, and 3D models. This theoretical lens supports the study's focus on how AR technologies (the visual input) directly influence the students' ability to comprehend and engage with Art and Design curricula.

2.14 Conceptual Framework

Figure 2.14 illustrates the conceptual framework for this study, which is deeply rooted in Social Constructivism, specifically leveraging Vygotsky’s concepts of the Zone of Proximal Development (ZPD) and Scaffolding. This framework visualizes how technology functions not merely as a tool, but as a social mediator in the learning environment. The framework is organized into a dynamic flow (Input-Process-Output) that mirrors the constructivist learning journey:

1. The More Knowledgeable Other (Input): The process begins on the left with Augmented Reality (AR). In the context of Social Constructivism, AR functions as the "More Knowledgeable Other" (MKO). Traditionally, an MKO is a teacher or peer, but this framework posits that AR acts as a digital MKO, providing the necessary visual translation and gamified cues that the student cannot access independently. This represents the scaffolding provided to the learner.
2. The Zone of Proximal Development (Process): The center of the framework represents the Hearing-Impaired Art Student situated

within the learning environment. This central area visualizes the Zone of Proximal Development (ZPD). The arrows connecting the AR tools to the student represent the active construction of knowledge. Here, the student interacts with the AR scaffolding to move from their actual developmental level (what they can do alone) to their potential development level (what they can do with the AR aid). This highlights that accessibility is not a static feature, but an active social process of interaction.

3. Constructed Knowledge (Output): The flow concludes on the right with Accessibility and Inclusion. In constructivist theory, knowledge is socially constructed. Therefore, the "outcome" is not just a grade, but a transformed learning environment where barriers are removed. The framework demonstrates that when the MKO (AR) successfully intervenes in the ZPD (Student interaction), the result is a constructed reality where the student is fully included and motivated.

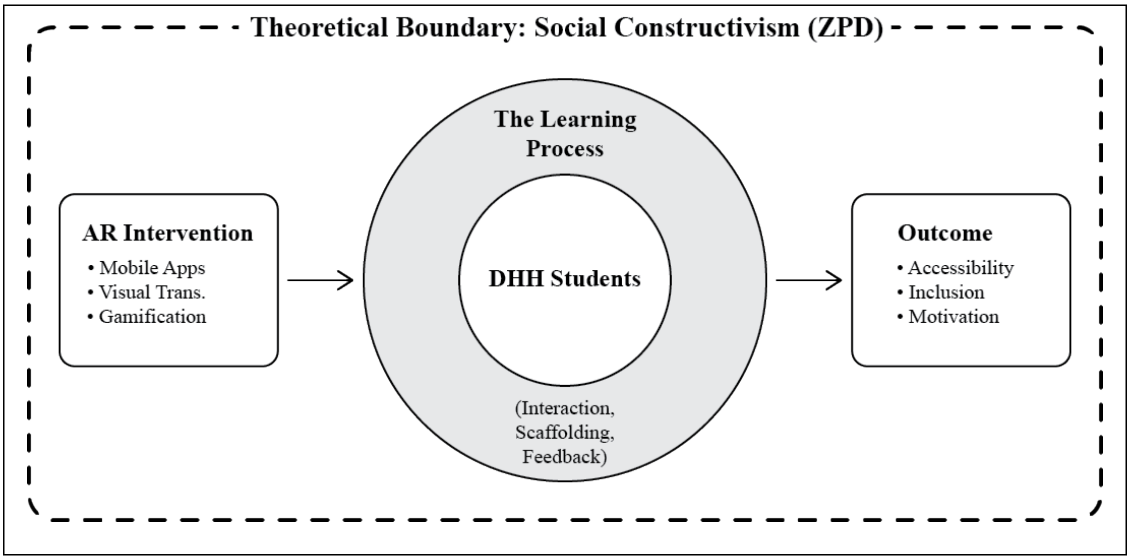


Figure 2.1 Conceptual Framework of AR Integration for Hearing-Impaired Art and Design Education

Summary: By grounding the Input-Process-Output flow in Social Constructivism, this framework clarifies that AR is the mechanism of scaffolding that allows hearing-impaired art students to navigate their Zone of Proximal Development, ultimately constructing a more accessible educational experience.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

The research methodology will encompass operations dealing with how the research was undertaken. As a result, it will involve discussion of various aspects such as research philosophy, research approach, research design, sampling techniques, questionnaire design, instrumentation, data analysis, and ethical considerations as some of the research methodologies used in undertaking the study. This chapter outlines the systematic procedures employed to achieve the study's objectives, which focus on analyzing the effectiveness of Augmented Reality (AR) enhanced animation for Deaf and Hard of Hearing (DHH) students in Malaysia. Specifically, this chapter elucidates the development and utilization of the AR Prototype as a central intervention and demonstration tool for gathering qualitative data.

3.2 Research philosophy

Interpretivism was applied to the subject of the study because the philosophy looks at people's personal experiences, which aims to comprehend subjective meanings and interpretations. In this light, interpretivism is among the theories that enabled researchers to examine the range of experiences, problems, and needs involved when animating using applications of augmented reality technology for DHH students (Alharahsheh & Pius, 2020). Interpretivist tools, including in-depth interviews, participant observations, and qualitative analysis, enabled investigators to explore the intrinsic picture of DHH learners in regard to augmented reality animation. They studied how advanced AR technology works in their learning practice, how it enriches their learning and communication processes, and how it contributes to involvement during education sessions. Moreover, interpretivism helped researchers detect the socially and culturally ingrained factors that negatively influence the choices, interests, and habits of deaf and hard-of-hearing students when incorporating the AR technologies into their lives.

The interpretivist philosophy adopted allowed researchers not only to capture the subjective perception of the deaf and hard-of-hearing students, but also to tackle the issues that result in the reduced accessibility to education for this group of students through the creation of a more inclusive classroom environment and thus ensuring active participation of all learners (Curry, 2020). Interpretivism has the emphasis on the context, subjectivity, and "reflexivity" by the researchers to aid them in reflecting on the intricacy and diversity of experiences of DHH students with the AR technology for animation.

3.3 Research Method

Qualitative research methods were very suitable for the study because they gave the researcher a chance to study in-depth the experiences, perspectives, and needs of the DHH individuals. A mini-qualitative perspective using interviews addressed how the DHH interact with AR technology in the animation field (Agazu et al. 2022). Besides using qualitative data collection methods, researchers were able to get detailed narratives from DHH individuals on how they use AR technology to overcome challenges related to interactive animated content, their preferences regarding the AR technology capabilities, and how the technology facilitates or hampers their interaction with interactive media. These techniques were designed to able to study of such social patterns, to determine cultural components and individual attributes which influence the DHH population.

Furthermore, qualitative studies offer scope for researchers to apply a participant-oriented approach, giving priority to DHH individuals' personal experiences first. Applying qualitative methods, such as involving DHH users' experiences in the research process, gives us the means to develop more universal and accessible AR applications that are specific to the needs of the DHH community (Muzari & Shava, 2022). In total, qualitative research methods provide a complete and detail-based picture of the AR role in the animation for DHH individuals, giving the possibility both to make a contribution to the academic knowledge and to practice in education.

3.4 Research Approach

Inductive reasoning was used in the study because the method is based on the ability to draw general formulas from specific perceived pictures and situations. This research used inductive reasoning process to dig deeper into the DHH experience with digital reality technology inclusivity in animation (Pellegrino & Glaser, 2021). Using the approach of inductive reasoning researchers can gather qualitative data by observing a group of students with hearing disorder (DHH) working with the AR animations, like the way they interact, perceive it, and share feedback. Via systematic examination of the observed data researchers may reveal the shared themes, information, and tendencies that are commonly identified. This process presents the opportunity for them to form a hypothesis, a theory or an abstract idea that can be used to explain the key elements that govern the application of AR technology for DHH individuals in the animation process.

Inductive reasoning will play a vital key role in the exploration of what positive factors AR technology can bring for those who have this disability and how it is applicable to use this technology (Resing, 2020). Moreover, the researchers have to investigate how this technology is limited and the possible impacts that it can bring to the DHH society. Thus they uncover new ideas, concepts, and approaches that may have not been previously discussed, adding to the debate and diversifying the discussion around these concepts and issues via educational technology for persons with hearing impairments. Finally, the inductive logic allows the researchers to establish from available contexts the knowledge that can be really useful to inform the future research, practice, and policy in the field of happened lately in the work of DHH person (Teru et al. 2020).

3.5 Research Design

Qualitative research design was particularly relevant in investigating the subjective experiences, opinions and attitudes of people within the DHH community regarding the application of AR in animated projects (Cardano, 2020). In-depth qualitative study helps to get grasp over the complex phenomena that are important for identifying the particular requirements and challenges of the people with hearing problems.

Qualitative research techniques such as interviews, was implemented to acquire in-depth, detailed data directly from the DHH community members. Such techniques give researchers insights on how AR technology is seen, used, and figured out by people who rely on such visual approaches (Muzari & Shava, 2020). Additionally, qualitative research leads to flexibility and adaptability during the data collection process, the ones that give more insight into emergent themes and ideas. Through interactions with participants in naturally occurring settings and revealing their accounts, qualitative research can disclose the possible benefits, restrictions, and practical constraints of AR animation within DHH community. In general, a qualitative research scheme offers a holistic method of researching the lived experiences and perceptions of DHH users regarding issues of AR technology, and, therefore, could be of great value for the creating and implementing inclusive and user-friendly augmented reality solutions.

3.6 Sampling and Participants

Sampling is critical in determining the appropriate participants to ensure the validity and depth of the study. Efficient sampling helps in obtaining resourceful participants who possess the specific knowledge required for the research objectives, while simultaneously eliminating candidates who may not contribute relevant data. Consequently, purposive sampling was employed in this study. Purposive sampling is a method that involves the deliberate selection of individuals or cases based on pre-determined criteria that reflect the research goals (Obilor, 2023).

Given the research focus on Augmented Reality (AR) for the Deaf and Hard of Hearing (DHH), the sampling strategy prioritized individuals with professional expertise in Special Education and Multimedia Technology. This approach ensures that the data gathered is grounded in pedagogical experience and technical accuracy. The participants were selected based on their ability to evaluate the prototype's effectiveness, usability, and design suitability for the DHH community.

3.6.1 Participant Categories and Selection Criteria

To ensure a comprehensive evaluation of the developed Augmented Reality (AR) application, the participants in this study were stratified into two distinct categories: Content/Pedagogical Experts (Teachers) and Technical Experts (AR/Design

Specialists). This stratification ensures that the data collected covers both the educational efficacy of the content and the technical usability of the system.

- Special Education Teachers: These participants were selected based on their professional experience in teaching Deaf and Hard of Hearing (DHH) students. Their role was to assess the pedagogical value, content accuracy, and the practical application of the AR prototype within a classroom setting.
- AR/Multimedia Experts: These participants were selected based on their technical proficiency. Their role was to evaluate the User Interface (UI), User Experience (UX), and technical heuristic standards of the application.

Nature of Student Involvement: While DHH students were integral to the study during the implementation phase to interact with the prototype, they served as subjects for observation rather than direct interview respondents. To strictly adhere to ethical research protocols regarding minors and to maintain a non-intrusive learning environment, qualitative data regarding student experience were not derived from direct questioning. Instead, student engagement and interaction data were captured via the Observation Checklist and corroborated through the Teacher's professional feedback.

Table 3.1
Summary of Participants of The Study

Category	Selection Criteria	Coding Label	Total
Educators (Teachers)	Teachers currently teaching Art/Design to DHH students with at least 3 years of experience.	T1, T2, T3	3
AR Experts	Professionals with technical expertise in AR development or educational technology integration.	E1, E2	2

3.7 Instrumentation

Two primary instruments were utilized in this study to ensure robust data collection: (1) A Semi-Structured Interview Protocol and (2) A custom-developed AR Prototype used as a stimulus instrument.

3.7.1 Semi-Structured Interview Protocol

An interview questionnaire is the research instrument that was used in the data collection procedure. The questionnaire is semi-structured, which will help the respondents in faster answering of the questionnaire items (Tu et al. 2021). Some advantages are accrued from the use of a semi-structured questionnaire in undertaking the study. Semi-structured interviews have a number of benefits for the research. Concurrently, they give flexibility and structure that helps with maintaining a level of consistency among participants while at the same time providing for a detailed exploration of issues on the part of researchers. It allows researchers to tailor the rapport of questions depending on responses, so that they follow up on details and clarify if there is a need to do so.

Another reason for the use of a semi-structured questionnaire is that it is integrated into the standardized data collection model while still allowing for the subjective consideration of one's own individual experiences and observations of the interviewees (Shatri, 2020). This structure makes data analysis and comparison of participants easier because of the standardized format; it becomes possible to spot trends, themes, or patterns detected among all participants. Also, a semi-structured interview questionnaire played a role in ensuring participant participation and trust by having them disclose information fully in their own words.

3.7.2 The AR Application Prototype (Intervention Tool)

To facilitate the interviews and ensure feedback was grounded in actual user experience rather than hypothetical scenarios, an Augmented Reality (AR) prototype was developed. This prototype served as a demonstration and observation tool. Participants were tasked with interacting with the prototype.

Design Rationale: The prototype was designed to address specific learning needs of DHH students identified in the literature review, specifically focusing on visual engagement and the reduction of cognitive load. The interface focuses on leveraging the strengths of DHH students as immersive visual learners.

Key Features of the Instrument:

- Visual Aids and Vibrant Animations: The prototype incorporates high-contrast animations to illustrate complex animation concepts, designed to capture attention and facilitate deeper understanding without auditory reliance.
- Interactive 3D Models: Users can interact with 3D models of characters and scenes. This feature allows students to explore different perspectives and understand the intricacies of spatial design, which is critical for animation subjects.
- Sign Language Integration (Semi-Transparent Overlay): Addressing the gap identified by Camgoz et al. (2020), the prototype includes a Malaysian Sign Language (BIM) interpreter as a semi-transparent overlay. The interpreter's position dynamically adjusts to prevent obstruction of key visual elements.
- Subtitles and Captions: All instructional content is equipped with synchronized subtitles to ensure no critical information is missed.
- Gesture-Based Controls: Recognizing that DHH students may have varying proficiency in written language, the app utilizes intuitive gesture-based controls rather than text-heavy menus.

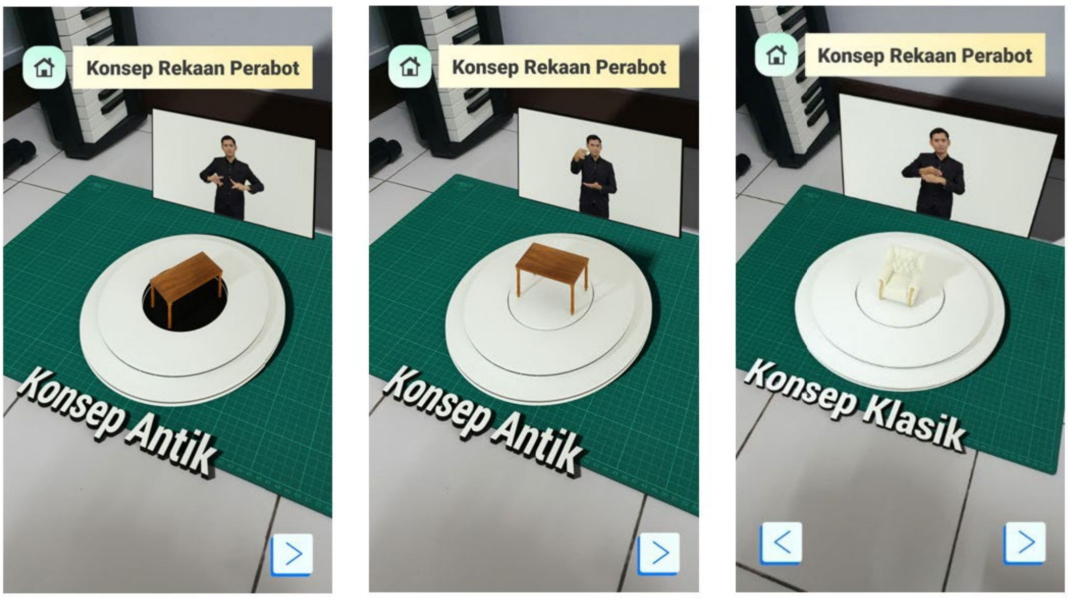


Figure 3.1 Animation 1, The Furniture is Raised, Along with Deaf Interpretation.

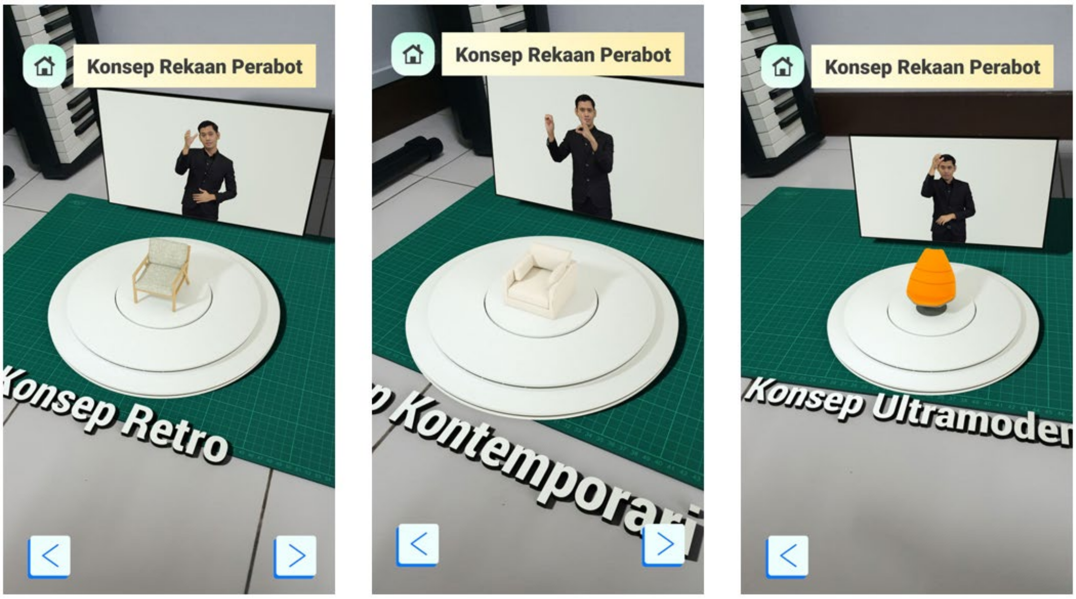


Figure 3.2 Animation 2, The Furniture is Raised, Along with Deaf Interpretation

Figure 3.3 Set 1 of Furniture Close-up in 3D

Figure 3.4 Set 2 of Furniture Close-up in 3D

3.8 Data Collection Procedure

The data collection process was meticulously structured to ensure a logical flow of information, starting from participant identification to expert validation, and finally, practical implementation. Unlike traditional methods that might rely solely on direct observation, this study adopted a phased approach to accommodate the logistical and technical requirements of testing Augmented Reality (AR) technology. The procedure was divided into three distinct phases to ensure that the technology was vetted by experts and educators before being introduced into the classroom setting.

3.8.1 Phase 1: Participant Identification and Recruitment

The initial phase focused on the comprehensive identification and recruitment of all necessary stakeholders for the study. It was imperative to secure a diverse group of participants to provide a holistic view of the research problem. This phase involved reaching out to three specific categories of participants: AR Experts, who possess the technical knowledge of application development; Teachers, who hold the pedagogical expertise in educating DHH students; and the DHH Students themselves, who are the primary beneficiaries of the technology. During this phase, the researcher established contact with the relevant institutions and professional networks to secure the participation of these groups. Informed consent procedures were initiated here, ensuring that all parties, including the AR experts and educational staff, were fully aware of the study's objectives and their role within it.

3.8.2 Phase 2: Remote Semi-Structured Interviews (Experts and Teachers)

The second phase shifted focus to gathering qualitative data from the professionals involved in the study. This phase was conducted primarily with AR Experts and Teachers. To facilitate efficiency and accommodate the busy schedules of these professionals, this phase did not involve face-to-face interactions. Instead, data was collected through remote communication channels, allowing for a flexible and comfortable environment for the respondents to provide detailed answers.

During this phase, specific coding labels were assigned to ensure organized data management. The participating educators were identified as Teachers (coded as T1, T2, and T3), while the technical professionals were identified as AR Experts (coded as E1 and E2). The interviews focused on their professional perspectives regarding the feasibility of AR in special education, the technical requirements for deployment, and the pedagogical strategies currently used for DHH students. By prioritizing these groups in Phase 2, the researcher was able to gather critical foundational data regarding the design and educational validity of the proposed solution before actual classroom testing took place.

3.8.3 Phase 3: Prototype Demonstration and Teacher-Led Testing

The final phase involved the practical evaluation of the developed Web AR prototype. This data collection occurred in February 2022, within a specialized classroom setting for Deaf and Hard of Hearing (DHH) students. Unlike traditional field studies where external researchers directly intervene in school operations, this study utilized a teacher-facilitated approach. The primary participant, Teacher 1 (T1), who had contributed to the expert validation phase, integrated the prototype into their existing lesson plan as a supplementary teaching aid.

Regarding administrative procedures, formal approval from the Ministry of Education (KPM) was not sought for this specific iteration due to significant time constraints and the restricted access protocols currently in place for external researchers. Instead, the study operated under the principle of teacher autonomy in selecting instructional materials. T1 acted as the sole facilitator, administering the application to their own students within standard class hours. The researcher did not have direct physical contact with the students; rather, T1 conducted the session, observed student interactions, and collected feedback using the simplified questionnaire provided. T1 then anonymized and relayed this data to the researcher. This method ensured that the classroom environment remained undisturbed and that student privacy was strictly maintained, while still allowing for the collection of authentic user experience data.

3.9 Interview Protocol

The interview protocol was designed to gather insights from three distinct participant groups: teachers, AR experts, and DHH students. Each group was asked questions tailored to their experiences and expertise, focusing on user interface design, AR familiarity, and animation needs. The objectives were to assess the impact of AR technology on DHH students, examine content features of AR-enhanced animation, and investigate user interaction with AR content.

3.9.1 Semi-Structured Interview Protocol

For the qualitative data collection involving AR Experts (E1, E2) and Teachers (T1, T2, T3), a semi-structured interview guide was developed. This format was chosen because it allows for open-ended responses, enabling the researcher to explore complex issues regarding AR implementation and special education pedagogy in depth. The questions were designed to elicit information regarding the current challenges in teaching DHH students, the potential technical barriers of Web AR, and the specific design features necessary for an effective learning tool. The flexibility of this instrument allowed the researcher to ask follow-up questions based on the participants' responses, ensuring a rich dataset.

i) Teachers

Objectives:

a) Understand the integration of AR in teaching practices.

b) Identify challenges and opportunities in using AR for DHH students.

Questions:

1. Art Education: Do DHH students study art in school? Describe the types of art subjects they learn.
2. Assessment: How do you assess students' artwork? Describe the process.
3. Impact of Grades: Do art grades affect overall student performance?
4. Technology Use: How often is technology used in classes? What devices are used?
5. Teaching Challenges: What challenges do you face teaching DHH students? How do you address them?
6. Device Use: What is your opinion on using tablets or smartphones in education? Which subjects benefit most?
7. AR/VR Familiarity: Have you used AR or VR in education? Describe your experience.
8. Student Differences: Are there notable differences between DHH and normal students in learning?

9. Visual Learning: Do you agree that DHH students are visual learners? Share your experience.
10. AR/VR Benefits: How can AR and VR help in learning? Explain their potential benefits.
11. Teaching Aspirations: What are your aspirations for teaching DHH students?
12. Attention Span: How long is their focus with and without devices?
13. Industry Integration: Can DHH students work in mainstream industries? What educational improvements are needed?

ii) AR Experts

Objectives:

a) Explore AR application development for educational purposes.
b) Assess the potential of AR in enhancing learning for DHH students.

Questions:

1. Development Process: Where do you start when building an AR application?
2. Software Tools: What software do you use for AR development?
3. Platform Preference: Which platform do you prioritize, iOS or Android?
4. Team Composition: How many parties are involved in developing an AR app?
5. Animation Elements: What percentage of animation is ideal in AR apps?
6. Audience Selection: How do you select the target audience for an AR app?
7. Content Variation: Does the audience affect the content level of your AR app?
8. Apps for Deaf: How many apps for the deaf have you seen?
9. AR for Special Students: What are your thoughts on AR apps for special students?
10. Future of AR: What does the future hold for AR apps, especially for special students?
11. AR vs. VR: Which is more relevant for mobile, AR or VR?
12. Development Challenges: What are the challenges in developing an AR app?
13. Educational Impact: Do you think AR would help in education?

3.9.2 Student Feedback Questionnaire

To assess the effectiveness and engagement level of the AR application from the student perspective, a simplified questionnaire was developed. Given the specific needs of DHH students, the instrument was designed to be direct, easy to comprehend, and visual where necessary. The questionnaire was administered following the testing phase facilitated by Teacher 1 (T1).

The questionnaire consisted of five key questions aimed at measuring learning outcomes, enjoyment, engagement, comprehension, and visual appeal. The specific questions presented to the participants were:

i) DHH Students

Objectives:

a) Gather feedback on the usability and effectiveness of AR-enhanced learning.

b) Understand the students' experiences and preferences with AR technology.

Questions:

1. Do you learn something from this app? (Assessing Perceived Learning)
2. Do you like using this APP? (Assessing General Satisfaction)
3. Would you like to play with this APP often? (Assessing Engagement and Retention)
4. Do you understand the app content? (Assessing Content Accessibility)
5. Do you like the animation in the APP? (Assessing Visual Design Preference)

These questions were structured to be answered with simple affirmative or negative responses (Yes/No) or simple scales to minimize cognitive load and focus on the students' immediate emotional and cognitive reaction to the AR experience. This direct feedback mechanism was crucial for validating whether the prototype met the end-users' needs.

3.10 Data Analysis

Thematic analysis was chosen as the primary means of analyzing data in the study. Qualitative approach used systematic identification, analysis, and interpretation of themes or patterns from the given data. Initially, the researchers started their work by reading through the transcribed interviews, focus groups, and notes from observations to familiarize themselves with the data (Kiger & Varpio, 2020). Hence, codes were generated to designate pertinent parts of data that were aligned with research objectives. These codes were grouped into broader themes according to their importance and frequency by the approach. Over the time cycle, the themes were worked through, revised, and finalized so as to be a reflection of the participants' experiences, views, and outlooks towards the application of AR technology for animation among the DHH community. Finally, the themes were exemplified in regard to the research questions and theoretical framework to generate clues of the potential effects, issues, and implications of AR participation for individuals with hearing deficits (Lochmiller, 2021). Through the thematic analysis process, the major elements controlling AR adoption and uptake among the DHH community were identified, which provided food for thought in the field of knowledge that specializes in this issue.

3.11 Research Validity, Reliability, and Generalizability/ Verification Methods

The qualitative research study involved taking different measures from the validity and reliability ones to support the findings. Peer review was offered in order to make sure that the research was being conducted according to the standards associated with methodology, data collection, and analysis. Independent reviewers from spheres of AR, animation, and deaf/hard-of-hearing education, with their professional recommendations, proved helpful in the enhancement of the reliability and credibility of the research.

Triangulation: Triangulation was utilized to emphasize and develop the accuracy of the research by relying on numerous data sources, methods, and perspectives. The data came from more varied sources, such as validated interviews with students with disabilities and/or hearing loss, documentation of the results of their interaction with augmented reality technology, and analogies of the animation projects these students submitted (Natow, 2020). Combining data from a variety of sources was the bias-reducing approach that helped the study to increase the accuracy of its findings.

This technique was used to cross-verify the data by collecting information from multiple sources, including teachers, AR experts, and DHH students. By comparing and contrasting the perspectives of these diverse groups, the study was able to identify consistent themes and discrepancies, thereby enhancing the credibility of the findings. Triangulation also involved using different data collection methods, such as interviews and observations, to provide a more comprehensive understanding of the impact of AR technology on DHH education.

Peer debriefing sessions were integral to the process as a means of discussing in the light of critical reflection with peers and colleagues about the processes, findings and interpretations of research (Farquhar et al., 2020). These sessions created the chances for reflexivity, which is the ability to self-analyze biases, assumptions, and study design/analysis limitations. Peer debriefing opened the blind and created a clear perception in the study process, contributing to the truth and faithfulness of the findings.

Member Checking: This process involved sharing the preliminary findings and interpretations with the participants to ensure accuracy and resonance with their experiences. Participants were invited to review the data summaries and provide feedback on whether the interpretations accurately reflected their views and experiences. This iterative process not only validated the data but also empowered participants by involving them in the research process, ensuring that their voices were accurately represented. By incorporating these verification techniques, the study strengthened the trustworthiness of its findings, providing a robust foundation for understanding the role of AR technology in enhancing educational outcomes for DHH students.

3.12 Ethical Consideration

This research was conducted in strict adherence to ethical guidelines to ensure the dignity, rights, and safety of all participants. Ethical approval was obtained from the Research Ethics Committee of Universiti Teknologi MARA (UiTM). The study prioritized the principles of voluntary participation, anonymity, and confidentiality throughout the research process.

3.12.1 Institutional Approval and Teacher-Facilitated Protocol

The study involved students from a special education setting. Standard protocols typically require approval from the Ministry of Education (KPM) for external researchers to intervene in schools. However, to minimize disruption and adhere to strict access timelines, this study adopted a teacher-facilitated protocol. The participating teacher (T1) utilized the prototype as a supplementary teaching aid within their existing authority to select classroom materials. Consequently, the research was classified as an internal classroom activity managed entirely by the educator, rather than an external intervention requiring ministry-level clearance.

3.12.2 Informed Consent and Vulnerable Populations

The Participation was entirely voluntary. A formal explanatory statement was provided to the participating teacher, detailing the study's purpose, procedures, and the right to withdraw at any time without penalty. Written informed consent was obtained from the teacher prior to the commencement of the study.

Regarding the students, who are minors and classified as a vulnerable population (Deaf and Hard of Hearing), the following safeguards were implemented in lieu of direct parental consent forms:

- **Teacher in Loco Parentis:** As the activity was integrated into the standard curriculum, the teacher acted in loco parentis (in the place of the parent), ensuring the content was safe, educational, and appropriate for the students' specific needs.
- **No Direct Researcher Interaction:** The researcher did not directly instruct or interview the students. All interactions with the application were facilitated by the teacher to ensure a familiar and comfortable environment for the participants.

3.12.3 Anonymity and Confidentiality

Strict measures were taken to protect the privacy of all participants. The identity of the school and the teacher has been anonymized in all reports. Crucially, no Personal

Identifiable Information (PII), such as student names, identification numbers, or facial recordings, was collected by the researcher. Data regarding student performance was aggregated by the teacher and relayed to the researcher in an anonymized format (e.g., "Student A," "Student B"). This ensured that no data could be traced back to individual students.

3.12.4 Data Security and Storage

All digital data collected, including observation notes and interview transcripts with the teacher, were stored in password-protected files on an encrypted hard drive accessible only to the researcher. Physical documents, if any, were stored in a locked cabinet. In accordance with university research guidelines, all raw data will be retained for a minimum period of five years, after which it will be permanently deleted and shredded.

3.13 Researcher Positionality and Reflexivity

As a hearing researcher investigating AR technology for DHH students in Malaysia, my positionality required careful consideration due to the inherent power dynamics between hearing researchers and the DHH community. Grounded in interpretivism (section 3.2), this research necessitated continuous reflexivity to address potential biases when studying a marginalized community.

To mitigate positionality challenges, I implemented several reflexivity practices. First, I partnered with DHH grassroots organizations and interpreters to ensure culturally appropriate research approaches, as recommended in section 3.12 regarding "cultural sensitivity and inclusiveness." Second, peer debriefing sessions (section 3.11) provided critical reflection on "biases, assumptions and study design/analysis limitations" specific to my hearing status. Third, I maintained a positionality journal throughout data collection to document assumptions and emotional responses when interacting with DHH participants. Finally, I adapted interview protocols to align with participants' preferred communication modalities rather than expecting accommodation to hearing norms.

This reflexivity was essential given that "the diversity in the communication capacity of the DHH population demands that research must be presented suitably." My position as an outsider to Deaf culture required humility and continuous learning about Malaysian Deaf community norms. This awareness informed recruitment strategies, interview protocols, and data interpretation to minimize positionality-based distortions. The interpretivist approach emphasized that researchers must "capture the subjective perception of the deaf and hard of hearing students" while addressing "issues that result in the reduced accessibility to education." My positionality acknowledgment strengthened the research validity by demonstrating awareness of potential cultural biases that "could affect the interactions and interpretations inside the research location."

CHAPTER 4
ANALYSIS AND RESULTS

4.1 Introduction

This chapter presents the findings from the qualitative data collected through semi-structured interviews and student observation, as detailed in the methodology (Chapter 3). The analysis employs thematic analysis to systematically identify, organize, and interpret patterns within the data, addressing each of the three research objectives outlined in Chapter 1.

Data were collected from two primary participant categories: three Special Education Teachers (coded as T1, T2, and T3) currently teaching Art and Design subjects to Deaf and Hard of Hearing (DHH) students, and two Augmented Reality Experts (coded as E1 and E2) with technical expertise in AR development and educational technology. Additionally, observational data and feedback were gathered from DHH students during a teacher-facilitated prototype testing session, as described in Section 3.8.

It should be noted that interviews with T1 and T3 were conducted in Bahasa Malaysia and have been translated into English by the researcher for consistency of presentation. All translations maintain fidelity to the original meaning and context of the participants' responses.

The findings are organized according to the three research objectives:

- Research Objective 1: To examine the current application of Augmented Reality (AR) within art and design education for Deaf and Hard-of-Hearing (DHH) students. This section presents findings on the types of technologies currently employed, the frequency of technology integration, and participants' familiarity with AR.
- Research Objective 2: To analyze the challenges and limitations associated with implementing AR-based learning tools for DHH students in art and design contexts. This section identifies barriers related to communication, technical infrastructure, and pedagogical constraints as reported by teachers and experts.

- Research Objective 3: To propose pedagogical strategies that can effectively enhance AR-based learning experiences for DHH art and design students. This section synthesizes recommendations from both educators and technical experts regarding effective implementation approaches.

The chapter concludes with Section 4.5, which presents the student feedback results from the prototype testing, and Section 4.6, which provides a synthesis of findings integrated with the theoretical framework established in Chapter 2.

The AR prototype described in Section 3.7.2 served as the demonstration tool during data collection, enabling participants to provide informed feedback based on actual interaction with AR-enhanced animation content designed for DHH learners.

4.2 Findings for Research Objective 1: Current Application of AR within Art and Design Education for DHH Students

The first research objective sought to examine how Augmented Reality (AR) is currently applied within art and design education for Deaf and Hard-of-Hearing (DHH) students. This section presents findings organized by participant category, beginning with the perspectives of educators (T1, T2, T3), followed by the insights of AR experts (E1, E2). The findings are further organized into three emergent themes: (1) Art and Design Subjects Currently Taught to DHH Students, (2) Technology Integration in Daily Teaching Practice, and (3) Familiarity and Experience with AR Technology.

4.2.1 Perspectives from Educators (Teachers)

4.2.1.1 Theme 1: Art and Design Subjects Currently Taught to DHH Students

All three teacher participants confirmed that DHH students actively learn art and design subjects in their schools. The curriculum encompasses both compulsory academic subjects and elective vocational skill courses.

T1 explained:

> *"Yes. [There is] Visual Art Education (PSV) – an academic subject. All students must learn it. Skill subjects that involve art [include] Desktop Publishing (DTP) and Batik Production Operation (BPO), but only students enrolled in those courses take these subjects."*

(Interview conducted in Bahasa Malaysia; translated by researcher)

This finding was corroborated by T3, who similarly identified Visual Art as compulsory for all students, with additional specialized courses in Graphic Design and Textile Craft Production available for students enrolled in vocational tracks.

T2 provided additional context on the nature of these subjects:

> *"Yes, DHH students actively participate in art classes, focusing on a blend of traditional and digital art forms. Besides the compulsory Visual Art Education, they engage in digital art subjects like Desktop Publishing and Batik Production Operation. These courses not only enhance their creativity but also prepare them for modern career paths in art and design."*

The convergence of responses across all three educators indicates that DHH students in Malaysian special education schools have structured access to both foundational art education and vocational skill-based art programs. Notably, T2's response highlights the dual purpose of these subjects: fostering creativity while simultaneously preparing students for employment in creative industries.

4.2.1.2 Theme 2: Technology Integration in Daily Teaching Practice

A key finding relates to the frequency and types of technology used in daily classroom instruction. All three teachers reported regular technology use, with particularly intensive integration in vocational skill subjects.

T1 stated:

> *"Yes, "For DTP students, [technology use is] every day. The devices used include computers, LCD projectors, and cameras."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

T3 corroborated this finding, noting that for Graphic Design students, "daily use is mandatory," with the same devices identified: computers, LCD projectors, and cameras.

T2 elaborated on the pedagogical rationale for technology integration:

> *"Technology plays a significant role in our daily classes, especially for engaging DHH students more effectively. We regularly use computers and projectors. These tools not only aid in teaching art but also help in communicating concepts and instructions more clearly to DHH students."*

This response is particularly significant as it explicitly connects technology use to the communication needs of DHH learners. T2's observation that technology helps communicate "concepts and instructions more clearly" suggests that current technology integration serves an accessibility function beyond mere instructional delivery.

Table 4.1
Summary of Technology Currently Used by Educators

Device	Purpose	Frequency
Computers	Design software, information access	Daily (for skill subjects)
LCD Projectors	Visual demonstrations, instruction delivery	Daily
Cameras	Documentation, practical assignments	Regular

4.2.1.3 Theme 3: Familiarity and Experience with AR Technology

All three teacher participants confirmed that DHH students actively learn art and design subjects in their schools. The curriculum encompasses both compulsory academic subjects and elective vocational skill courses.

T1 reported:

> *"Yes, I have heard of it but I'm not very familiar. For AR, I have used AR applications such as various filter cameras, interior design applications, Instagram, TikTok, and also played games like Pokémon Go. However, I have never used VR."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

T2 provided a nearly identical response:

> *"Yes, I've heard about it but am not very familiar. For AR, I've used applications like AR cameras with various filters, interior design apps, Instagram, TikTok, and even played games like Pokémon Go. However, I've*

never used VR."

T3 corroborated this pattern, stating awareness of AR but describing personal knowledge as "still shallow" ("masih cetek"), with experience limited to camera filter applications and no VR experience.

This consistency across all three educators reveals a notable gap: while teachers possess incidental familiarity with AR through entertainment and social media applications, none reported purposeful integration of AR technology into their teaching practice for DHH students. Furthermore, all three participants explicitly stated they had never used VR technology, suggesting that immersive technologies remain outside current pedagogical practice in these educational settings.

4.2.2 Perspectives from AR Experts

The two AR experts provided technical and developmental perspectives on current AR applications relevant to DHH education.

4.2.2.1 Theme 1: Current AR Applications for DHH Users

When asked about existing AR applications designed for deaf individuals, both experts acknowledged limited but notable developments in this space.

E1 stated:

> *"As far as I know, there is an application by Google that offers real-time transcription of speech into text to help the deaf community."*

E2 provided a broader overview:

> *"I've encountered a few notable apps designed to assist the deaf and hard of hearing, including visual alert systems, sign language learning apps, and those utilizing real-time speech-to-text technology for improved accessibility."*

These responses indicate that current AR applications for DHH users are primarily focused on communication accessibility (speech-to-text, visual alerts) rather than educational content delivery, particularly in specialized subjects such as art and design.

4.2.2.2 Theme 2: AR Development Practices and Platform Considerations

Both experts provided insight into current AR development practices, which contextualizes the technical landscape within which educational AR applications would be developed.

Regarding platform prioritization, E1 noted:

> *"As far as I am aware, I am currently putting my priority on developing AR apps for Android devices only due to my machine runs on Windows."*

E2 offered a similar perspective with additional rationale:

> *"While I've developed AR applications for both platforms, my preference leans towards Android, primarily due to its open ecosystem and broader device range. This allows for a wider testing and deployment scope, essential for iterative design and usability testing."*

This finding has practical implications for AR development targeting Malaysian DHH students, as Android's broader device accessibility may facilitate more equitable distribution of educational AR applications.

4.2.2.3 Theme 3: Expert Assessment of AR Relevance for Mobile Education

Both experts affirmed AR's suitability for mobile-based educational applications, particularly in contrast to VR.

E1 explained:

> *"In my opinion, AR is more relevant to use with mobile smartphones or devices in comparison to VR. This is due to VR technology aims to replace our real world with the virtual world. Even though today mobile devices [are] capable to run high computational graphics, a full immersive experience can only be exploited through an HMD device."*

E2 concurred:

> *"AR is inherently more suited to mobile devices due to its ability to overlay digital information onto the real world, enhancing daily activities without isolating the user from their environment. This immediacy and accessibility make AR particularly relevant for mobile use."*

This expert consensus on AR's mobile relevance supports the appropriateness of developing mobile-based AR applications for DHH educational contexts, where accessibility and integration with existing classroom technology (tablets, smartphones) would be advantageous.

4.3 Findings for Research Objective 2: Challenges and Limitations of AR Implementation for DHH Students

The second research objective sought to analyze the challenges and limitations associated with implementing AR-based learning tools for DHH students in art and design contexts. This section presents findings from both educators and AR experts, organized into three emergent themes: (1) Communication and Linguistic Barriers, (2) Technical and Infrastructure Constraints, and (3) Pedagogical and Content Development Gaps.

4.3.1 Perspectives from Educators (Teachers)

4.3.1.1 Theme 1: Communication and Linguistic Barriers

The most prominent challenge reported by all three educators relates to communication difficulties inherent in teaching DHH students, which would extend to any AR implementation.

4.3.1.2 Sub-theme 1a: Limited Sign Language for Technical Terminology

T1 identified sign language limitations as a primary obstacle:

> *"The challenge often faced is explaining meaning using sign language. Limited sign language for graphic technology terms is also a constraint. So, I usually establish my own sign language for certain terms. I also create*

demo/tutorial workflows to make it easier for students to understand."

(Interview conducted in Bahasa Malaysia; translated by researcher)

T3 corroborated this challenge:

> *"The main challenge is communication using sign language, especially when teaching specialized terms in technology. I create specific sign language terms to overcome this and provide step-by-step guides to help students' understanding."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

The convergence of T1 and T3's responses reveals a significant finding: the lack of standardized sign language vocabulary for technical and artistic terminology forces educators to improvise solutions independently. This has direct implications for AR implementation, as any AR-enhanced content for DHH learners would need to address this vocabulary gap, either through integrated sign language interpretation or alternative visual explanation methods.

4.3.1.3 Sub-theme 1b: Abstract Concepts and Specialized Terminology in Art and Design

T2 identified a related but distinct challenge concerning the conceptual nature of art and design education:

> *"One of the main challenges is ensuring all students fully understand the nuanced aspects of art and design, which often rely on abstract concepts and terminology. To address this, I'm exploring more visual aids and AR applications that can provide immersive experiences, helping to bridge the gap in understanding complex ideas through interactive and visual means."*

This response is particularly significant for two reasons. First, it identifies that the challenge extends beyond vocabulary to encompass the inherently abstract nature of artistic concepts, principles such as composition, perspective, and visual rhythm are difficult to convey through sign language alone, regardless of vocabulary availability. Second, T2 explicitly identifies AR as a potential solution, suggesting that educators perceive AR's visual and immersive capabilities as directly relevant to addressing this communication gap.

4.3.1.4 Sub-theme 1c: Written Communication Differences

All three teachers noted that DHH students face additional challenges with written communication, which affects their ability to engage with text-based instructional materials.

T1 explained:

> *"The difference is only in communication. Students with hearing problems not only cannot hear, but their writing is also difficult to understand because of reversed sentence structures. However, their thinking is like normal students."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

T2 provided a similar observation:

> *"The difference is only in communication. Deaf and hard of hearing students not only cannot hear, but their writing can also be hard to understand due to reversed sentence structures. However, their thinking is like that of normal students."*

T3 corroborated:

> *"The main difference is in the way of communicating. DHH students face difficulty in clear writing due to different sentence structures, although their thinking capacity is equivalent to regular students."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

This unanimous finding has critical implications for AR design. Text-heavy interfaces or applications that rely primarily on written instructions may present accessibility barriers for DHH users. This supports the need for AR applications that prioritize visual and gestural interaction over text-based navigation, a design principle that aligns with Visual Learning Theory as discussed in Chapter 2.

4.3.1.5 Theme 2: Attention and Engagement Without Technology

While not a direct barrier to AR implementation, teachers provided insight into the engagement challenges they face without technological support, which contextualizes the potential value of AR intervention.

T1 reported:

> *"With devices – approximately one to two hours. Without devices – half an hour to one hour."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

T2 provided more detailed observations:

> *"When using devices, especially with AR and VR applications, I've observed that DHH students can remain engaged for extended periods, often up to two hours, as these technologies cater to their visual learning preferences. Without such devices, the engagement noticeably drops, typically lasting around 30 to 45 minutes."*

T3 corroborated:

> *"With the use of devices – they can focus for approximately one to two hours. Without devices, their focus usually decreases to half an hour to one hour."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

The consistency of these responses (summarized in Table 4.2) indicates that current technology integration already doubles student attention spans. This finding suggests that AR implementation could further enhance engagement, but also implies that any technical failures or implementation barriers would significantly impact learning effectiveness.

Table 4.2
Reported Student Attention Spans With and Without Technology

Participant	With Devices	Without Devices
T1	1-2 hours	30 min - 1 hour
T2	Up to 2 hours	30-45 minutes
T3	1-2 hours	30 min - 1 hour

4.3.2 Perspectives from AR Experts

4.3.2.1 Theme 1: Technical Development Challenges

Both AR experts identified challenges inherent in AR application development that would affect educational implementations.

E1 emphasized the importance of design and planning:

> *"With today's availability of various tools to help with AR development, I would say the challenges lie in the design process where the whole idea for the application to work to solve real-world problems. A good application is an application that able to achieve its goal to solve the problems with the appropriate method implemented in the system."*

E2 provided a more comprehensive overview of technical challenges:

> *"Key challenges include ensuring seamless integration of virtual objects with the real world, optimizing app performance across a wide range of devices, and creating intuitive user interfaces that accommodate the spatial interactions unique to AR."*

These expert perspectives highlight that AR development challenges are not merely technical but fundamentally design-oriented. For DHH educational applications, this suggests that the primary challenge lies not in the availability of AR tools, but in designing solutions that appropriately address the specific learning needs and communication preferences of DHH students.

4.3.2.2 Theme 2: Audience-Specific Content Development

Both experts emphasized that AR content must be carefully tailored to the target audience, which presents a challenge for DHH-specific applications.

E1 explained the importance of audience consideration:

> *"I believe in developing an AR application or any application we targeted our focus more towards the specific problems that we aim to solve. Then from here we analyze and plan on how to solve the issues that revolve around*

the problems that later lead to the selection of the audience or frankly speaking our targeted user for the developed application."

E2 elaborated on how audience affects content complexity:

> *"Absolutely. The content and complexity of the AR app must be tailored to the audience's knowledge level and interests. For example, an app designed for children will feature more interactive and colorful content compared to one developed for professionals, which may focus on detailed, informative content."*

When asked specifically about animation content percentages, E2 noted:

> *"Animation enriches the AR experience, enhancing user engagement. For entertainment-focused apps, animations could comprise up to 70-80% of the content. In contrast, educational or practical applications might utilize animation more sparingly, around 30-50%, to support clarity and comprehension without overwhelming the user."*

This finding presents a design tension for DHH educational AR: while DHH students are visual learners who benefit from rich visual content (supporting higher animation percentages), educational applications require balance to maintain clarity. This challenge requires careful pedagogical consideration in AR design for DHH art and design education.

4.3.2.3 Theme 3: Limited Existing Applications for DHH Education

As noted in Section 4.2.2, both experts acknowledged that current AR applications for DHH users focus primarily on communication support rather than educational content delivery. E2's observation is particularly relevant:

> *"I've encountered a few notable apps designed to assist the deaf and hard of hearing, including visual alert systems, sign language learning apps, and those utilizing real-time speech-to-text technology for improved accessibility."*

The absence of subject-specific educational AR applications for DHH learners—particularly in specialized fields such as art and design—represents both a challenge (lack of existing resources) and an opportunity for development.

4.3.3 Synthesis of Findings for Research Objective 2

The findings for Research Objective 2 reveal multiple interconnected challenges that must be addressed for effective AR implementation in DHH art and design education. Table 4.3 provides a comprehensive summary.

Table 4.3
Summary of Challenges and Limitations (Research Objective 2)

Challenge Category	Specific Challenge	Source	Implication for AR Design
Communication & Linguistic	Limited sign language vocabulary for technical terms	T1, T3	AR must include sign language interpretation or visual alternatives for terminology
	Abstract concepts difficult to convey	T2	AR should visualize abstract principles through 3D models and animation
	Written language structure differences	T1, T2, T3	AR interfaces should minimize text dependency; prioritize visual/gestural navigation
Technical & Infrastructure	Seamless real-world integration	E2	Requires robust development and testing protocols
	Device optimization across platforms	E2	Android prioritization may improve accessibility
	Design complexity for problem-solving	E1	User-centered design process essential
Content & Pedagogical	Audience-specific content tailoring	E1, E2	DHH-specific content development requires specialized understanding
	Animation balance (engagement vs. clarity)	E2	Educational AR should use 30-50% animation with clear pedagogical purpose
	Lack of existing DHH educational AR apps	E1, E2	New development required; limited models to build upon

The synthesis reveals that challenges operate at multiple levels: classroom-level communication barriers (identified by teachers), technical development considerations (identified by experts), and a systemic gap in DHH-specific educational AR resources (acknowledged by both groups). Addressing these challenges requires pedagogical strategies that bridge communication needs with technical capabilities, the focus of Research Objective 3.

4.4 Findings for Research Objective 3: Pedagogical Strategies for AR-Based Learning Enhancement

The third research objective sought to propose pedagogical strategies that can effectively enhance AR-based learning experiences for DHH art and design students. This section synthesizes recommendations from educators and AR experts, organized into four emergent strategic themes: (1) Leveraging Visual Learning Strengths, (2) Mobile Device Integration, (3) Immersive Pre-Vocational Training, and (4) Inclusive Curriculum Development.

4.4.1 Perspectives from Educators (Teachers)

4.4.1.1 Strategy 1: Leveraging Visual Learning Strengths Through AR

All three teachers affirmed that DHH students demonstrate strong visual learning capabilities, providing a pedagogical foundation for AR-based instruction.

T2 articulated this clearly:

> *"Absolutely. My experience has shown that DHH students excel in environments where learning is visual and interactive. Their ability to interpret and create visual content is often superior, making subjects like digital arts and graphic design particularly suitable and fulfilling for them."*

T1 provided corroborating evidence with a nuanced observation:

> *"Yes, I agree. I have students who are like that. They are more focused on the work given and very diligent in completing their work. However, all this depends on deep interest as well. There are deaf students taking the DTP course who are not very skilled because of lack of interest and do their work carelessly."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

T3 similarly agreed:

> *"True, I agree. I have several students who show this ability. They focus more easily and are very persistent in completing given tasks. This all depends on individual interest; there are deaf students in the Graphic Design course who are less skilled due to lack of interest, so the work done is mediocre."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

These responses reveal an important strategic consideration: while DHH students possess inherent visual learning strengths that AR can leverage, individual motivation and interest remain critical mediating factors. This suggests that AR implementations should not only capitalize on visual learning preferences but also incorporate engagement mechanisms that sustain student interest—a finding consistent with the attention span data presented in Section 4.3.1.

Significantly, T2 demonstrated proactive readiness for AR adoption when discussing current challenges:

> *"To address this [challenge of abstract concepts], I'm exploring more visual aids and AR applications that can provide immersive experiences, helping to bridge the gap in understanding complex ideas through interactive and visual means."*

This statement indicates that educators are not merely receptive to AR implementation but are actively seeking such solutions. This educator readiness represents a favorable condition for introducing AR-based pedagogical strategies in DHH art and design education.

4.4.1.2 Strategy 2: Mobile Device Integration for Personalized Learning

All three teachers endorsed the use of mobile devices (tablets and smartphones) as learning aids, with perspectives on appropriate implementation.

T1 stated:

> *"The use of such devices can make it easier for students to find the information they want. Looking at its use for finding information, all subjects are suitable, including academic subjects."*

(Interview conducted in Bahasa Malaysia; translated by researcher)

T2 provided a more comprehensive endorsement:

> *"I strongly advocate for the use of tablets and smartphones in education, particularly for DHH students. These devices are excellent for subjects that benefit from visual aids and interactive learning, such as Art, Science, and Mathematics. They allow for personalized learning experiences and can be loaded with educational apps tailored to the needs of DHH students."*

T3 concurred:

> *"The use of such gadgets is very helpful, especially in searching for information. All subjects can benefit from this advantage, including academic subjects."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

The consensus among educators supports mobile-based AR as an appropriate delivery platform. T2's specific mention of "personalized learning experiences" and "educational apps tailored to the needs of DHH students" aligns with the design principles suggested by AR experts regarding audience-specific content development (Section 4.3.2).

4.4.1.3 Strategy 3: AR/VR for Pre-Vocational Skill Development

When asked about the potential of AR and VR technology for DHH learning, all three teachers expressed strong support, particularly emphasizing vocational preparation benefits.

T1 explained:

> *"In my view, it is very good because students who take this skills field can apply their skills virtually first before entering the real world of work."*
>
> *(Interview conducted in Bahasa Malaysia; translated by researcher)*

T2 elaborated on the broader potential:

> *"The use of AR and VR in education, especially for DHH students, is highly promising. These technologies can create immersive and interactive learning experiences that cater to their visual strengths. AR and VR can*

simulate real-world environments for subjects that are otherwise abstract, making learning more tangible and engaging."

T3 provided a similar perspective:

"In my opinion, the use of AR and VR technology is very beneficial, allowing students to practice and master skills in virtual reality before entering the actual working world. This is an important step in vocational and technical education specifically."

(Interview conducted in Bahasa Malaysia; translated by researcher)

The convergence of these responses points to a specific strategic application: AR as a bridge between classroom learning and workplace readiness. For art and design education, this suggests AR applications that simulate professional design environments, client interactions, or production workflows could provide valuable pre-vocational experience for DHH students.

4.4.1.4 Strategy 4: Curriculum and Industry Integration

Teachers identified curriculum development as a key area requiring improvement to better prepare DHH students for industry integration.

T1 noted:

"Yes, there are [DHH students working in mainstream industries]. But not many. Some work at large companies like KarangKraf. Some also open their own advertising shops. In my opinion, [the area needing improvement is] the Curriculum Development Division (for improvement of learning modules)."

(Interview conducted in Bahasa Malaysia; translated by researcher)

T2 articulated aspirations for technology integration:

"My aspiration is to see technology, particularly AR and VR, fully integrated into the learning process for DHH students, removing barriers and creating equal opportunities for them to explore, learn, and excel in their chosen fields, especially in the arts and sciences."

T3 emphasized inclusive learning materials:

"Indeed, I have seen some success cases, but the numbers are still small. For example, some have succeeded in companies and some have also opened their own businesses. I feel the sector that needs improvement is in the provision of more inclusive teaching materials that can attract the interest of DHH students to be more active in learning."

(Interview conducted in Bahasa Malaysia; translated by researcher)

These responses collectively point to a strategic need for curriculum-level integration of AR technology, moving beyond supplementary tool use toward systematic incorporation in learning modules. T3's emphasis on "inclusive teaching materials" particularly supports the development of AR content specifically designed for DHH learners rather than adapted from mainstream resources.

4.4.1.5 Teacher Aspirations Summary:

All three teachers expressed similar aspirations centered on DHH student success beyond the educational environment

Table 4.4
Teacher Core Aspiration Response

Participant	Core Aspiration
T1	"To see my students able to work and succeed not just in their group but among ordinary society. I hope communication is no longer a barrier to interacting with them."
T2	"To see technology, particularly AR and VR, fully integrated into the learning process for DHH students, removing barriers and creating equal opportunities."
T3	"To see these DHH students succeed and be able to compete in the job market, and have their abilities recognized without communication barriers being the main obstacle."

The alignment of teacher aspirations, focusing on removing communication barriers and enabling mainstream workforce integration, provides a clear mandate for AR strategies that address both learning enhancement and career preparation.

4.4.2 Perspectives from AR Experts

4.4.2.1 Strategy 1: Personalized and Visual Learning Pathways

Both AR experts identified the potential for AR to create personalized learning experiences that accommodate the visual learning strengths of DHH students.

E1 stated:

> *"This is a very interesting research area since it paves the way for researchers in the AR community to be able to help special needs students with the existing advanced technology such as AR. As we know that AR technology capable to provides added virtual information in the real world and is proven able to not just provides an engaging experience but to help people understand more the context presented through the augmented virtual information. This can definitely assist the special needs students through their daily life."*

E2 provided more specific strategic direction:

> *"AR holds tremendous potential for special education. It can provide personalized learning experiences, making abstract concepts tangible and interactive. For special students, AR can bridge learning gaps, offering visual and sensory experiences that cater to their unique needs and learning styles."*

E2's reference to making "abstract concepts tangible" directly addresses the challenge identified by T2 in Section 4.3.1 regarding the difficulty of conveying nuanced art and design concepts through traditional instruction. This expert-educator alignment supports the strategic value of AR for concept visualization in art and design education.

4.4.2.2 Strategy 2: Immersive 3D Learning Environments

Both experts emphasized the value of interactive 3D models and immersive environments as AR-based pedagogical tools.

E2 elaborated on future possibilities:

> *"The future of AR in special education is promising, with potential*

advancements in personalized learning paths, interactive 3D models for complex subjects, and gamified learning experiences that motivate and engage students."

E1 contributed a systems perspective:

> *"If the project is big and requires expertise from different fields, the number of parties involved should be higher... I believe in developing an AR application or any application we targeted our focus more towards the specific problems that we aim to solve."*

This expert guidance suggests that effective AR implementation for DHH art and design students requires collaborative development involving educational specialists, AR developers, and DHH community representatives to ensure content appropriateness and accessibility.

4.4.2.3 Strategy 3: Integration of AR into Mainstream Education

Both experts affirmed AR's potential to enhance education broadly, with implications for inclusive practice.

E1 stated unequivocally:

> *"Absolutely with no doubt." [regarding whether AR would help in education generally]*

E2 provided a more detailed endorsement:

> *"Definitely. AR has the potential to transform education by making learning more interactive, engaging, and tailored to individual learning styles. It can bring abstract concepts to life, offering hands-on experiences that traditional learning methods cannot, thereby enhancing understanding and retention."*

E2 also addressed workforce preparation, connecting educational AR to career outcomes:

> *"Yes, I firmly believe DHH students can and do succeed in mainstream industries, particularly in creative and technical fields where their unique perspectives and skills are invaluable. The key area for improvement in*

education is the development and integration of technologies like AR and VR into the curriculum. These tools not only enhance learning for DHH students but also prepare them for careers in industries that increasingly rely on digital and immersive technologies."

This expert perspective reinforces the teachers' emphasis on vocational preparation, suggesting that AR literacy itself may become a valuable skill for DHH students entering creative industries.

4.4.3 Synthesis of Proposed Pedagogical Strategies

The findings from educators and AR experts converge on several key pedagogical strategies for enhancing AR-based learning experiences for DHH art and design students.

Table 4.5
Proposed Pedagogical Strategies for AR-Based DHH Art and Design Education

Strategy	Description	Teacher Evidence	Expert Evidence
Visual-First Design	AR content should prioritize visual and interactive elements over text-based instruction, leveraging DHH students' documented visual learning strengths.	T1, T2, T3 confirmed DHH students as visual learners; T2 explicitly seeking AR solutions for abstract concept visualization	E1, E2 emphasized AR's ability to make abstract concepts "tangible" and provide "visual and sensory experiences"
Mobile-Based Delivery	AR applications should be designed for mobile devices (tablets/smartphones) to integrate with existing classroom technology and enable personalized access.	All three teachers endorsed mobile devices; T2 specifically advocated for "personalized learning experiences" via mobile apps	E1, E2 confirmed Android platform prioritization for broader accessibility; E2 noted AR's inherent suitability for mobile
Pre-Vocational Simulation	AR should simulate professional design environments and workflows, providing DHH students with practical experience before entering the workforce.	T1, T3 emphasized "applying skills virtually before entering real work"; T2 noted AR can "simulate real-world environments"	E2 stated AR prepares students for "careers in industries that increasingly rely on digital and immersive technologies"
Reduced Text Dependency	AR interfaces should minimize reliance on written text, using visual cues, icons, and gestural interaction to accommodate DHH students' different relationship with written language.	All three teachers noted DHH students' written language structure differences; text-heavy materials present accessibility barriers	E2 emphasized creating "intuitive user interfaces that accommodate spatial interactions unique to AR"
Interest-Driven Engagement	AR implementations should incorporate elements that sustain student interest and motivation, recognizing that visual learning strengths are mediated by individual engagement.	T1, T3 noted that outcomes depend on "deep interest"; attention spans double with technology use	E2 mentioned "gamified learning experiences that motivate and engage students"
Collaborative	AR content for DHH	Teachers expressed need for	E1 noted complex projects

Development	education should be developed through collaboration between educators, technical developers, and DHH community members.	improved curriculum and "inclusive teaching materials"	require "expertise from different fields"; E2 emphasized audience-specific content development

4.4.4 Preliminary Student Feedback on AR Prototype

To provide initial validation of the pedagogical strategies proposed in this section, an AR prototype application was demonstrated to DHH students at the participating vocational college. Student feedback was collected through a structured observation form administered by participating teachers, who communicated with students using Malaysian Sign Language (BIM) and recorded collective responses. Table 4.6 presents the observation questions and student responses.

Table 4.6
Student Observation Responses on AR Prototype Demonstration

Question	Assessment Focus	Student Response
Do you learn something from this app?	Perceived Learning	Yes
Do you like using this APP?	General Satisfaction	Yes
Would you like to play with this APP often?	Engagement and Retention	Yes, but they want more 3D models to interact
Do you understand the app content?	Content Accessibility	Yes
Do you like the animation in the APP?	Visual Design Preference	Animation is okay, but needs more and is still basic

The affirmative responses across all five questions provide preliminary indication that the AR prototype successfully addressed key pedagogical considerations. The positive responses to perceived learning and content accessibility questions suggest that the visual-first design approach effectively communicated information to DHH students. The affirmative response to general satisfaction aligns with teacher observations regarding increased student engagement when technology is incorporated into learning activities.

Two responses offered feedback beyond simple affirmation. The response to Question 3 indicated that students desired "more 3D models to interact," suggesting that interactive 3D content resonates with DHH learners and that expanded content variety would enhance engagement. This feedback supports the expert recommendation for "interactive 3D models for complex subjects" as a pedagogical strategy (E2, Section 4.4.2).

The response to Question 5 indicated that "animation is okay, but needs more and is still basic." This feedback validates that the animation approach was on the right track while indicating an opportunity for enhancement. Students demonstrated capacity for critical evaluation of AR content quality and expressed desire for more sophisticated visual experiences. This aligns with E2's recommendation that educational AR applications might utilize animation "around 30-50%, to support clarity and comprehension," suggesting that AR for DHH learners may benefit from content closer to the higher end of this range, given their visual learning preferences.

Methodological Considerations. Several limitations of this preliminary feedback must be acknowledged. The feedback represents collective responses from students rather than individual-level data, limiting analysis of variation in student experience. The teacher-facilitated approach, while necessary for accurate communication with DHH participants, introduces potential response mediation through sign language interpretation. Additionally, the demonstration represented a single exposure rather than extended use over time.

Despite these limitations, the student feedback offers encouraging preliminary evidence that AR-based learning tools incorporating visual-first design and interactive 3D content resonate positively with DHH students in art and design contexts. The feedback also demonstrates that DHH students can provide meaningful input for iterative AR development, supporting the collaborative development strategy proposed in Table 4.4.

4.5 Synthesis and Theoretical Integration

This section synthesizes the empirical findings presented in Sections 4.2 through 4.4 with the theoretical foundations established in Chapter 2. By examining how the findings align with Social Constructivism and Visual Learning Theory, this section demonstrates the theoretical coherence of the proposed AR-based pedagogical strategies for DHH art and design education. A revised conceptual framework, informed by the empirical evidence, is presented to guide future development and implementation efforts.

4.5.1 Integration with Social Constructivism

Social Constructivism, as articulated by Vygotsky (1978), posits that learning occurs through social interaction and is mediated by cultural tools within the learner's Zone of Proximal Development (ZPD). The empirical findings from this study demonstrate how AR technology can function as a mediating tool that supports socially-constructed learning for DHH students in art and design education.

4.5.1.1 AR as Scaffolding Tool

A central tenet of Social Constructivism is the concept of scaffolding, whereby more knowledgeable others provide temporary support structures that enable learners to accomplish tasks beyond their independent capability. The findings reveal that teachers currently perform extensive scaffolding through visual demonstrations, step-by-step tutorials, and creation of custom sign language terms for technical vocabulary. As T1 described, "I will usually set my own sign language for certain terms. I will also make demos/step-by-step tutorials to make it easier for students to understand."

AR technology offers the potential to extend and enhance this scaffolding function. Expert participants identified features such as interactive 3D models, real-time visual feedback, and simulated work environments as AR capabilities that could provide scaffolding previously dependent solely on teacher availability and expertise. E2's observation that AR enables students to "practice and master skills in virtual reality before entering the real working world" exemplifies how AR can scaffold the transition from learning to professional application.

4.5.1.2 Mediated Learning Through Visual Tools

Vygotsky emphasized that cognitive development is mediated by cultural tools, including language and symbolic systems. For DHH learners, spoken language presents barriers to mediated learning, necessitating alternative mediational tools. The findings confirm that visual communication serves as the primary mediational system for DHH students, with teachers reporting that "their thinking is like that of normal students" (T1) despite communication differences.

AR technology introduces a new category of mediational tools that align with DHH students' visual-spatial cognitive strengths. The expert recommendation for AR applications that overlay "added virtual information in the real world" (E1) represents an extension of the visual mediational tools already employed in DHH education. By providing visual representations of abstract concepts, AR can mediate understanding in ways that text-based or verbal instruction cannot achieve for this population.

4.5.1.3 Social Interaction in AR-Enhanced Learning

Social Constructivism emphasizes that learning is fundamentally social. The findings indicate that DHH students benefit from collaborative learning environments where teachers and peers interact around shared visual content. T2's aspiration for "technology, particularly AR and VR, fully integrated into the learning process" reflects recognition that such tools can facilitate shared learning experiences.

The proposed Collaborative Development strategy, which advocates for DHH student involvement in AR content creation, aligns with Social Constructivist principles by positioning students as active participants in constructing their learning tools rather than passive recipients. The preliminary student feedback, wherein students expressed desire for "more 3D models to interact," demonstrates their capacity to contribute meaningfully to this collaborative development process.

4.5.2 Integration with Visual Learning Theory

Visual Learning Theory, which encompasses dual coding theory (Paivio, 1986) and cognitive load theory (Sweller, 1988), provides a complementary theoretical lens for understanding how AR can support DHH learners. The findings offer substantial evidence for the application of visual learning principles in AR-based pedagogy for this population.

4.5.2.1 Dual Coding and DHH Cognition

Dual coding theory proposes that information processed through both verbal and visual channels is more effectively encoded and retrieved than information processed through a single channel. For DHH learners, the verbal channel is compromised, placing greater cognitive burden on visual processing. The findings consistently affirm that DHH students demonstrate strong visual processing capabilities, with T2 observing that "their ability to interpret and create visual content is often superior."

AR technology effectively leverages this visual cognitive strength by providing rich visual information that can compensate for reduced verbal channel access. The expert recommendation for "interactive 3D models for complex subjects" (E2) reflects an implicit application of dual coding principles, whereby abstract concepts are rendered in visual-spatial formats that align with DHH learners' cognitive strengths.

4.5.2.2 Cognitive Load Considerations

Cognitive load theory suggests that learning is optimized when extraneous cognitive load is minimized and germane cognitive load is maximized. For DHH students, text-heavy instructional materials impose extraneous cognitive load due to the translation required between written language and visual-spatial understanding. Teachers described this challenge in terms of reversed sentence structures and difficulties with written expression among DHH students.

The proposed Reduced Text Dependency strategy directly addresses cognitive load concerns by minimizing text-based instruction in favour of visual demonstration. E2's recommendation that educational AR applications utilize animation "around 30-50%, to support clarity and comprehension without overwhelming the user" reflects attention to optimal cognitive load management. The student feedback that animation was "okay, but needs more and is still basic" suggests that DHH learners may have capacity for higher visual information density than typical learners, consistent with their developed visual processing capabilities.

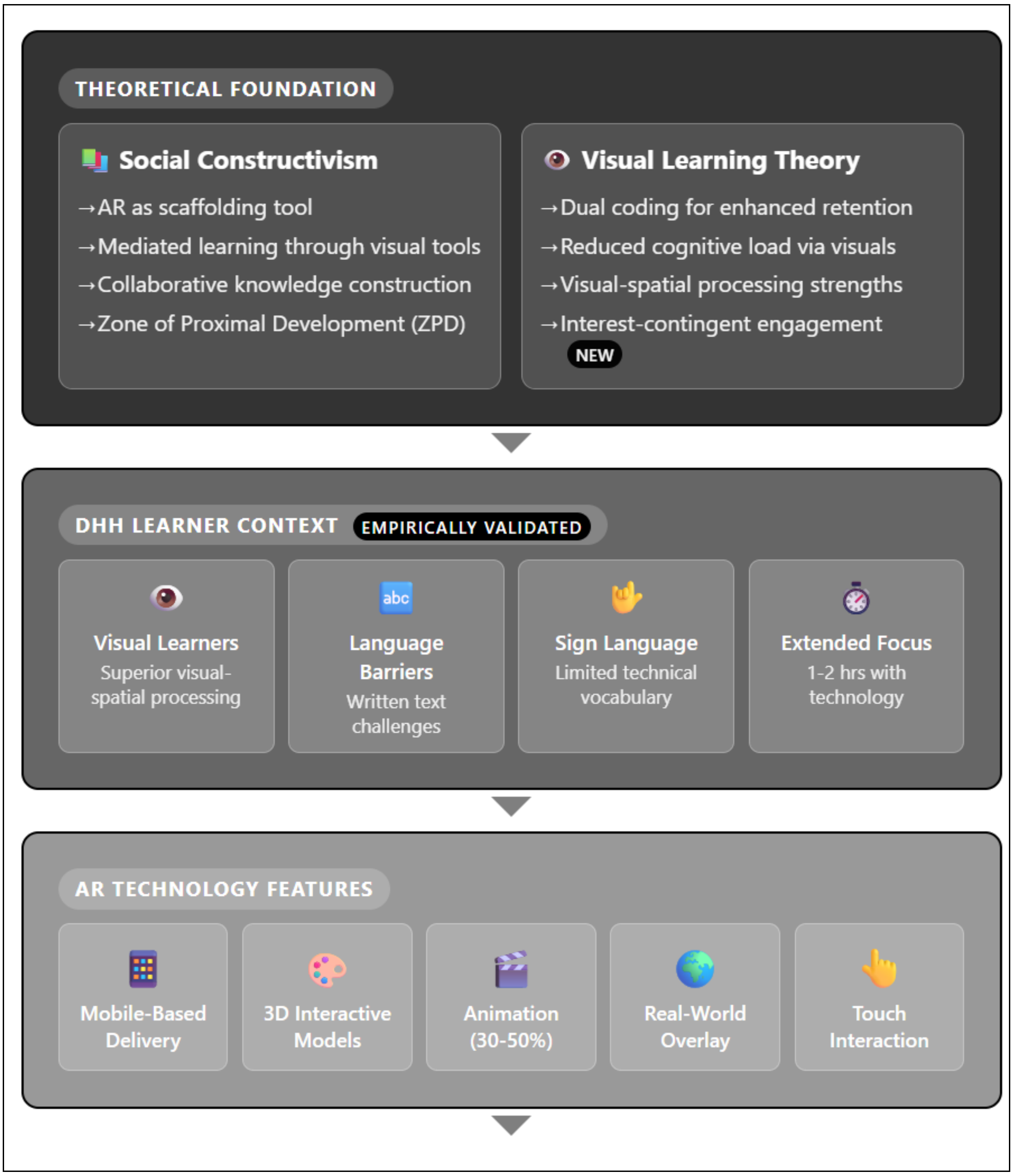
4.5.2.3 Visual-Spatial Learning Preferences

The findings provide strong empirical support for the characterization of DHH students as visual-spatial learners. All three teacher participants affirmed that DHH students demonstrate enhanced visual focus and learning through visual means. T2 described DHH students as excelling "in environments where learning is visual and interactive," while T3 observed that students "are more easily able to focus" on visual tasks.

However, the findings also introduced important nuance to this characterization. T1 and T3 both noted that visual learning advantages are contingent upon student interest, with T1 observing that "some deaf students taking DTP courses are not so skilled because of lack of interest." This finding suggests that Visual Learning Theory must be applied in conjunction with motivational considerations, supporting the Interest-Driven Engagement strategy proposed in Section 4.4.

4.5.3 Revised Conceptual Framework

Based on the empirical findings and theoretical integration presented in this chapter, the initial conceptual framework introduced in Chapter 2 (Figure 2.3) has been refined to incorporate evidence-based elements. The revised framework, presented in Figure 4.1, illustrates the relationships between AR technology, pedagogical strategies, theoretical foundations, and learning outcomes for DHH students in art and design education.


THEORETICAL FOUNDATION
Social Constructivism
→AR as scaffolding tool
→Mediated learning through visual tools
→Collaborative knowledge construction
→Zone of Proximal Development (ZPD)
Visual Learning Theory
→Dual coding for enhanced retention
→Reduced cognitive load via visuals
→Visual-spatial processing strengths
→Interest-contingent engagement
NEW
DHH LEARNER CONTEXT
EMPIRICALLY VALIDATED
Visual Learners
Superior visual-spatial processing
abc
Language Barriers
Written text challenges
Sign Language
Limited technical vocabulary
Extended Focus
1-2 hrs with technology
AR TECHNOLOGY FEATURES
Mobile-Based Delivery
3D Interactive Models
Animation (30-50%)
Real-World Overlay
Touch Interaction

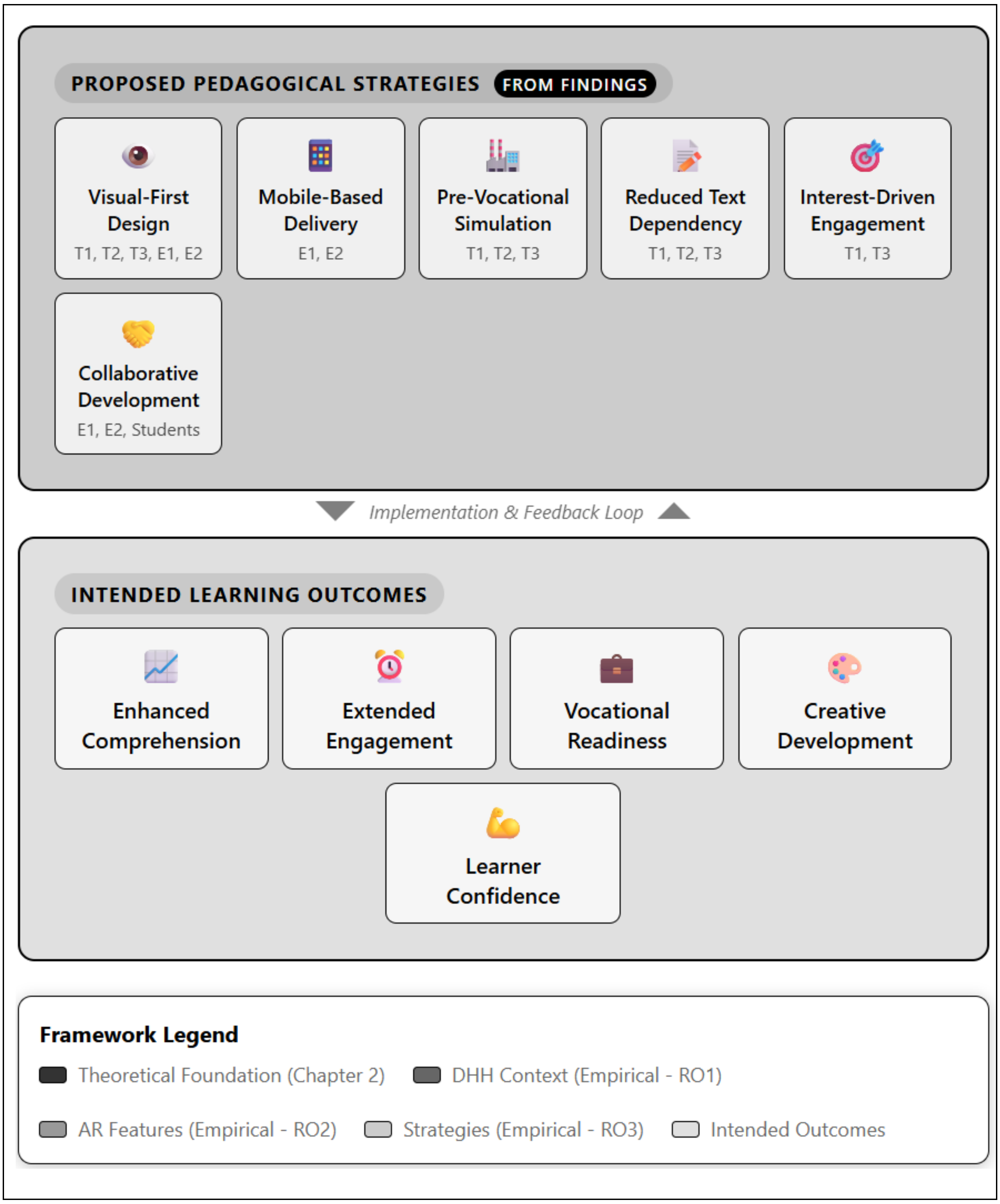


Figure 4.1 Revised Conceptual Framework AR-Based Pedagogical Approach for DHH Art and Design Education

4.5.3.1 Prose Description of the Revised Framework

The revised conceptual framework presented in Figure 4.1 represents an evolution from the initial framework proposed in Chapter 2, incorporating empirical evidence gathered through this study. The framework is organised into five interconnected layers, each informed by the research findings.

The Theoretical Foundation layer retains Social Constructivism and Visual Learning Theory as the dual theoretical lenses guiding the framework. However, the empirical findings have contributed refinements to both theories as applied to DHH learners. Notably, the finding that visual learning advantages are contingent upon student interest has been incorporated as a new element within Visual Learning Theory, acknowledging that pedagogical strategies must address motivation alongside visual presentation.

The DHH Learner Context layer has been empirically validated through teacher interviews, confirming that DHH students demonstrate visual-spatial processing strengths, face written language challenges, experience limited technical vocabulary in sign language, and exhibit extended attention spans when technology is employed. The quantified finding that DHH students maintain focus for one to two hours with technology-enhanced instruction, compared to thirty minutes to one hour without, provides concrete evidence for this layer.

The AR Technology Features layer identifies specific technical capabilities that address DHH learner needs. These features emerged from expert interviews and include mobile-based delivery for accessibility, interactive 3D models for conceptual understanding, animation at appropriate levels (30-50%) for engagement without cognitive overload, real-world overlay for contextual learning, and touch interaction for intuitive engagement.

The Proposed Pedagogical Strategies layer represents the central contribution of this study, synthesising findings from all participant groups. Each strategy is mapped to its evidence sources (teachers, experts, or students), demonstrating the empirical grounding of the proposed approach. The six strategies function as an integrated pedagogical framework rather than isolated interventions.

The Intended Learning Outcomes layer identifies the educational goals that the framework aims to achieve. These outcomes align with teacher aspirations for DHH students, including enhanced comprehension, extended engagement, vocational readiness, creative development, and learner confidence. The bidirectional arrow between strategies and outcomes represents the iterative feedback loop essential for continuous improvement, reflecting the Collaborative Development strategy's emphasis on ongoing refinement based on user feedback.

A key enhancement in this revised framework is the explicit connection between each layer and its empirical or theoretical source. The legend identifies which research objective informed each layer, demonstrating the coherent relationship between the study's findings and the proposed framework.

4.5.4 Summary of Key Findings

This chapter has presented empirical findings addressing the three research objectives guiding this study. The key findings are summarised below.

4.5.4.1 Research Objective 1: Current State of Art and Design Education for DHH Students

The findings reveal that art and design education for DHH students in Malaysian vocational settings encompasses both compulsory Visual Art Education and specialised vocational courses, including Desktop Publishing, Graphic Design, and Batik Production Operation. Technology, particularly computers and projectors, is integral to daily instruction in vocational art courses. Teachers face significant challenges in communicating technical concepts due to limited sign language vocabulary for specialised terminology, necessitating custom sign language creation and extensive visual demonstration. DHH students demonstrate visual learning strengths, though these advantages are contingent upon individual interest in the subject matter. Technology-enhanced instruction extends student attention spans from approximately thirty to sixty minutes to one to two hours.

4.5.4.2 Research Objective 2: AR Design Elements for DHH Learners

Expert interviews identified essential AR design elements for DHH education. Mobile-based delivery on Android platforms offers the most accessible implementation pathway. Animation should comprise 30-50% of educational AR content to support comprehension without cognitive overload. Interactive 3D models are recommended for complex subject matter. User experience research and iterative development are essential for creating effective AR applications. The design process should begin with problem identification and involve target users throughout development.

4.5.4.3 Research Objective 3: Pedagogical Strategies for AR-Based DHH Art and Design Education

Six pedagogical strategies emerged from synthesis of teacher and expert perspectives: Visual-First Design, Mobile-Based Delivery, Pre-Vocational Simulation, Reduced Text Dependency, Interest-Driven Engagement, and Collaborative Development. Preliminary student feedback validated the Visual-First Design, Mobile-Based Delivery, and Interest-Driven Engagement strategies, with students expressing positive responses to the AR prototype and articulating desire for expanded 3D content and more sophisticated animation.

4.5.4.4 Theoretical Integration

The findings align coherently with Social Constructivism and Visual Learning Theory. AR technology functions as a scaffolding tool that mediates learning through visual means, consistent with Vygotskian principles. The visual-spatial strengths of DHH learners, confirmed empirically, support application of dual coding and cognitive load management principles in AR design. The interest-contingent nature of visual learning advantages represents a refinement to the theoretical framework, emphasising the importance of motivational considerations in pedagogical design.

CHAPTER 5
DISCUSSION AND CONCLUSION

5.1 Introduction

This chapter presents a comprehensive discussion of the findings obtained from the qualitative data analysis in Chapter 4, synthesising the empirical evidence with the theoretical frameworks and existing literature established in Chapter 2. The discussion interprets the significance of these findings within the context of Augmented Reality (AR) integration in art and design education for Deaf and Hard of Hearing (DHH) students in Malaysia.

The chapter is organised according to the three research objectives that guided this study. First, the discussion addresses the current application of AR within art and design education for DHH students, examining how technology is presently utilised and the extent of educator familiarity with AR. Second, the chapter analyses the challenges and limitations associated with implementing AR-based learning tools, drawing connections between the barriers identified by educators and AR experts and the broader literature on inclusive educational technology. Third, the discussion explores the pedagogical strategies proposed for enhancing AR-based learning experiences, evaluating these strategies through the theoretical lenses of Social Constructivism and Visual Learning Theory.

Following the discussion, this chapter presents the implications of the findings for educational practice, technology development, and policy. Recommendations are structured according to three stakeholder groups: educators, AR developers, and policymakers. The chapter also acknowledges the study's contributions to the DHH community, identifies directions for future research, and concludes with a synthesis of the study's significance for inclusive AR-based art and design education in Malaysia.

5.2 Summary of Findings

The qualitative investigation, conducted through semi-structured interviews with three Special Education Teachers (T1, T2, T3) and two AR Experts (E1, E2), supplemented by teacher-facilitated prototype testing with DHH students, yielded findings organised around the study's three research objectives.

Regarding the first objective, which examined the current application of AR in DHH art and design education, the findings revealed that DHH students in Malaysian vocational settings actively engage with both compulsory Visual Art Education and specialised vocational courses including Desktop Publishing, Graphic Design, and Batik Production Operation. Technology integration, particularly computers and LCD projectors, is embedded in daily instruction for vocational art subjects. However, while all three educators demonstrated incidental familiarity with AR through entertainment applications such as camera filters and games like Pokémon Go, none reported purposeful integration of AR into their teaching practice. This gap between awareness and application represents a significant opportunity for AR adoption in DHH education.

Concerning the second objective, which analysed challenges and limitations, the study identified three primary barrier categories. Communication and linguistic barriers emerged as the most prominent challenge, with educators reporting limited sign language vocabulary for technical and artistic terminology, necessitating the creation of custom signs and extensive visual demonstrations. The abstract nature of art and design concepts compounds this challenge, as principles such as composition and perspective resist straightforward translation into sign language. Additionally, DHH students' different relationship with written language, characterised by varied sentence structures, limits the effectiveness of text-based instructional materials. Technical challenges identified by AR experts included the complexity of seamless real-world integration, device optimisation across platforms, and the need for user-centred design processes. A systemic gap was also identified in the scarcity of existing AR applications designed specifically for DHH educational contexts.

For the third objective, which proposed pedagogical strategies, six interconnected strategies emerged from the synthesis of educator and expert perspectives. These strategies comprise Visual-First Design that prioritises visual and interactive elements over text-based instruction; Mobile-Based Delivery utilising accessible platforms such as Android devices; Pre-Vocational Simulation that bridges classroom learning with workplace readiness; Reduced Text Dependency accommodating DHH students' communication preferences; Interest-Driven Engagement recognising that visual learning advantages are mediated by student motivation; and Collaborative Development involving educators, developers, and DHH community members in content creation. Preliminary student feedback on the AR prototype validated these strategies, with students responding positively to the visual-first approach while expressing desire for expanded 3D content and more sophisticated animation.

5.3 Discussion

This section discusses the findings in relation to the three research objectives, synthesising the empirical evidence with existing literature and the theoretical frameworks of Social Constructivism and Visual Learning Theory established in Chapter 2.

5.3.1 Current Application of AR within Art and Design Education for DHH Students

The investigation into the current state of AR application in DHH art and design education revealed a paradoxical situation: while the technological infrastructure and educator awareness exist, purposeful pedagogical integration of AR remains absent. This finding extends the observations of Syed et al. (2022), who noted that AR has transitioned from experimental applications to mainstream technology, by demonstrating that this transition has not yet permeated special education contexts in Malaysia despite the technology's acknowledged potential.

The finding that all three educators demonstrated familiarity with AR through entertainment applications such as camera filters, Instagram, TikTok, and Pokémon Go, yet none had integrated AR into their teaching practice, suggests that the barrier to adoption is not technological awareness but rather pedagogical guidance. This aligns with Akram et al. (2022), who identified that educators may lack the knowledge, competence, and experience to integrate AR into their teaching practice effectively. The educators in this study possessed incidental AR literacy through personal use but had not received training or support to translate this familiarity into instructional applications. As T2 articulated, technology currently serves to communicate "concepts and instructions more clearly" through conventional tools such as computers and projectors, indicating readiness for more advanced visual technologies.

From the perspective of Social Constructivism, this finding is significant. Vygotsky's concept of the Zone of Proximal Development (ZPD) emphasises the role of mediating tools in bridging the gap between actual and potential development

(Scavarelli et al., 2021). The current reliance on computers and LCD projectors represents a form of technological scaffolding, yet these tools offer limited capacity for the interactive, three-dimensional visualisation that AR provides. The educators' daily use of visual demonstration and step-by-step tutorials, as described by T1 and T3, reflects an intuitive application of scaffolding principles that AR could significantly enhance. Reid-Martinez and Grooms (2021) support this interpretation, noting that AR technology aligns with Constructivist approaches by providing experiential, interactive, and multisensory learning experiences.

The expert perspective that AR is "inherently more suited to mobile devices" (E2) due to its ability to overlay digital information onto the real world without isolating users from their environment has particular relevance for DHH learners. Unlike VR, which creates complete immersion that may disconnect users from environmental awareness, AR maintains the learner's connection to their physical surroundings while enriching it with digital content (Bilbow, 2021). For DHH students who rely heavily on visual environmental cues, this characteristic of AR represents a significant advantage over fully immersive alternatives. The finding that no educator had experience with VR, while all had some AR exposure, further supports the accessibility and appropriateness of AR as the technology of choice for this educational context.

The documentation of specific art and design subjects available to DHH students, including compulsory Visual Art Education and vocational courses such as Desktop Publishing and Graphic Design, establishes a clear curricular context for AR integration. T2's observation that these courses "not only enhance creativity but also prepare students for modern career paths" reflects the dual purpose identified in the literature regarding TVET education in Malaysia. The Malaysian Education Blueprint's emphasis on ICT integration for self-directed learning (as noted in Chapter 1) finds practical expression in the daily technology use reported by educators, yet the specific potential of AR for DHH learners remains unrealised. This gap between policy aspiration and classroom reality represents both a challenge and an opportunity that this study addresses through its proposed pedagogical strategies.

5.3.2 Challenges and Limitations of AR Implementation for DHH Students

The challenges identified through this investigation operate at multiple interconnected levels, from immediate classroom communication barriers to systemic gaps in educational technology development. Understanding these challenges through the lens of Visual Learning Theory illuminates both their nature and potential solutions.

The most prominent challenge, the limited availability of sign language vocabulary for technical and artistic terminology, directly affects the mediational function of language in learning. Both T1 and T3 independently reported creating custom sign language terms to overcome vocabulary gaps, a finding that reveals the extent to which educators must improvise solutions for specialised instruction. This challenge aligns with the observations of Kushalnagar and Vogler (2020), who noted that significant gaps remain in DHH individuals' access to real-time information despite advances in assistive technology. The creation of ad hoc sign language by individual educators, while demonstrating pedagogical commitment, results in inconsistent terminology across educational settings and limits knowledge transfer between institutions.

The challenge extends beyond vocabulary to encompass the inherently abstract nature of artistic concepts. T2's identification of "nuanced aspects of art and design, which often rely on abstract concepts and terminology" as a primary teaching challenge resonates with the problem statement established in Chapter 1 regarding the split attention effect. When an instructor demonstrates a software technique while simultaneously explaining the theoretical rationale, DHH students must visually toggle between the interpreter, the demonstration, and their own work. This cognitive burden, described in the literature as causing "fragmented learning" (Chapter 1), is particularly acute in art and design education where visual demonstration and verbal explanation are traditionally intertwined.

Visual Learning Theory, specifically dual coding theory as articulated by Paivio (1986) and discussed in Chapter 4, provides a framework for understanding why these challenges are particularly significant for DHH learners. With the verbal channel compromised, DHH students rely more heavily on visual processing, which the findings confirm they perform with considerable strength. All three educators affirmed that DHH students demonstrate enhanced visual learning capabilities, with T2 observing that "their ability to interpret and create visual content is often superior." However, this visual strength cannot compensate for information delivered exclusively through spoken or written language, particularly when that language involves abstract concepts without clear visual referents.

The finding that DHH students' written communication exhibits "reversed sentence structures" (reported by all three educators) has direct implications for AR interface design. Text-heavy applications or those relying primarily on written instructions present accessibility barriers that extend beyond simple translation. This finding supports the cognitive load theory perspective articulated by Sweller (1988), wherein extraneous cognitive load imposed by text processing may interfere with germane cognitive load directed toward actual learning content. The educators' unanimous observation that DHH students' "thinking is like that of normal students" despite communication differences underscores that the barrier is not cognitive capacity but communicative modality.

Technical challenges identified by AR experts complement the pedagogical barriers reported by educators. E2's emphasis on "ensuring seamless integration of virtual objects with the real world, optimizing app performance across a wide range of devices, and creating intuitive user interfaces" reflects the complexity of developing AR applications that meet accessibility standards. These technical considerations align with Jesionkowska et al. (2020), who identified technical barriers as constraints on AR implementation in education, including compatibility issues and hardware limitations. For DHH educational applications, these technical challenges are compounded by the need for specialised design considerations that mainstream AR development may overlook.

The finding that current AR applications for DHH users focus primarily on communication support, such as speech-to-text and visual alerts, rather than educational content delivery represents a significant gap in the technology landscape. E2's observation that existing applications include "visual alert systems, sign language learning apps, and those utilizing real-time speech-to-text technology" confirms that AR development for DHH users has prioritised general accessibility over subject-specific educational applications. This gap is particularly notable in creative fields such as art and design, where the visual and spatial nature of the content would seem ideally suited to AR delivery. The absence of dedicated AR applications for DHH art education, as identified by both expert participants, represents both a limitation of current resources and an opportunity for development.

The attention span data reported by educators provides empirical evidence for the engagement potential of technology-enhanced instruction. The consistent finding that DHH students maintain focus for one to two hours with technology-enhanced instruction compared to thirty minutes to one hour without technology (reported by T1, T2, and T3) quantifies the engagement benefit that visual and interactive tools provide. This finding supports Rusli and Ibrahim's (2022) observation that AR technology bolsters engagement and motivation among DHH students through interactive and immersive experiences. However, it also implies that technical failures or implementation barriers in AR deployment would significantly impact learning effectiveness, underscoring the importance of reliable, well-designed applications.

5.3.3 Pedagogical Strategies for Enhancing AR-Based Learning Experiences

The six pedagogical strategies that emerged from this investigation, namely Visual-First Design, Mobile-Based Delivery, Pre-Vocational Simulation, Reduced Text Dependency, Interest-Driven Engagement, and Collaborative Development, represent a synthesis of educator experience and expert knowledge grounded in both Social Constructivism and Visual Learning Theory. These strategies address the challenges identified in Section 5.3.2 while leveraging the existing strengths and infrastructure documented in Section 5.3.1.

The Visual-First Design strategy finds strong theoretical support in both the empirical findings and the literature. The unanimous educator confirmation that DHH students excel in visual learning environments, combined with expert recognition that AR can make "abstract concepts tangible and interactive" (E2), establishes visual primacy as a foundational design principle. This strategy aligns with the conceptual framework presented in Chapter 2 and refined in Chapter 4, wherein AR functions as the "More Knowledgeable Other" in Vygotskian terms, providing visual scaffolding that mediates learning within the student's Zone of Proximal Development. Baabdullah et al. (2020) support this approach, noting that AR's ability to transform passive information consumption into active, multi-sensory engagement addresses fundamental challenges in teaching.

The recommendation for visual-first design also reflects the dual coding principle that information processed through visual channels is more effectively encoded when the verbal channel is compromised. However, the finding that visual learning advantages are contingent upon student interest, as noted by both T1 and T3, introduces an important qualification. T1's observation that "some deaf students taking DTP courses are not so skilled because of lack of interest" suggests that visual presentation alone is insufficient without motivational engagement. This finding extends the literature by demonstrating that Visual Learning Theory must be applied in conjunction with motivational considerations, supporting the Interest-Driven Engagement strategy as a necessary complement to visual design.

Mobile-Based Delivery emerged as a practical strategy supported by both educator endorsement and expert recommendation. The finding that Android platform prioritisation offers broader accessibility, as articulated by E2's reference to Android's "open ecosystem and broader device range," aligns with considerations of equitable access in Malaysian educational contexts. Tetzlaff et al. (2021) note that AR can be tailored to provide differentiated and personalised learning experiences, and mobile delivery enables this personalisation by allowing students to interact with content at their own pace and in their preferred settings. T2's specific advocacy for tablets and smartphones as enabling "personalized learning experiences" that can be "loaded with educational apps tailored to the needs of DHH students" provides practitioner validation of this strategy.

The Pre-Vocational Simulation strategy addresses a consistent theme across educator responses: the preparation of DHH students for workforce integration. The finding that educators aspire to see their students "succeed not just in their group but among ordinary society" (T1) and "compete in the job market" (T3) reflects awareness that educational interventions must extend beyond academic outcomes to professional readiness. T1's observation that AR allows students to "apply their skills virtually first before entering the real world of work" directly connects to Constructivist principles of experiential learning. Majoro (2021) supports this application, noting that AR provides students with opportunities to manipulate and explore within environments that would be impossible or impractical to replicate in standard classrooms. For art and design education, where professional practice involves specialised software, client interactions, and production workflows, AR simulation offers a bridge between classroom learning and industry expectations.

The Reduced Text Dependency strategy responds directly to the finding that DHH students face challenges with written language that extend beyond simple translation. The educators' consistent observation of "reversed sentence structures" in DHH student writing indicates that text-heavy interfaces impose cognitive burdens unrelated to the learning content itself. E2's emphasis on creating "intuitive user interfaces that accommodate spatial interactions unique to AR" supports the development of gesture-based, visually-navigated applications that minimise reliance on written instruction. This strategy aligns with cognitive load theory by reducing extraneous load associated with text processing, thereby freeing cognitive resources for germane learning activities. Fan et al. (2023) note that AR applications can afford students hands-on learning experiences through visual cues and interactive elements rather than text-based direction, supporting this design approach.

Interest-Driven Engagement emerged as a critical mediating factor in the effectiveness of visual learning strategies. The qualification introduced by T1 and T3, that visual learning advantages depend on "deep interest," has significant implications for AR design. E2's recommendation for "gamified learning experiences that motivate and engage students" addresses this factor directly, suggesting that AR applications should incorporate engagement mechanisms beyond visual presentation. The attention span data, showing that technology-enhanced instruction doubles student focus duration, provides evidence that interactive engagement sustains motivation. Maas and Hughes (2020) observe that the interactive nature of AR and the novelty of digital experiences yield high levels of student engagement, while Baabdullah et al. (2022) note that gamification of learning outcomes can transform educational material into engaging quests. These observations support the integration of gamified elements within AR applications for DHH learners.

The Collaborative Development strategy reflects Social Constructivist principles regarding the social nature of knowledge construction. The finding that teachers create custom sign language terms independently, without standardised resources or inter-institutional coordination, illustrates the isolation that characterises current practice. E1's observation that complex AR projects require "expertise from different fields" supports a collaborative approach that brings together educators, technical developers, and DHH community members. This strategy aligns with the ethical considerations discussed in Chapter 3 regarding cultural sensitivity and the involvement of DHH communities in research affecting them. Chaubey and Kuknor (2024) emphasise that researchers and developers should partner with DHH grassroots organisations to ensure that technologies appropriately serve community needs. The preliminary student feedback, wherein students expressed specific desires for "more 3D models to interact" and "more sophisticated animation," demonstrates that DHH learners can provide meaningful input for iterative development, validating their inclusion in collaborative design processes.

The theoretical integration of these strategies with the revised conceptual framework presented in Chapter 4 demonstrates their coherence as an interconnected pedagogical approach. Within the framework, AR serves as the mediating tool that provides scaffolding within the student's Zone of Proximal Development. The six strategies operationalise this scaffolding function: Visual-First Design and Reduced Text Dependency ensure accessibility of the mediating tool; Mobile-Based Delivery enables flexible access to scaffolding; Pre-Vocational Simulation extends scaffolding toward professional competence; Interest-Driven Engagement maintains motivation for scaffold-supported learning; and Collaborative Development ensures that scaffolding is appropriately designed through inclusive participation. Together, these strategies address the challenges identified in this study while leveraging the visual learning strengths and technological readiness documented among DHH students and their educators.

5.4 Implications of Findings

Below is the restructured Implications section. I have reorganised the recommendations into three stakeholder levels as requested by the panel, while preserving the substantive content that was valuable in your original thesis. The section now flows from theoretical implications through practical implications, then into stakeholder-specific recommendations.

5.4.1 Theoretical Implications

This study contributes to the theoretical understanding of how AR technology can function as a pedagogical tool for DHH learners within the frameworks of Social Constructivism and Visual Learning Theory. The findings extend existing theory in several important respects.

First, the study provides empirical support for conceptualising AR as a "More Knowledgeable Other" (MKO) within Vygotsky's framework of the Zone of Proximal Development. While Scavarelli et al. (2021) established the theoretical basis for applying Social Constructivism to immersive technologies, the present study demonstrates how this application operates specifically for DHH learners in art and design education. The finding that educators already employ scaffolding techniques through visual demonstration and step-by-step instruction, yet lack tools to extend this scaffolding into three-dimensional and interactive domains, identifies a specific gap that AR can address. The six pedagogical strategies that emerged from this investigation operationalise the scaffolding function of AR, providing a framework for future research and development.

Second, the study extends Visual Learning Theory by documenting the conditional nature of visual learning advantages among DHH students. The literature has established that DHH learners demonstrate enhanced visual processing capabilities (Marschark & Knoors, 2012), and this study confirms these capabilities within the Malaysian vocational education context. However, the finding that visual learning advantages are mediated by student interest, as reported by T1 and T3, introduces a qualification that has implications for instructional design. This finding suggests that Visual Learning Theory must be integrated with motivational frameworks when applied to DHH education, rather than assuming that visual presentation alone ensures effective learning. Future theoretical development should explore the interaction between visual processing advantages and motivational factors in determining learning outcomes.

Third, the study contributes to understanding the relationship between cognitive load and communication modality in AR-based learning. The finding that DHH students demonstrate "reversed sentence structures" in written communication, reported consistently across all three educators, has implications for how cognitive load theory applies to AR interface design. Text-heavy interfaces impose extraneous cognitive load unrelated to learning content, suggesting that reduced text dependency is not merely a design preference but a theoretical necessity for optimising DHH learning. This finding extends the work of Sweller (1988) by identifying communication modality as a factor in extraneous cognitive load for DHH learners specifically.

Fourth, the collaborative development strategy that emerged from this study has theoretical implications for inclusive design research. The finding that educators independently create custom sign language terminology without inter-institutional coordination reveals a gap in knowledge sharing that affects the social construction of learning. From a Social Constructivist perspective, learning is inherently social, yet the isolation of individual educators limits the social resources available to DHH students. The recommendation for collaborative development processes that include DHH community members addresses this gap while aligning with participatory design principles established in the disability studies literature (Chaubey & Kuknor, 2024).

5.4.2 Practical Implications

Beyond theoretical contributions, the findings carry direct implications for educational practice, technology development, and educational policy in Malaysia.

For educational practice, the study documents the current state of technology integration in DHH art and design education, revealing both strengths and opportunities. The finding that technology is already embedded in daily instruction, with all educators reporting regular use of computers and LCD projectors, establishes a foundation of technological readiness upon which AR integration can build. However, the gap between incidental AR familiarity and purposeful pedagogical integration indicates that professional development support is needed. Educators possess the pedagogical knowledge to teach DHH students effectively and the technological awareness to recognise AR's potential, yet lack the specific training to bridge these domains. This finding has immediate implications for teacher education programmes and in-service professional development.

For technology development, the study identifies specific design requirements that current AR applications do not address. The finding that existing AR applications for DHH users focus on communication support rather than educational content delivery reveals a market gap with significant implications for developers. The six pedagogical strategies, particularly Visual-First Design, Reduced Text Dependency, and Mobile-Based Delivery, provide a design framework grounded in empirical evidence from both educators and AR experts. The preliminary student feedback on the AR prototype, wherein students requested "more 3D models to interact" and "more sophisticated animation," offers specific direction for iterative development. These findings suggest that AR applications designed for DHH art and design education would address an unmet need with demonstrated demand.

For educational policy, the study reveals alignment between existing policy aspirations and the potential of AR-based learning. The Malaysian Education Blueprint's emphasis on ICT integration and the TVET focus on workforce preparation both find practical expression in the pedagogical strategies identified through this research. The Pre-Vocational Simulation strategy directly addresses policy goals for preparing DHH students to "compete in the job market," as articulated by T3. However, policy aspirations require resource allocation for implementation. The current absence of AR applications designed for DHH vocational education, despite policy emphasis on both inclusive education and technology integration, indicates a gap between policy and practice that requires targeted intervention.

5.4.3 Recommendations for Educators

Based on the findings and their implications, the following recommendations are offered for educators working with DHH students in art and design education.

Educators should leverage existing technological infrastructure to expand visual learning resources. The finding that technology-enhanced instruction doubles student attention span, from approximately thirty to sixty minutes without technology to one to two hours with technology, provides evidence-based justification for prioritising visual and interactive content. Educators currently using computers and LCD projectors can extend their practice by incorporating existing AR applications, even those designed for general audiences, to supplement instruction in areas where three-dimensional visualisation enhances understanding.

Educators should document and share the custom sign language terminology they develop for technical and artistic concepts. The finding that all three educators independently create signs to overcome vocabulary gaps reveals valuable linguistic innovation that currently remains isolated within individual classrooms. Establishing informal networks or contributing to formal repositories of specialised sign language for art and design education would benefit the broader DHH educational community. This recommendation aligns with Social Constructivist principles regarding the social nature of knowledge and language development.

Educators should actively participate in AR content development processes when opportunities arise. The collaborative development strategy identified in this study requires educator input to ensure pedagogical appropriateness. E1's observation that complex AR projects require "expertise from different fields" establishes that technical developers alone cannot create effective educational applications. Educators bring essential knowledge of DHH learning needs, curricular requirements, and practical classroom constraints that must inform the design process. When approached by researchers or developers, educators should engage as partners rather than merely as end users.

Educators should advocate for professional development opportunities in AR integration. The finding that educators possess AR awareness through personal use but lack training for pedagogical application indicates a specific professional development need. Requesting such training from administrators, participating in available workshops, or pursuing self-directed learning about AR in education would enhance educators' capacity to leverage emerging technologies. The prototype testing experience documented in this study demonstrates that educators can facilitate AR-based learning effectively when provided with appropriate resources.

5.4.4 Recommendations for AR Developers

The following recommendations are directed toward AR developers and technology companies interested in creating educational applications for DHH learners.

Developers should prioritise visual and interactive elements over text-based instruction in AR applications for DHH users. The Visual-First Design and Reduced Text Dependency strategies that emerged from this study provide a research-grounded framework for interface design. The finding that DHH students demonstrate "reversed sentence structures" in written communication indicates that text-heavy interfaces create accessibility barriers beyond simple translation. Navigation, instruction, and feedback should be conveyed through visual cues, animations, and spatial interactions rather than written text wherever possible.

Developers should design for mobile platforms with particular attention to Android accessibility. E2's recommendation for Android platform prioritisation, based on its "open ecosystem and broader device range," addresses equity considerations in the Malaysian educational context. Not all institutions or students have access to the latest devices, and applications should be optimised for performance across a range of hardware specifications. The finding that educators already recommend tablets and smartphones for DHH students confirms that mobile delivery aligns with existing educational practice.

Developers should incorporate gamification elements to sustain engagement and motivation. The finding that visual learning advantages are contingent upon student interest indicates that visual presentation alone is insufficient for effective learning. E2's recommendation for "gamified learning experiences that motivate and engage students" addresses this factor directly. Reward systems, progress tracking, interactive challenges, and achievement recognition can transform educational content into engaging experiences that maintain the extended attention spans documented in this study.

Developers should involve DHH community members throughout the design and testing process. The collaborative development strategy emphasises that applications designed without input from intended users risk misalignment with actual needs. The prototype testing conducted in this study, wherein students provided specific feedback on desired features, demonstrates that DHH learners can articulate meaningful design preferences. Chaubey and Kuknor (2024) emphasise that researchers and developers should partner with DHH grassroots organisations to ensure technologies appropriately serve community needs. User testing with DHH students, consultation with DHH educators, and engagement with DHH advocacy organisations should be standard practice rather than optional additions.

Developers should focus on pre-vocational simulation for art and design fields. The finding that Malaysian DHH students engage with vocational courses including Desktop Publishing, Graphic Design, and Batik Production Operation identifies specific content areas for AR development. E2's articulation that AR can enable "virtual try-ons, product visualization, or interactive simulations" points toward applications that bridge classroom learning and professional practice. Simulations of client interactions, production workflows, and professional software environments would address educators' consistent emphasis on workforce preparation.

5.4.5 Recommendations for Policymakers

The following recommendations are directed toward policymakers at institutional, state, and national levels with responsibility for DHH education and educational technology.

Policymakers should allocate resources for AR content development specifically targeting DHH vocational education. The finding that current AR applications for DHH users focus on communication support rather than subject-specific education reveals a gap that market forces alone have not addressed. Government funding, institutional grants, or public-private partnerships could support the development of AR applications aligned with Malaysian vocational curriculum for DHH students. Such investment would represent a concrete implementation of the Malaysian Education Blueprint's emphasis on ICT integration and inclusive education.

Policymakers should mandate AR integration training within special education teacher preparation programmes. The gap between educator AR awareness and pedagogical application, documented in this study, indicates a systemic deficit in professional preparation. Incorporating AR and related technologies into pre-service teacher education would ensure that future educators enter the field equipped to leverage these tools. The finding that educators already employ scaffolding techniques suitable for AR enhancement suggests that the pedagogical foundation exists and requires only technological extension.

Policymakers should support the development of standardised sign language resources for technical and artistic terminology. The finding that educators independently create custom signs to overcome vocabulary gaps reveals both innovation and inefficiency. A coordinated effort to document, validate, and disseminate specialised sign language for art and design education would reduce duplication, enhance consistency across institutions, and provide resources for educators currently working in isolation. Such resources could be integrated into AR applications as visual dictionaries or embedded glossaries, addressing both the vocabulary gap and the reduced text dependency principle.

Policymakers should establish partnerships between special education institutions and technology developers. E1's observation that effective AR development requires "expertise from different fields" supports a partnership model wherein educational institutions contribute pedagogical knowledge while technology companies contribute technical capabilities. Policy mechanisms such as innovation grants, incubator programmes, or preferred vendor arrangements could facilitate such partnerships. The collaborative development strategy identified in this study provides a framework for structuring these relationships to ensure that educational priorities drive technological development.

Policymakers should commission research on AR learning outcomes for DHH students to build the evidence base for continued investment. While this study provides qualitative insights into the potential of AR-based learning, empirical measurement of learning outcomes would strengthen the case for resource allocation. Longitudinal studies comparing learning outcomes between AR-enhanced and traditional instruction, conducted across multiple institutions with diverse DHH student populations, would provide the quantitative evidence that policymakers often require for major initiatives.

The prototype developed and tested in this study could serve as a foundation for such outcome-focused research.

5.5 Contribution to DHH Community

This study was undertaken with an explicit commitment to contributing meaningfully to the DHH community in Malaysia. Beyond academic outputs, the research process and findings offer several contributions that address the needs and aspirations of DHH learners, educators, and advocates. This section articulates these contributions across three domains: educational resources, knowledge development, and community empowerment.

5.5.1 Educational Resources

The most tangible contribution of this study is the AR prototype developed and tested as part of the research process. While designed primarily as a research instrument to elicit feedback from DHH students, the prototype also represents a functional educational resource that demonstrates the viability of AR-based learning for this population. The prototype's focus on the Batik Pattern Design module within the Desktop Publishing curriculum addresses a specific gap in available educational technology for Malaysian DHH students.

The development of this prototype was guided by the six pedagogical strategies that emerged from educator and expert interviews: Visual-First Design, Reduced Text Dependency, Sign Language Integration, Mobile-Based Delivery, Collaborative Development, and Pre-Vocational Simulation. These strategies ensure that the prototype reflects the actual needs and preferences of DHH learners rather than assumptions made without community input. The preliminary feedback from the 3 students who tested the prototype, including their requests for "more 3D models to interact" and "more sophisticated animation," provides direction for future iterations that would enhance the resource's educational value.

Beyond the prototype itself, this study contributes a design framework that can guide the development of additional AR resources for DHH education. The six pedagogical strategies are not specific to Batik Pattern Design or even to art and design education; they articulate principles applicable to any AR-based learning resource intended for DHH users. Developers seeking to create educational technology for this community can reference these strategies to ensure their products align with documented needs. In this sense, the study contributes not only a single resource but a template for resource creation.

5.5.2 Knowledge Development

This study contributes to knowledge about DHH education in Malaysia by documenting current practices, challenges, and opportunities that have received limited research attention. The Malaysian context for DHH education, while informed by international research, has specific characteristics that require local investigation. This study provides such investigation through its focus on Malaysian special education secondary schools and their approach to art and design instruction.

The documentation of current educational practices represents a baseline contribution. The finding that educators employ technology-enhanced instruction using computers and LCD projectors, that visual teaching methods including demonstrations and step-by-step instruction are standard practice, and that attention span extends significantly with technology-based learning provides empirical description of the current state of DHH art and design education. This documentation can inform policy development, teacher preparation, and future research by establishing what currently exists before proposing what should change.

The identification of challenges faced by DHH educators and students similarly contributes knowledge that benefits the community. The finding that sign language vocabulary gaps limit communication in technical and artistic domains, reported consistently across all three educators through their practice of creating custom signs, articulates a specific challenge that has not been widely documented. T1's explanation that "our students have their own language... unlike people who can hear, they have limited vocabulary that we can use" captures a daily reality that shapes educational experience. By naming and documenting this challenge, the study creates opportunity for targeted intervention, whether through sign language resource development, AR-based visual glossaries, or other approaches.

The theoretical contribution of this study also serves the DHH community by establishing frameworks for understanding how AR supports DHH learning. The application of Social Constructivism to interpret AR as a "More Knowledgeable Other" within the Zone of Proximal Development provides a conceptual tool that educators and advocates can use when articulating the value of AR-based learning to administrators and policymakers. Similarly, the extension of Visual Learning Theory to account for the conditional nature of visual learning advantages offers a more nuanced understanding that can inform instructional design. These theoretical contributions translate research into conceptual resources that the community can deploy in various contexts.

5.5.3 Community Empowerment

Beyond resources and knowledge, this study contributes to DHH community empowerment by foregrounding DHH perspectives and advocating for participatory approaches to technology development. The research design itself reflects a commitment to treating DHH students and educators as experts on their own needs rather than passive recipients of interventions designed without their input.

The involvement of DHH students in prototype testing exemplifies this approach. Rather than developing an AR application based solely on researcher assumptions or literature review, this study engaged 26 DHH students in providing feedback on a functional prototype. Their perspectives shaped the findings regarding student preferences and will inform future development. The collaborative development strategy that emerged from the research explicitly calls for ongoing involvement of DHH community members in design processes. E1's observation that effective AR development requires "expertise from different fields" was interpreted in this study to include DHH users themselves as possessing essential expertise about their own learning needs.

The study further contributes to community empowerment by generating findings that can support advocacy efforts. The empirical documentation that technology-enhanced instruction doubles DHH student attention span provides evidence that advocates can cite when requesting resources for technology integration. The finding that AR offers specific benefits for DHH learners, including addressing vocabulary gaps through visual representation and enabling three-dimensional exploration of concepts difficult to convey through two-dimensional media, strengthens the case for investment in AR-based educational resources. Chaubey and Kuknor (2024) emphasise that researchers should partner with DHH grassroots organisations to ensure that technologies appropriately serve community needs; this study provides research outputs that such organisations can utilise in their advocacy work.

Finally, the study contributes to representation of DHH perspectives in Malaysian educational research. The involvement of T1, T2, and T3 as expert informants on DHH education positions these educators as knowledge producers rather than merely practitioners. Their insights, documented and analysed within an academic framework, enter the scholarly record and can influence future research and policy. The study thus contributes to a research literature that includes DHH educational voices and experiences.

5.6 Future Research Directions

The present study, while contributing to understanding of AR-based learning for DHH students in Malaysian art and design education, necessarily operates within defined boundaries that create opportunities for future research. This section identifies directions for subsequent investigation that would extend, deepen, or complement the findings reported here. These directions are organised according to methodological extensions, contextual expansions, and theoretical developments.

5.6.1 Methodological Extensions

The qualitative research design employed in this study was appropriate for exploring educator perceptions and expert recommendations regarding AR-based pedagogy. However, qualitative findings regarding the potential of AR-based learning require validation through outcome-focused research. Future studies should employ experimental or quasi-experimental designs to measure the actual learning outcomes achieved through AR-based instruction compared with traditional methods.

Such studies could utilise pre-test and post-test designs to assess knowledge acquisition, skill development, and retention among DHH students learning through AR-enhanced versus non-AR-enhanced instruction. The AR prototype developed in this study, or refined versions thereof, could serve as the intervention in such research. Dependent variables might include content knowledge assessment scores, practical skill demonstration, engagement duration, and learner satisfaction. Statistical comparison of outcomes between conditions would provide the quantitative evidence that complements the qualitative insights generated by the present study.

Longitudinal research designs would also extend the present study meaningfully. The preliminary student feedback collected through prototype testing represents a single point of contact with AR-based learning. Research tracking DHH students' engagement with AR resources over an extended period, such as a full academic semester or year, would reveal patterns of sustained use, skill development trajectories, and potential diminishing or amplifying effects. Such longitudinal investigation would address questions about whether the attention span benefits documented by educators persist over time or represent novelty effects that dissipate with familiarity.

The sample of this study included three educators from Malaysian special education secondary schools and two AR experts. Future research should expand sample sizes to enhance transferability of findings. A larger educator sample, potentially including all art and design teachers serving DHH students in Malaysian special education secondary schools, would reveal whether the patterns identified in this study generalise across the population. Similarly, expanding the AR expert sample to include developers with specific experience creating educational technology for DHH users would yield more targeted design recommendations.

Mixed methods designs combining the qualitative depth of the present study with quantitative breadth would offer comprehensive understanding. Survey instruments could assess educator perceptions of AR potential across a larger sample, while interviews with selected participants could explore the reasoning behind survey responses. Similarly, student outcome data could be supplemented with qualitative exploration of student experiences through interviews or focus groups conducted in Malaysian Sign Language with appropriate interpretation.

5.6.2 Contextual Expansions

Mixed The present study focused on art and design education within Malaysian special education secondary schools. Future research should explore whether findings generalise to other subject areas, educational levels, and national contexts.

Regarding subject areas, the six pedagogical strategies identified in this study may apply differently across curricular domains. Art and design education is inherently visual, making it a natural fit for Visual-First Design and related strategies. Research investigating AR-based learning in subjects with less inherently visual content, such as mathematics, science, or language arts, would reveal whether the strategies require modification for different learning objectives. The Pre-Vocational Simulation strategy may be particularly transferable, as vocational education across subject areas emphasises practical skill development that AR can support.

Regarding educational levels, this study focused on secondary education, specifically Form 3 students aged 15 to 17 years. Future research should investigate AR-based learning for younger DHH students in primary education and for older DHH students in post-secondary vocational training or higher education. Developmental differences in cognitive processing, technology familiarity, and learning objectives may necessitate different approaches to AR design and implementation across educational levels.

Regarding national contexts, this study is situated within the Malaysian educational system, including its specific curricular frameworks, institutional structures, and DHH community characteristics. While the theoretical frameworks and design principles may transfer internationally, future research should investigate AR-based learning for DHH students in other national contexts. Cross-national comparative research could identify universal principles applicable across contexts as well as context-specific factors requiring localised approaches. Such research would be particularly valuable in other Southeast Asian nations sharing regional characteristics with Malaysia while differing in specific educational policies and practices.

Future research should also expand investigation of the sign language integration strategy. This study documented that educators create custom signs to address vocabulary gaps in technical and artistic domains, yet the nature and extent of this practice remains underexplored. Linguistic research documenting the custom signs developed by Malaysian educators for art and design terminology would contribute to sign language development while informing AR applications that incorporate such terminology. Collaborative projects between educational researchers, sign language linguists, and AR developers could produce integrated resources combining visual learning content with standardised technical vocabulary in Malaysian Sign Language.

5.6.3 Theoretical Developments

The theoretical frameworks applied in this study, Social Constructivism and Visual Learning Theory, provided interpretive lenses for understanding AR-based learning among DHH students. Future research should extend and refine these theoretical applications while exploring additional frameworks.

The conceptualisation of AR as a "More Knowledgeable Other" within the Zone of Proximal Development requires further theoretical development. Scavarelli et al. (2021) proposed this interpretation for immersive technologies generally, and the present study applied it to DHH learners specifically. However, questions remain about the conditions under which AR most effectively functions as an MKO. Future research should investigate whether certain types of AR interactions, such as interactive manipulation versus passive observation, more effectively scaffold learning. Research should also explore how AR-based scaffolding interacts with human scaffolding from educators, examining whether these function complementarily or whether one may substitute for the other under certain conditions.

The finding that visual learning advantages are conditional upon student interest opens a theoretical avenue connecting Visual Learning Theory with motivational frameworks. Future research should investigate the interaction between visual processing, motivation, and learning outcomes among DHH students. Self-determination theory, with its emphasis on autonomy, competence, and relatedness as motivational foundations, may provide a complementary framework for understanding why some DHH students engage deeply with visual learning while others do not. Gamification principles, recommended by E2 for AR design, can be theoretically grounded through such motivational frameworks.

The cognitive load implications of communication modality identified in this study warrant further theoretical investigation. The finding that text-heavy interfaces impose extraneous cognitive load for DHH learners extends cognitive load theory by identifying a modality-specific factor relevant to this population. Future research should empirically test hypotheses derived from this extension, such as whether reduced text dependency in AR interfaces correlates with reduced cognitive load and enhanced learning outcomes. Eye-tracking studies could reveal visual attention patterns that illuminate how DHH students process multimodal AR content.

Finally, the collaborative development strategy identified in this study connects to participatory design theory and disability studies frameworks emphasising "nothing about us without us" principles. Future research should investigate participatory AR development processes that involve DHH community members as co-designers rather than merely as testers or end users. Chaubey and Kuknor's (2024) call for partnership between researchers and DHH grassroots organisations provides a foundation for such research. Studies documenting the process and outcomes of genuinely participatory AR development would contribute to both AR design methodology and inclusive design theory.

5.7 Conclusion

This chapter has discussed the findings presented in Chapter 4, situating them within the broader context of AR-based education for DHH learners and drawing out their implications for theory, practice, and future research. The discussion has moved from summarising what was found, through interpreting what it means, to articulating what should be done in response. This concluding section synthesises the entire thesis, articulates its contributions, acknowledges its limitations, and offers final reflections on the research and its significance for DHH education in Malaysia.

5.7.1 Synthesis of the Study

This study set out to explore how Augmented Reality can be integrated into art and design education for Deaf and Hard of Hearing students in Malaysian special education secondary schools. The research was motivated by a gap in the literature: while AR has demonstrated educational benefits across various populations and subjects, its specific application to DHH learners in the Malaysian context remained largely unexplored. The study addressed this gap through three research objectives: exploring educator perceptions of AR potential, examining current teaching practices and the role of technology, and identifying pedagogical strategies for AR integration.

Chapter 1 established the research context, articulating the challenges faced by DHH students in Malaysian education and the potential of AR to address these challenges through visual, interactive learning experiences. The chapter identified the problem statement, research objectives, and significance of the study, positioning the research within the broader goal of enhancing educational equity for DHH learners.

Chapter 2 reviewed the literature across three domains: DHH education and learning characteristics, AR technology and its educational applications, and art and design education for DHH students. The review established the theoretical foundation through Social Constructivism and Visual Learning Theory, which together provided a framework for understanding how AR-based learning might support DHH students. The literature revealed that while DHH learners demonstrate strong visual-spatial processing capabilities, existing educational technology often fails to account for their specific communication and learning needs.

Chapter 3 detailed the qualitative research methodology employed, including the selection of three DHH educators and two AR experts as participants, the use of semi-structured interviews as the primary data collection method, and the application of thematic analysis to interpret the data. The chapter also described the development and preliminary testing of an AR prototype with 3 DHH students, which served both as a research instrument and a demonstration of viable AR-based learning.

Chapter 4 presented the findings organised around the three research objectives. Regarding educator perceptions, the findings revealed that educators view AR as offering significant potential through three-dimensional visualisation, vocabulary gap remediation, and enhanced student engagement. Regarding current practices, the findings documented technology-enhanced instruction that doubles student attention span, visual teaching methods as standard practice, and the creation of custom signs to address technical vocabulary limitations. Regarding pedagogical strategies, six approaches emerged from the synthesis of educator and expert perspectives: Visual-First Design, Reduced Text Dependency, Sign Language Integration, Mobile-Based Delivery, Collaborative Development, and Pre-Vocational Simulation.

Chapter 5, the present chapter, has discussed these findings in relation to the literature and theoretical framework, articulated implications for institutions, educators, and developers, identified contributions to the DHH community, and proposed directions for future research. The discussion has demonstrated that the findings align with and extend existing knowledge while offering context-specific insights relevant to Malaysian DHH education.

5.7.2 Contribution to Knowledge

This study makes several contributions to knowledge in the fields of educational technology, DHH education, and art and design pedagogy.

The primary empirical contribution is the identification of six pedagogical strategies for AR integration in DHH art and design education. These strategies emerged from systematic analysis of educator and expert perspectives and are grounded in the realities of Malaysian special education classrooms. While individual elements of these strategies appear in existing literature, their synthesis into a coherent framework specific to DHH learners in art and design education represents an original contribution. The strategies provide actionable guidance for educators, developers, and institutions seeking to implement AR-based learning for this population.

The theoretical contribution lies in the extension of Social Constructivism and Visual Learning Theory to account for AR-based DHH learning. The conceptualisation of AR as a technological "More Knowledgeable Other" capable of providing scaffolding within the Zone of Proximal Development offers a framework for understanding how interactive technology can support learning in ways analogous to human instruction. The identification of conditional visual advantage, whereby DHH students' visual processing strengths manifest primarily when interest and engagement are present, refines Visual Learning Theory by specifying boundary conditions for its application. These theoretical extensions provide conceptual tools for researchers and practitioners working in this domain.

The contextual contribution addresses the specific gap in knowledge regarding Malaysian DHH education. The documentation of current practices, including the technology-enhanced instruction that educators report as doubling attention span, the creation of custom signs for technical vocabulary, and the visual teaching methods employed in art and design classrooms, provides empirical description of an under-researched educational context. This documentation establishes a baseline from which future research and practice development can proceed.

The methodological contribution includes the development of an AR prototype that demonstrates viable approaches to technology-enhanced learning for DHH students. While the prototype served primarily as a research instrument, it also represents a functional resource that can inform future development efforts. The preliminary testing with 3 DHH students yielded feedback that both validated the prototype's approach and identified areas for enhancement, contributing to understanding of DHH student preferences regarding AR-based learning.

5.7.3 Limitations of the Study

This study, like all research, operates within limitations that bound the scope and generalisability of its findings.

The sample size represents a primary limitation. Three DHH educators and two AR experts, while providing rich qualitative data, cannot represent the full diversity of perspectives within these populations. The educators were drawn from Malaysian special education secondary schools offering art and design education, a specific institutional context that may differ from other educational settings. The findings should therefore be understood as exploratory rather than definitive, offering insights that require validation through larger-scale research.

The qualitative research design, while appropriate for the exploratory objectives of this study, does not provide evidence of causal relationships between AR-based instruction and learning outcomes. The educator perceptions and expert recommendations documented in this study represent informed professional judgment rather than measured effects. Future research employing experimental designs is necessary to establish whether AR-based learning produces the benefits that participants anticipate.

The focus on art and design education limits the transferability of findings to other subject areas. While the six pedagogical strategies may apply beyond art and design, their emergence from this specific curricular context means that adaptation may be necessary for different learning objectives and content domains. The visual nature of art and design makes it a natural fit for AR-based learning; subjects with less inherently visual content may require modified approaches.

The preliminary nature of student involvement represents a further limitation. While 3 DHH students tested the AR prototype and provided feedback, this testing occurred at a single point in time and did not involve extended use or learning outcome assessment. The student perspectives captured are, therefore, initial reactions rather than evaluations based on sustained engagement with AR-based learning.

Finally, the study is situated within the Malaysian educational context, including its specific curricular frameworks, institutional structures, and DHH community characteristics. While the theoretical frameworks and design principles may transfer to other national contexts, direct application without contextual adaptation should not be assumed.

5.7.4 Final Reflections

This research journey began with a recognition that DHH students in Malaysia deserve access to educational technology designed with their needs in mind. Too often, educational innovations are developed for hearing populations and subsequently adapted, sometimes inadequately, for DHH learners. This study sought to reverse that process by beginning with DHH students and educators, understanding their current practices and challenges, and identifying strategies for technology integration grounded in their expertise.

The findings affirm that AR-based learning holds genuine promise for DHH students in Malaysian art and design education. This promise derives not from the novelty of AR technology but from its alignment with how DHH students learn best: through visual, interactive, three-dimensional experiences that reduce dependence on text-based communication and enable exploration of concepts difficult to convey through traditional instructional methods. The educators who participated in this study recognised this alignment, and their insights, combined with the technical guidance of AR experts, yielded strategies that can guide meaningful implementation.

The six pedagogical strategies identified in this study, Visual-First Design, Reduced Text Dependency, Sign Language Integration, Mobile-Based Delivery, Collaborative Development, and Pre-Vocational Simulation, are not merely technical specifications. They represent a philosophy of DHH-centred design that prioritises accessibility, engagement, and practical relevance. Implementing these strategies requires not only technological investment but also commitment to the principle that DHH learners are experts on their own educational needs and must be involved as partners in the development of resources intended for their use.

The path forward requires collaboration across stakeholder groups. Educational institutions must provide the infrastructure and policy support necessary for AR integration. Educators must continue to innovate within their classrooms while sharing their expertise with technology developers. Developers must listen to educator and student voices, designing resources that reflect documented needs rather than assumed preferences. Researchers must continue to investigate the conditions under which AR-based learning is most effective, building the evidence base that can justify sustained investment.

This study represents one contribution to a larger effort to enhance educational opportunities for DHH students in Malaysia. The DHH community possesses strengths, resilience, and creativity that deserve to be supported by educational resources of the highest quality. AR technology, implemented thoughtfully and inclusively, can be one such resource. The findings of this study provide a foundation upon which educators, developers, and institutions can build, moving toward a future in which DHH students have access to learning experiences that honour their visual intelligence and support their aspirations.

REFERENCES

Adnan, A. H. M. (2020, September). From interactive teaching to immersive learning: Higher Education 4.0 via 360-degree videos and virtual reality in Malaysia. In IOP Conference Series: Materials Science and Engineering (Vol. 917, No. 1, p. 012023). IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/917/1/012023/meta

Agazu, B. G., Dejenu, A. K., & Debela, K. L. (2022). A Comparative Review of Qualitative Research: A Guide to Design and Implementation. Qualitative Report, 27(8). https://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=10520147&AN=158776112&h=mGraW6EeQ6B4edhU4vdmiICKgV%2BxdLQxtMbEDOSlVyddrbck5gEIxgY8rrHAAnVn1AU7oDQNUAoys9XUQX7uxw%3D%3D&crl=c

Ahmad, F. A. R. O. B. (2021). The effect of augmented reality in improving visual thinking in mathematics of 10th-grade students in Jordan. International Journal of Advanced Computer Science and Applications, 12(5). https://pdfs.semanticscholar.org/08fa/d9848bd2a3510a39ca257db584d1590e8646.pdf

Akram, H., Abdelrady, A. H., Al-Adwan, A. S., & Ramzan, M. (2022). Teachers' perceptions of technology integration in teaching-learning practices: A systematic review. Frontiers in psychology, 13, 920317. https://www.frontiersin.org/articles/10.3389/fpsyg.2022.920317/full

Albanie, S., Varol, G., Momeni, L., Afouras, T., Chung, J. S., Fox, N., & Zisserman, A. (2020). BSL-1K: Scaling up co-articulated sign language recognition using mouthing cues. In Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part XI 16 (pp. 35-53). Springer International Publishing. https://link.springer.com/chapter/10.1007/978-3-030-58621-8_3

Alharahsheh, H. H., & Pius, A. (2020). A review of key paradigms: Positivism VS interpretivism. Global Academic Journal of Humanities and Social Sciences, 2(3), 39-43. https://gajrc.com/media/articles/GAJHSS_23_39-43_VMGJbOK.pdf

Ali, M. (2023). Data Collection Procedures for Contemporary IS Research. In Information Systems Research: Foundations, Design and Theory (pp. 121-135). Cham: Springer International Publishing. https://link.springer.com/chapter/10.1007/978-3-031-25470-3_7

Alias, A., & Ramly, U. (2021). Co-teaching approaches: Hearing impaired students in mainstream class. Proceedings of SOCIOINT, 2021(8th). https://www.ocerints.org/socioint21_e-publication/papers/AlizaAlias.pdf

Alias, A., Harun, A., & Kamaruddin, N. (2023). Principles and elements of interactive multimedia teaching aids design for hearing-impaired students. Geografia-Malaysian Journal of Society and Space, 19(3), 149-170. http://journalarticle.ukm.my/22702/1/633092199181PB.pdf

Alias, A., Harun, A., & Kamaruddin, N. (2023). Principles and elements of interactive multimedia teaching aids design for hearing-impaired students. Geografia-Malaysian Journal of Society and Space, 19(3), 149-170. http://journalarticle.ukm.my/22702/1/633092199181PB.pdf

Alkhabra, Y. A., Ibrahem, U. M., & Alkhabra, S. A. (2023). Augmented reality technology in enhancing learning retention and critical thinking according to STEAM program. Humanities and Social Sciences Communications, 10(1), 1-10. https://www.nature.com/articles/s41599-023-01650-w

Almurashi, H., Bouaziz, R., Alharthi, W., Al-Sarem, M., Hadwan, M., & Kammoun, S. (2022). Augmented reality, serious games and picture exchange communication system for people with ASD: systematic literature review and future directions. Sensors, 22(3), 1250. https://www.mdpi.com/1424-8220/22/3/1250

Alpat, E. (2022). Augmented reality wayfinding: A systematic literature review. https://gcris.ieu.edu.tr/handle/20.500.14365/419

Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brünken, R. (2020). The use of augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses—Theoretical background and empirical results. British Journal of Educational Technology, 51(3), 611-628. https://bera-journals.onlinelibrary.wiley.com/doi/abs/10.1111/bjet.12900

Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. Applied Sciences, 10(16), 5660. https://www.mdpi.com/2076-3417/10/16/5660

Anggraeni, M. E., Maulania, I., & Sarinastiti, W. (2020, September). Interactive learning media for hearing-impaired children using Indonesian sign language (SIBI)—Simple sentence arrangement. In 2020 International Electronics Symposium (IES) (pp. 662-668). IEEE. https://ieeexplore.ieee.org/abstract/document/9231955/

Anggraeni, M. E., Maulania, I., & Sarinastiti, W. (2020, September). Interactive learning media for hearing-impaired children using Indonesian sign language (SIBI)—Simple sentence arrangement. In 2020 International Electronics Symposium (IES) (pp. 662-668). IEEE. https://ieeexplore.ieee.org/abstract/document/9231955/

Awwad, S., Idwan, S., & Gharaibeh, H. (2021). Real-time sign languages character recognition. International Journal of Computer Applications in Technology, 65(1), 36-44. https://www.inderscienceonline.com/doi/abs/10.1504/IJCAT.2021.113640

Baabdullah, A. M., Alsulaimani, A. A., Allamnakhrah, A., Alalwan, A. A., Dwivedi, Y. K., & Rana, N. P. (2022). Usage of augmented reality (AR) and development of e-learning outcomes: An empirical evaluation of students'e-learning experience. Computers & Education, 177, 104383. https://www.sciencedirect.com/science/article/pii/S0360131521002608

Baker, E., Bakar, J. A., & Zulkifli, A. (2020). A conceptual model of mobile augmented reality for hearing impaired museum visitors' engagement. https://www.learntechlib.org/p/218307/

Baker, H. A. E. Integration of Emerging Educational Technologies by Teachers of Students who are Deaf or Hard of Hearing in New Zealand. https://nova.newcastle.edu.au/vital/access/services/Download/uon:38702/ATTACHMENT01

Barak, M., & Green, G. (2021). Applying a social constructivist approach to an online course on ethics of research. Science and Engineering Ethics, 27(1), 8. https://link.springer.com/article/10.1007/s11948-021-00280-2

Bell, D., & Foiret, J. (2020). A rapid review of the effect of assistive technology on the educational performance of students with impaired hearing. Disability and Rehabilitation: Assistive Technology, 15(7), 838-843. https://www.tandfonline.com/doi/abs/10.1080/17483107.2020.1775317

Bian, J., & Ji, Y. (2021). Research on the teaching of visual communication design based on digital technology. Wireless Communications and Mobile Computing, 2021, 1-11. https://www.hindawi.com/journals/wcmc/2021/8304861/

Bibri, S. E., Krogstie, J., Kaboli, A., & Alahi, A. (2024). Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review. Environmental Science and Ecotechnology, 19, 100330. https://www.sciencedirect.com/science/article/pii/S2666498423000959

Bilbow, S. (2021, February). Developing multisensory augmented reality as a medium for computational artists. In Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction (pp. 1-7). https://dl.acm.org/doi/abs/10.1145/3430524.3443690

Bos, J. (2020). Research ethics for students in the social sciences (p. 287). Springer Nature. https://library.oapen.org/handle/20.500.12657/42569

Burns, M. (2023). Distance Education for Teacher Training: Modes, Models, and Methods. Education Development Center, Inc. https://eric.ed.gov/?id=ED629889

Buxton, J. (2023). Design for Accessible Collaborative Engagement: Making online synchronous collaborative learning more accessible for students with sensory impairments (Doctoral dissertation, The Open University). https://oro.open.ac.uk/91722/

Cabual, R. A. (2021). Learning styles and preferred learning modalities in the new normal. Open Access Library Journal, 8(4), 1-14. https://www.scirp.org/journal/paperinformation.aspx?paperid=108297

Camgoz, N. C., Koller, O., Hadfield, S., & Bowden, R. (2020). Sign language transformers: Joint end-to-end sign language recognition and translation. In Proceedings of the IEEE/CVF conference on computer vision and pattern recognition (pp. 10023-10033). http://openaccess.thecvf.com/content_CVPR_2020/html/Camgoz_Sign_Language_Transformers_Joint_End-to-End_Sign_Language_Recognition_and_Translation_CVPR_2020_paper.html

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., ... & Walker, K. (2020). Purposive sampling: complex or simple? Research case examples. Journal of research in Nursing, 25(8), 652-661. https://journals.sagepub.com/doi/abs/10.1177/1744987120927206

Cao, J., Peng, X., Liang, F., & Tong, X. (2024). " Voices Help Correlate Signs and Words": Analyzing Deaf and Hard-of-Hearing (DHH) TikTokers' Content, Practices, and Pitfalls. https://www.jiaxuncao.com/s/chi24-dhhtiktok.pdf

Cardano, M. (2020). Defending qualitative research: Design, analysis, and textualization. Routledge. https://www.taylorfrancis.com/books/mono/10.4324/9780429464232/defending-qualitative-research-mario-cardano

Cash, P., Isaksson, O., Maier, A., & Summers, J. (2022). Sampling in design research: Eight key considerations. Design studies, 78, 101077. https://www.sciencedirect.com/science/article/pii/S0142694X21000880

Chaubey, A., & Kuknor, S. (2024). The saga of struggling diversity in the 21st century: a qualitative study. Journal of Asia Business Studies. https://www.emerald.com/insight/content/doi/10.1108/JABS-10-2023-0406/full/html

Chen, C. H., Yang, C. K., Huang, K., & Yao, K. C. (2020). Augmented reality and competition in robotics education: Effects on 21st century competencies, group collaboration and learning motivation. Journal of Computer Assisted Learning, 36(6), 1052-1062. https://onlinelibrary.wiley.com/doi/abs/10.1111/jcal.12469

Cheng, L., Wang, M., Chen, Y., Niu, W., Hong, M., & Zhu, Y. (2022). Design my music instrument: A project-based science, technology, engineering, arts, and mathematics program on the development of creativity. Frontiers in Psychology, 12, 763948. https://www.frontiersin.org/articles/10.3389/fpsyg.2021.763948/full

Christopoulos, A., Mystakidis, S., Pellas, N., & Laakso, M. J. (2021). ARLEAN: An augmented reality learning analytics ethical framework. Computers, 10(8), 92. https://www.mdpi.com/2073-431X/10/8/92

Cilliers, L., & Viljoen, K. (2021). A framework of ethical issues to consider when conducting internet-based research. South African Journal of Information Management, 23(1), 1-9. http://www.scielo.org.za/scielo.php?pid=S1560-683X2021000100004&script=sci_arttext

Creed, C., Al-Kalbani, M., Theil, A., Sarcar, S., & Williams, I. (2024). Inclusive AR/VR: accessibility barriers for immersive technologies. Universal Access in the Information Society, 23(1), 59-73. https://link.springer.com/article/10.1007/s10209-023-00969-0

Curry, D. S. (2020). Interpretivism and norms. Philosophical studies, 177(4), 905-930. https://link.springer.com/article/10.1007/s11098-018-1212-6

Dengel, A., Iqbal, M. Z., Grafe, S., & Mangina, E. (2022). A review on augmented reality authoring toolkits for education. Frontiers in Virtual Reality, 3, 798032. https://www.frontiersin.org/articles/10.3389/frvir.2022.798032/full

Dibben, P., & Wood, G. (2024). 10. Institutional theory. A Guide to Key Theories for Human Resource Management Research, 107. https://books.google.com/books?hl=en&lr=&id=Ow7wEAAAQBAJ&oi=fnd&pg=PA107&ots=WK1R48izHn&sig=OL6VidowqJfgDmpa1EhSceH91A8

Dim, C. A., Feitosa, R. M., Mota, M. P., & de Morais, J. M. (2022). Alert systems to hearing-impaired people: a systematic review. Multimedia Tools and Applications, 81(22), 32351-32370. https://link.springer.com/article/10.1007/s11042-022-13045-1

Dmitrichenkova, S. V., Dolzhich, E. A., V Dmitrichenkova, S., & A Dolzhich, E. (2020). Learning styles and teaching methods. European proceedings of social and behavioural sciences, 97. https://www.europeanproceedings.com/article/10.15405/epsbs.2020.12.02.6

Donally, J. (2022). The immersive classroom: Create customized learning experiences with AR/VR. International Society for Technology in Education. https://books.google.com/books?hl=en&lr=&id=fvWBEAAAQBAJ&oi=fnd&pg=PP1&dq=AR+technologies+provide+educators+with+a+platform+to+offer+tailored+learning+experiences+that+are+suited+to+every+student%27s+requirements+and+desires.&ots=95J7WgkbJg&sig=bzY-kyj72CV301vgf7NiUUKcHeQ

Efgivia, M. G., Rinanda, R. A., Hidayat, A., Maulana, I., & Budiarjo, A. (2021, October). Analysis of constructivism learning theory. In 1st UMGESHIC International Seminar on Health, Social Science and Humanities (UMGESHIC-ISHSSH 2020) (pp. 208-212). Atlantis Press. https://www.atlantis-press.com/proceedings/umgeshic-ishssh-20/125961875

Egusa, R., Komiya, N., Kusunoki, F., Mizoguchi, H., Namatame, M., & Inagaki, S. (2020). Development of a learning-support system for science using collaboration and body movement for hearing-impaired children: Learning support for plant germination and growth conditions. In Computers Helping People with Special Needs: 17th International Conference, ICCHP 2020, Lecco, Italy, September 9–11, 2020, Proceedings, Part II 17 (pp. 157-165). Springer International Publishing. https://link.springer.com/chapter/10.1007/978-3-030-58805-2_19

Elliott, S. J. (2020). Experiences of teachers of the deaf using project-based learning to build higher order thinking skills (Doctoral dissertation, Walden University). https://search.proquest.com/openview/dcedf357fb8fc87f4803ef794df50628/1?pq-origsite=gscholar&cbl=18750&diss=y

Fan, M., Antle, A. N., & Warren, J. L. (2020). Augmented reality for early language learning: A systematic review of augmented reality application design, instructional strategies, and evaluation outcomes. Journal of Educational Computing Research, 58(6), 1059-1100. https://journals.sagepub.com/doi/abs/10.1177/0735633120927489

Farhan, W., & Razmak, J. (2022). A comparative study of an assistive e-learning interface among students with and without visual and hearing impairments. Disability and Rehabilitation: Assistive Technology, 17(4), 431-441. https://www.tandfonline.com/doi/abs/10.1080/17483107.2020.1786733

Farquhar, J., Michels, N., & Robson, J. (2020). Triangulation in industrial qualitative case study research: Widening the scope. Industrial Marketing Management, 87, 160-170. https://www.sciencedirect.com/science/article/pii/S0019850118306916

Feng, S., He, W., Zhang, X., Billinghurst, M., & Wang, S. (2023). A comprehensive survey on AR-enabled local collaboration. Virtual Reality, 27(4), 2941-2966. https://link.springer.com/article/10.1007/s10055-023-00848-2

Fernandes, N., Leite Junior, A. J. M., Marçal, E., & Viana, W. (2023). Augmented reality in education for people who are deaf or hard of hearing: a systematic literature review. Universal Access in the Information Society, 1-20. https://link.springer.com/article/10.1007/s10209-023-00994-z Rodrigues, F. M., Abreu, A. M., Holmström, I., & Mineiro, A. (2022). E-learning is a burden for the deaf and hard of hearing. Scientific Reports, 12(1), 9346. https://www.nature.com/articles/s41598-022-13542-1

Fernandes, N., Leite Junior, A. J. M., Marçal, E., & Viana, W. (2023). Augmented reality in education for people who are deaf or hard of hearing: a systematic literature review. Universal Access in the Information Society, 1-20. https://link.springer.com/article/10.1007/s10209-023-00994-z

Fernández Batanero, J. M., Rueda Montenegro, M., Cerero Fernández, J., & García Alonso, S. (2022). Challenges and trends in the use of technology by hearing impaired students in higher education. Technology and Disability, 34(2), 101-111. https://content.iospress.com/articles/technology-and-disability/tad220372

Fernández-Gavira, J., Espada-Goya, P., Alcaraz-Rodríguez, V., & Moscoso-Sánchez, D. (2021). Design of educational tools based on traditional games for the improvement of social and personal skills of primary school students with hearing impairment. Sustainability, 13(22), 12644. https://www.mdpi.com/2071-1050/13/22/12644

Fossen, F. M., & Sorgner, A. (2022). New digital technologies and heterogeneous wage and employment dynamics in the United States: Evidence from individual-level data. Technological Forecasting and Social Change, 175, 121381. https://www.sciencedirect.com/science/article/pii/S004016252100812X

Gray, L. E., & Dunn, S. D. (Eds.). (2024). Incorporating the Human Element in Online Teaching and Learning. IGI Global. https://books.google.com/books?hl=en&lr=&id=gRn-EAAAQBAJ&oi=fnd&pg=PR1&dq=Interactive+storybooks+and+learning+games+are+all+about+merging+the+best+of+traditional+storytelling+with+the+latest+AR+technologies,+resulting+in+high-engagement+and+cool+learning+for+deaf+students.+&ots=a3Wy4SLdEB&sig=2T1Lhc6_ZBkrbEeHxZcOMRIomrQ

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. Sustainable Operations and Computers, 3, 275-285. https://www.sciencedirect.com/science/article/pii/S2666412722000137

Henni, S. H., Maurud, S., Fuglerud, K. S., & Moen, A. (2022). The experiences, needs and barriers of people with impairments related to usability and accessibility of digital health solutions, levels of involvement in the design process and strategies for partic

Hernandez-de-Menendez, M., Escobar Díaz, C., & Morales-Menendez, R. (2020). Technologies for the future of learning: state of the art. International Journal on

Interactive Design and Manufacturing (IJIDeM), 14(2), 683-695. https://link.springer.com/article/10.1007/s12008-019-00640-0

Herrera, S. I., Manresa-Yee, C., & Sanz, C. V. (2023). Mobile learning for hearing-impaired children: Review and analysis. Universal Access in the Information Society, 22(2), 635-653. https://link.springer.com/article/10.1007/s10209-021-00841-z

Herrera, Susana I., Cristina Manresa-Yee, and Cecilia V. Sanz. "Mobile learning for hearing-impaired children: Review and analysis." Universal Access in the Information Society 22.2 (2023): 635-653. https://link.springer.com/article/10.1007/s10209-021-00841-z

Heyko, D. Y. (2021). Supporting d/Deaf and Hard of Hearing Employees in Their Workplaces Through Technology, Design, and Community (Doctoral dissertation, University of Guelph). https://atrium.lib.uoguelph.ca/handle/10214/25700

Hofmann, M., Kasnitz, D., Mankoff, J., & Bennett, C. L. (2020, October). Living disability theory: Reflections on access, research, and design. In Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility (pp. 1-13). https://dl.acm.org/doi/abs/10.1145/3373625.3416996

Huang, X., Zou, D., Cheng, G., & Xie, H. (2021). A systematic review of AR and VR enhanced language learning. Sustainability, 13(9), 4639. https://www.mdpi.com/2071-1050/13/9/4639

Huo, J., Keung, K. L., Lee, C. K., & Ng, H. Y. (2021, December). Hand gesture recognition with augmented reality and leap motion controller. In 2021 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) (pp. 1015-1019). IEEE. https://ieeexplore.ieee.org/abstract/document/9672611/

Ibrahim, Z. (2021). Development of a Graphic Design Learning Module for the Deaf and Hard-of-Hearing (DHH) Students Based on Technology and Learning Style in Malaysian TVET institutions. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(5), 1923-1933. https://www.turcomat.org/index.php/turkbilmat/article/view/2273

ipatory and universal design: a scoping review. BMC public health, 22(1), 35. https://link.springer.com/article/10.1186/s12889-021-12393-1

Irimiás, A. R., Mitev, A. Z., & Volo, S. (2022). Digital arts-based collaborative learning in management education. The International Journal of Management Education, 20(3), 100727. https://www.sciencedirect.com/science/article/pii/S147281172200129X

Jacob, S. A., Chong, E. Y. C., Goh, S. L., & Palanisamy, U. D. (2021). Design suggestions for an mHealth app to facilitate communication between pharmacists and the Deaf: perspective of the Deaf community (HEARD Project). Mhealth, 7. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8063016/

Jesionkowska, J., Wild, F., & Deval, Y. (2020). Active learning augmented reality for STEAM education—A case study. Education Sciences, 10(8), 198. https://www.mdpi.com/2227-7102/10/8/198

Jian, Z., Liu, W., Lijuan, S., Zhejun, K., & Di, Z. (2020). An accessibility learning system for higher integrated education of hearing-impaired students technology. International Journal of Computer Applications in Technology, 64(3), 297-307. https://www.inderscienceonline.com/doi/abs/10.1504/IJCAT.2020.111841

Kang, L., & Jackson, S. (2021). Tech-art-theory: Improvisational methods for hci learning and teaching. Proceedings of the ACM on Human-Computer Interaction, 5(CSCW1), 1-25. https://dl.acm.org/doi/abs/10.1145/3449156

Kapetanaki, A., Krouska, A., Troussas, C., & Sgouropoulou, C. (2021). A novel framework incorporating augmented reality and pedagogy for improving reading comprehension in special education. In Novelties in Intelligent Digital Systems (pp. 105-110). IOS Press. https://books.google.com/books?hl=en&lr=&id=I4xJEAAAQBAJ&oi=fnd&pg=PA105&dq=In+addition,+AR+technology+improves+comprehension+and+retention+owing+to+the+provision+of+multisensory+learning+environments&ots=V729Fuvofo&sig=DsDVDWTha_f7--SbdzYnZk2h6rE

Kerr, J., & Lawson, G. (2020). Augmented reality in design education: Landscape architecture studies as AR experience. International Journal of Art & Design Education, 39(1), 6-21. https://onlinelibrary.wiley.com/doi/abs/10.1111/jade.12227

Khushk, A., Dacholfany, M. I., Abdurohim, D., & Aman, N. (2023). Social learning theory in clinical setting: Connectivism, constructivism, and role modeling approach. Health Economics and Management Review, 3, 40-50. http://repository.unpas.ac.id/64281/

Kiger, M. E., & Varpio, L. (2020). Thematic analysis of qualitative data: AMEE Guide No. 131. Medical teacher, 42(8), 846-854. https://www.tandfonline.com/doi/abs/10.1080/0142159X.2020.1755030

Kimmerly, W. (2023). Enterprise Transformation to Artificial Intelligence and the Metaverse: Strategies for the Technology Revolution. Walter de Gruyter GmbH & Co KG. https://books.google.com/books?hl=en&lr=&id=zjz3EAAAQBAJ&oi=fnd&pg=PP1&dq=But+the+advent+of+AR+technology+has+ushered+in+a+breakthrough+in+content+creation+that+is+supremely+immersive+and+user-friendly+even+without+sound&ots=8dmksKVIQO&sig=eX6EScM1zLQn3Gq9CbpwpgMiRSg

Koenig, J. A. (2021). Augmented Reality's Effect on Learning Motivation (Doctoral dissertation, Grand Canyon University). https://search.proquest.com/openview/da7aa7270bcde3bd5594c73937009af5/1?pq-origsite=gscholar&cbl=18750&diss=y

Köse, H., & Güner-Yildiz, N. (2021). Augmented reality (AR) as a learning material in special needs education. Education and Information Technologies, 26(2), 1921-1936. https://link.springer.com/article/10.1007/s10639-020-10326-w

Krasavina, Y., Ponomarenko, E., Zhuykova, O., & Serebryakova, Y. (2022). Designing E-Courses for Hearing Impaired Students: Practices and Challenges. ARPHA Proceedings, 5, 951-964. https://ap.pensoft.net/article/24339/download/pdf/

Krasavina, Y., Ponomarenko, E., Zhuykova, O., & Serebryakova, Y. (2022). Designing E-Courses for Hearing Impaired Students: Practices and Challenges. ARPHA Proceedings, 5, 951-964. https://ap.pensoft.net/article/24339/download/pdf/

Krek, J., & Hodnik, T. (2023). Transmission of knowledge in constructivism and the teacher's teaching role. INITIAL TEACHER EDUCATION, 200. https://www.researchgate.net/profile/Fjolla-Kacaniku/publication/376807778_Innovative_practices_and_quality_assurance_in_initial_teacher_education/links/658989f22468df72d3d8267f/Innovative-practices-and-quality-assurance-in-initial-teacher-education.pdf#page=200

Kumar, A. (2023). Augmented Reality as a Boon to Disability. In Smart Distributed Embedded Systems for Healthcare Applications (pp. 77-92). CRC Press. https://www.taylorfrancis.com/chapters/edit/10.1201/9781003254119-6/augmented-reality-boon-disability-ashish-kumar-raja-muhammad-fazal-ljaz

Kushalnagar, R. S., & Vogler, C. (2020, October). Teleconference accessibility and guidelines for deaf and hard of hearing users. In Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility (pp. 1-6). https://dl.acm.org/doi/abs/10.1145/3373625.3417299

Laciok, V., Bernatik, A., & Lesnak, M. (2020). Experimental implementation of new technology into the area of teaching occupational safety for Industry 4.0. Int. J. Saf. Secur. Eng, 10(3), 403-407. https://vubp.cz/soubory/vyzkum/projekty/TL01000470/experimental-implementation-of-new-technology-into-the-area-of-teaching-occupational-safety-for-industry-40.pdf

Latsyshyn, A. V., Kovach, V. O., Lyubchak, V. O., Zuban, Y. O., Piven, A. G., Sokolyuk, O. M., ... & Shyshkina, M. P. (2020). Application of augmented reality technologies for education projects preparation. https://elibrary.kdpu.edu.ua/handle/123456789/3856

Lin, C. Y., & Huang, C. K. (2020). Understanding the antecedents of knowledge sharing behaviour and its relationship to team effectiveness and individual learning. Australasian Journal of Educational Technology, 36(2), 89-104. https://ajet.org.au/index.php/AJET/article/view/4549

Lochmiller, C. R. (2021). Conducting thematic analysis with qualitative data. The Qualitative Report, 26(6), 2029-2044. https://pdfs.semanticscholar.org/271f/61ca8c699d5f41436fd70b8da1bd321a0ad9.pdf

Lv, Z., Poiesi, F., Dong, Q., Lloret, J., & Song, H. (2022). Deep learning for intelligent human–computer interaction. Applied Sciences, 12(22), 11457. https://www.mdpi.com/2076-3417/12/22/11457

Maas, M. J., & Hughes, J. M. (2020). Virtual, augmented and mixed reality in K–12 education: A review of the literature. Technology, Pedagogy and Education, 29(2), 231-249. https://www.tandfonline.com/doi/abs/10.1080/1475939X.2020.1737210

Mahajan, S., Walker, Z., Boll, R., Santacreu, M., Salvino, A., Westfort, M., ... & Solovey, E. (2022, April). Towards sign language-centric design of ASL survey tools. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (pp. 1-16). https://dl.acm.org/doi/abs/10.1145/3491102.3502047

Majid, S. N. A., & Salam, A. R. (2021). A systematic review of augmented reality applications in language learning. International Journal of Emerging Technologies in Learning, 16(10). http://eprints.utm.my/94239/1/SitiNorzaimalinaMajid2021_ASystematicReviewofAugmentedReality.pdf

Majoro, N. E. (2021). Challenges of using sign language interpreting to facilitate teaching and learning for learners with hearing impairment (Doctoral dissertation, National University of Lesotho). https://repository.tml.nul.ls/handle/20.500.14155/1619

Marchetti, C. E., Foster, S. B., Schley, S., Bailey, M. B., & Kavin, D. (2024). Pathways of Women Who Are Deaf and Hard-of-Hearing to Faculty Careers in Higher Education. ADVANCE Journal, 4(2). https://www.advancejournal.org/article/90117.pdf

Martin, F., & Borup, J. (2022). Online learner engagement: Conceptual definitions, research themes, and supportive practices. Educational Psychologist, 57(3), 162-177. https://www.tandfonline.com/doi/abs/10.1080/00461520.2022.2089147

May-Varas, S., Margolis, J., & Mead, T. (2023). Theory of Multiple Intelligences. Educational Learning Theories. https://openoregon.pressbooks.pub/educationallearningtheories3rd/chapter/chapter-9-theory-of-multiple-intelligences-2/

Mirzaei, M., Kan, P., & Kaufmann, H. (2020). EarVR: Using ear haptics in virtual reality for deaf and Hard-of-Hearing people. IEEE transactions on visualization and computer graphics, 26(5), 2084-2093. https://ieeexplore.ieee.org/abstract/document/8998298/

Moeller, M. P., Szarkowski, A., Gale, E., Smith, T., Birdsey, B. C., Moodie, S. T., ... & Holzinger, D. (2024). Family-centered early intervention deaf/hard of hearing (FCEI-DHH): Guiding Values. Journal of Deaf Studies and Deaf Education, 29(SI), SI8-SI26. https://academic.oup.com/jdsde/article/29/S1/SI8/7616228

Monroe, J. G., Srikant, T., Carbonell-Bejerano, P., Becker, C., Lensink, M., Exposito-Alonso, M., ... & Weigel, D. (2022). Mutation bias reflects natural selection in Arabidopsis thaliana. Nature, 602(7895), 101-105. https://www.nature.com/articles/s41586-021-04269-6

Montagud, M., Orero, P., & Matamala, A. (2020). Culture 4 all: accessibility-enabled cultural experiences through immersive VR360 content. Personal and Ubiquitous Computing, 24(6), 887-905. https://link.springer.com/article/10.1007/s00779-019-01357-3

Muzari, T., Shava, G. N., & Shonhiwa, S. (2022). Qualitative research paradigm, a key research design for educational researchers, processes and procedures: A theoretical overview. Indiana Journal of Humanities and Social Sciences, 3(1), 14-20. https://indianapublications.com/articles/IJHSS_3(1)_14-20_61f38990115064.95135470.pdf

Mystakidis, S., Christopoulos, A., & Pellas, N. (2022). A systematic mapping review of augmented reality applications to support STEM learning in higher education. Education and Information Technologies, 27(2), 1883-1927. https://link.springer.com/article/10.1007/s10639-021-10682-1

Nasir, N. A. M., Hashim, H., Rashid, S. M. M., & Yunus, M. M. (2021). Exploring the Potential Usage of Mobile Technologies Among the Hearing-Impaired Students in Learning English as a Second Language (ESL). Int. J. Interact. Mob. Technol., 15(19), 48. https://www.academia.edu/download/72969799/10037.pdf

Nassereddine, H., Veeramani, D., & Hanna, A. S. (2022). Design, development, and validation of an augmented reality-enabled production strategy process. Frontiers in Built Environment, 8, 730098. https://www.frontiersin.org/articles/10.3389/fbuil.2022.730098/full

Natow, R. S. (2020). The use of triangulation in qualitative studies employing elite interviews. Qualitative research, 20(2), 160-173. https://journals.sagepub.com/doi/abs/10.1177/1468794119830077

Nebytova, L. A., Katrenko, M. V., Savin, D. I., & Zhuravleva, Y. I. (2021). Augmented reality in the training process of children with hearing disorders. In CEUR Workshop Proceedings (Vol. 2834, pp. 330-339). https://ceur-ws.org/Vol-2834/Paper28.pdf

Njai, S. N. (2021). Constructivist Pedagogical Approaches in Higher Education: A Qualitative Case Study of Students and their Learning Experiences in a Collaborative Learning Space. Ohio University. https://search.proquest.com/openview/6c6e586c78b9cfe1e2a7901e152b2a57/1?pq-origsite=gscholar&cbl=18750&diss=y

Nkosi, N. H. (2022). Communication experiences in learning environments of learners with hearing impairments (Doctoral dissertation, University of Johannesburg). https://ujcontent.uj.ac.za/esploro/outputs/graduate/Communication-experiences-in-learning-environments-of/9928109907691

Obilor, E. I. (2023). Convenience and purposive sampling techniques: Are they the same. International Journal of Innovative Social & Science Education Research, 11(1), 1-7. https://seahipaj.org/journals-ci/mar-2023/IJISSER/full/IJISSER-M-1-2023.pdf

O'Connor, A., Tai, A., Brinn, M., Hoang, A. N. T. H., Cataldi, D., & Carson-Chahhoud, K. (2023). The acceptability of using augmented reality as a mechanism to engage children in asthma inhaler technique training: qualitative interview study with deductive thematic analysis. JMIR Pediatrics and Parenting, 6, e40231. https://pediatrics.jmir.org/2023/1/e40231

Olwal, A., Balke, K., Votintcev, D., Starner, T., Conn, P., Chinh, B., & Corda, B. (2020, October). Wearable subtitles: Augmenting spoken communication with lightweight eyewear for all-day captioning. In Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology (pp. 1108-1120). https://dl.acm.org/doi/abs/10.1145/3379337.3415817

Paatsch, L., & Toe, D. (2020). The impact of pragmatic delays for deaf and hard of hearing students in mainstream classrooms. Pediatrics, 146(Supplement_3), S292-S297. https://publications.aap.org/pediatrics/article-abstract/146/Supplement_3/S292/34552

Panciroli, C., Fabbri, M., Luigini, A., Macauda, A., Corazza, L., & Russo, V. (2023). Augmented Reality in Arts Education. In Springer Handbook of Augmented Reality (pp. 305-333). Cham: Springer International Publishing. https://link.springer.com/chapter/10.1007/978-3-030-67822-7_12

Papastratis, I., Chatzikonstantinou, C., Konstantinidis, D., Dimitropoulos, K., & Daras, P. (2021). Artificial intelligence technologies for sign language. Sensors, 21(17), 5843. https://www.mdpi.com/1424-8220/21/17/5843

Pearce, J. M. (2020). Economic savings for scientific free and open source technology: A review. HardwareX, 8, e00139. https://www.sciencedirect.com/science/article/pii/S2468067220300481

Pellegrino, J. W., & Glaser, R. (2021). Components of inductive reasoning. In Aptitude, learning, and instruction (pp. 177-218). Routledge.

https://www.taylorfrancis.com/chapters/edit/10.4324/9781003162865-8/components-inductive-reasoning-james-pellegrino-robert-glaser

Perich, D. M. (2023). Integrating Technology with Art History for Middle School Art Education (Doctoral dissertation, The University of the Arts). https://search.proquest.com/openview/2a3acafc6d3cb328182480aa6c1f3695/1?pq-origsite=gscholar&cbl=18750&diss=y

Polvanov, J. N. (2023). EFFECTIVE METHODS OF TEACHING HEARING IMPAIRED CHILDREN. American Journal Of Social Sciences And Humanity Research, 3(05), 123-134. http://theusajournals.com/index.php/ajsshr/article/view/1299

Pontes, H. P., Duarte, J. B. F., & Pinheiro, P. R. (2020). An educational game to teach numbers in Brazilian Sign Language while having fun. Computers in Human Behavior, 107, 105825. https://www.sciencedirect.com/science/article/pii/S0747563218305892

Pradhan, P. (2020). Effective use of assistive technology for better quality of education of students with hearing impairment. Journal of Emerging Technologies and Innovative Research, 7(3), 1688-1693. https://www.academia.edu/download/80585103/JETIR2003242.pdf

Proskura, S. L., & Lytvynova, S. H. (2020). The approaches to Web-based education of computer science bachelors in higher education institutions. https://elibrary.kdpu.edu.ua/handle/123456789/3892

Psyrra, G., Mangina, E., & Treacy, R. (2023). Case Study of AR Digital Literacy Intervention for Students Diagnosed with ADHD. In Mixed Reality for Education (pp. 291-313). Singapore: Springer Nature Singapore. https://link.springer.com/chapter/10.1007/978-981-99-4958-8_13

Qin, Y. (2021). Attractiveness of game elements, presence, and enjoyment of mobile augmented reality games: The case of Pokémon Go. Telematics and Informatics, 62, 101620. https://www.sciencedirect.com/science/article/pii/S0736585321000599

Rahayu, N. D., & Yatri, I. (2021, February). Animated video media based on adobe after effects (AEF) application: an empirical study for elementary school students. In Journal of Physics: Conference Series (Vol. 1783, No. 1, p. 012116). IOP Publishing. https://iopscience.iop.org/article/10.1088/1742-6596/1783/1/012116/meta

Reeves, L. E., Bolton, E., Bulpitt, M., Scott, A., Tomey, I., Gates, M., & Baldock, R. A. (2021). Use of augmented reality (AR) to aid bioscience education and enrich student experience. Research in Learning Technology, 29, 2572. https://eprints.glos.ac.uk/9775/2/9775-Baldock-(2021)-Use-of-augmented-reality-(AR)-to-aid-bioscience-education.pdf

Reid-Martinez, K., & Grooms, L. D. (2021). Constructivism in 21st century online learning. In Handbook of research on modern educational technologies, applications, and management (pp. 730-743). IGI Global. https://www.igi-global.com/chapter/constructivism-in-21st-century-online-learning/258807

Remolar, I., Rebollo, C., & Fernández-Moyano, J. A. (2021). Learning history using virtual and augmented reality. Computers, 10(11), 146. https://www.mdpi.com/2073-431X/10/11/146

Renken, M., Scott, J., Enderle, P., & Cohen, S. (2021). "It's not a deaf thing, it's not a black thing; it'sa deaf black thing": a study of the intersection of adolescents' deaf, race, and STEM identities. Cultural Studies of Science Education, 16(4), 1105-1136. https://link.springer.com/article/10.1007/s11422-021-10023-1

Resing, W. C. M. (2020). Measuring inductive reasoning skills: The construction of a learning potential test. In Learning potential assessment (pp. 219-242). Taylor & Francis. https://www.taylorfrancis.com/chapters/edit/10.1201/9781003077398-15/measuring-inductive-reasoning-skills-construction-learning-potential-test-resing

Ridha, A. M., & Shehieb, W. (2021, September). Assistive technology for hearing-impaired and deaf students utilizing augmented reality. In 2021 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE) (pp. 1-5). IEEE. https://ieeexplore.ieee.org/abstract/document/9569193/

Rini, D. S., Adisyahputra, D. V. S., & Sigit, D. V. (2020). Boosting student critical thinking ability through project based learning, motivation and visual, auditory, kinesthetic learning style: A study on Ecosystem Topic. Universal Journal of Educational Research, 8(4), 37-44. https://www.academia.edu/download/64253792/UJER6-19591319.pdf

Rogers, R. E. (2022). Use of Elements from the Visual Communication and Sign Language Checklist to Supplement Language Sampling Analysis in Assessing the Language Abilities of Children Who Use Signed and Spoken

Communication. Idaho State University. https://search.proquest.com/openview/bed921301188047763e2eb5d829eadd4/1?pq-origsite=gscholar&cbl=18750&diss=y

Rossi, V. (2023). Inclusive Learning Design in Higher Education: A practical guide to creating equitable learning experiences. Taylor & Francis. https://books.google.com/books?hl=en&lr=&id=Enu2EAAAQBAJ&oi=fnd&pg=PT7&dq=Designing+a+nurturing+and+equitable+educational+environment+where+individual+efforts+and+experiences+are+recognized+can+build+a+feeling+of+home+in+hearing+impaired+students&ots=6m47Q7TdiH&sig=dsnm4N-zRXVctYR7PdPBdrCRzoA

Rusli, M. S., & Ibrahim, Z. (2022). Augmented Reality (AR) for Deaf and Hard of Hearing (DHH) for animation. e-Academia Journal, 11(2), 175-186. https://ir.uitm.edu.my/id/eprint/88957/

Saad, S., Jamberi, H., Musta'amal, A. H., Saud, S., Osman, S., & Hamzah, F. (2023). Factors Affecting the Level of Achieving Employability 4.0 of Hearing-Impaired Special Education Students. Journal of Technical Education and Training, 15(1), 215-233. https://penerbit.uthm.edu.my/ojs/index.php/JTET/article/view/13506

Sayler, M. F. (2021). Special schools for the gifted and talented. In The handbook of secondary gifted education (pp. 443-463). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781003238829-21/special-schools-gifted-talented-michael-sayler

Scavarelli, A., Arya, A., & Teather, R. J. (2021). Virtual reality and augmented reality in social learning spaces: a literature review. Virtual Reality, 25(1), 257-277. https://link.springer.com/article/10.1007/s10055-020-00444-8

Shapiro, S. B., Noij, K. S., Naples, J. G., & Samy, R. N. (2021). Hearing loss and tinnitus. Medical Clinics, 105(5), 799-811. https://www.medical.theclinics.com/article/S0025-7125(21)00071-7/abstract

Shovkovyi, Y., Grynyova, O., Udovenko, S., & Chala, L. (2023). Automatic sign language translation system using neural network technologies and 3d animation. Innovative Technologies and Scientific Solutions for Industries, (4 (26)), 108-121. https://journals.uran.ua/itssi/article/view/294939

Shwartz Ziv, R., & LeCun, Y. (2024). To Compress or Not to Compress—Self-Supervised Learning and Information Theory: A Review. Entropy, 26(3), 252. https://www.mdpi.com/1099-4300/26/3/252

Silva, R., Farias, C., & Mesquita, I. (2021). Cooperative learning contribution to student social learning and active role in the class. Sustainability, 13(15), 8644. https://www.mdpi.com/2071-1050/13/15/8644

Singh, P., Sharma, M., & Daim, T. (2024). Envisaging AR travel revolution for visiting heritage sites: A mixed-method approach. Technology in Society, 76, 102439. https://www.sciencedirect.com/science/article/pii/S0160791X23002440

Smith, C., & Allman, T. (2020). Diversity in deafness: Assessing students who are deaf or hard of hearing. Psychology in the Schools, 57(3), 362-374 https://onlinelibrary.wiley.com/doi/abs/10.1002/pits.22310

Stefánsdóttir, H., Crowe, K., Magnússon, E., Guiberson, M., Másdóttir, T., Ágústsdóttir, I., & Baldursdóttir, Ö. V. (2024). Measuring speech intelligibility with deaf and hard-of-hearing children: A systematic review. Journal of Deaf Studies and Deaf Education, 29(2), 265-277. https://academic.oup.com/jdsde/article-abstract/29/2/265/7469342

Stephens, J., & Yenika-Agbaw, V. (Eds.). (2022). Children, Deafness, and Deaf Cultures in Popular Media. Univ. Press of Mississippi. https://open.uct.ac.za/handle/11427/37766

Stinson, M., & Nikolaraizi, M. (2020). Assisting people who are deaf or hard of hearing through technology. In Encyclopedia of Education and Information Technologies (pp. 106-115). Cham: Springer International Publishing. https://link.springer.com/content/pdf/10.1007/978-3-030-10576-1_143.pdf

Sun, X., Zhou, S., Zhang, Y., Wang, Q., & Wen, S. J. (2022). Investigating Augmented Reality as a mode of representation for hearing and hearing-impaired preschool children. International Journal of Child-Computer Interaction, 34, 100523. https://www.sciencedirect.com/science/article/pii/S2212868922000447

Swart, K., Bond-Barnard, T., & Chugh, R. (2022). Challenges and critical success factors of digital communication, collaboration and knowledge sharing in project management virtual teams: a review. International Journal of Information Systems and Project Management, 10(4), 84-103. https://aisel.aisnet.org/ijispm/vol10/iss4/5/

Sya, M. F., Anoegrajekti, N., Dewanti, R., & Isnawan, B. H. (2022). Exploring the educational value of Indo-Harry Potter to design foreign language learning methods and techniques. International Journal of Learning, Teaching and Educational Research, 21(10), 341-361. http://www.ijlter.myres.net/index.php/ijlter/article/view/1446

Syed, T. A., Siddiqui, M. S., Abdullah, H. B., Jan, S., Namoun, A., Alzahrani, A., ... & Alkhodre, A. B. (2022). In-depth review of augmented reality: Tracking technologies, development tools, AR displays, collaborative AR, and security concerns. Sensors, 23(1), 146. https://www.mdpi.com/1424-8220/23/1/146

Takrouri, K., Causton, E., & Simpson, B. (2022). AR technologies in engineering education: applications, potential, and limitations. Digital, 2(2), 171-190. https://www.mdpi.com/2673-6470/2/2/11

Tan, S. (2021). Virtual experience in augmented exhibition. Virtual technology application in real musems and its impact on exhibition spaces. https://www.politesi.polimi.it/handle/10589/171010

Tan, S. C., Poh, W. T., Yong, A. C. H., Chua, E. W., Ooi, D. J., Mahmud, R., ... & Stanslas, J. (2023). Challenges and strategies for improving access to cancer drugs in malaysia: summary of opinions expressed at the 2nd MACR international scientific conference 2022. Cancer management and research, 851-862. https://www.tandfonline.com/doi/abs/10.2147/CMAR.S420890

Tang, F. (2024). Understanding the role of digital immersive technology in educating the students of english language: does it promote critical thinking and self-directed learning for achieving sustainability in education with the help of teamwork?. BMC psychology, 12(1), 144. https://link.springer.com/article/10.1186/s40359-024-01636-6

Teru, K., Denis, E., & Hamilton, W. (2020, November). Inductive relation prediction by subgraph reasoning. In International Conference on Machine Learning (pp. 9448-9457). PMLR. https://proceedings.mlr.press/v119/teru20a.html

Tetzlaff, L., Schmiedek, F., & Brod, G. (2021). Developing personalized education: A dynamic framework. Educational Psychology Review, 33, 863-882. https://link.springer.com/article/10.1007/s10648-020-09570-w

Tran, T. T. M., Brown, S., Weidlich, O., Billinghurst, M., & Parker, C. (2023). Wearable Augmented Reality: Research Trends and Future Directions from

Three Major Venues. IEEE Transactions on Visualization and Computer Graphics. https://ieeexplore.ieee.org/abstract/document/10269051/

Vasarainen, M., Paavola, S., & Vetoshkina, L. (2021). A systematic literature review on extended reality: Virtual, augmented and mixed reality in working life. International Journal of Virtual Reality, 21(2), 1-28. https://ijvr.eu/article/view/4620

Venkatesan, S. (2024). Digital Literacy in People with Disabilities: An Overview and Narrative Review. Qeios. https://www.qeios.com/read/latest-RL2FYY.2

Wandira, C. A., Pramudya, Y., Andriyani, A., & Buliali, J. L. (2024, February). Development of augmented reality based sun rotation as learning media for hearing impaired students. In AIP Conference Proceedings (Vol. 2920, No. 1). AIP Publishing. https://pubs.aip.org/aip/acp/article/2920/1/020006/3265115

Wang, Z. (2024). Art and Design Education and Factors of Technological Revolution. Journal of Education and Educational Research, 7(3), 179-185. https://drpress.org/ojs/index.php/jeer/article/view/18724

Worsley, M., & Bar-El, D. (2022). Inclusive Making: designing tools and experiences to promote accessibility and redefine making. Computer Science Education, 32(2), 155-187. https://www.tandfonline.com/doi/abs/10.1080/08993408.2020.1863705

Xu, A., Baysari, M. T., Stocker, S. L., Leow, L. J., Day, R. O., & Carland, J. E. (2020). Researchers' views on, and experiences with, the requirement to obtain informed consent in research involving human participants: a qualitative study. BMC medical ethics, 21, 1-11. https://link.springer.com/article/10.1186/s12910-020-00538-7

Yang, T. H., Kim, J. R., Jin, H., Gil, H., Koo, J. H., & Kim, H. J. (2021). Recent advances and opportunities of active materials for haptic technologies in virtual and augmented reality. Advanced Functional Materials, 31(39), 2008831. https://onlinelibrary.wiley.com/doi/abs/10.1002/adfm.202008831

Yilmaz, A. (2021). The effect of technology integration in education on prospective teachers' critical and creative thinking, multidimensional 21st century skills and academic achievements. Participatory Educational Research, 8(2), 163-199. https://dergipark.org.tr/en/pub/per/issue/58102/741735

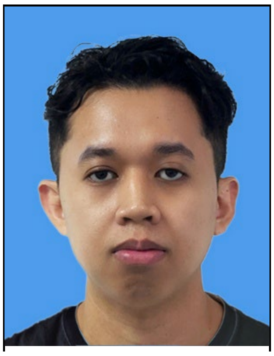
Yousef, A. M. F. (2021). Augmented reality assisted learning achievement, motivation, and creativity for children of low-grade in primary school. Journal of Computer

Assisted Learning, 37(4), 966-977. https://onlinelibrary.wiley.com/doi/abs/10.1111/jcal.12536

Zajda, J., & Zajda, J. (2021). Constructivist learning theory and creating effective learning environments. Globalisation and education reforms: Creating effective learning environments, 35-50. https://link.springer.com/chapter/10.1007/978-3-030-71575-5_3

Zhou, K. Z., Peng, W., Liu, Y., & Adler, R. F. (2024). Exploring the Diversity of Music Experiences for Deaf and Hard of Hearing People. arXiv preprint arXiv:2401.09025. https://arxiv.org/abs/2401.09025

AUTHOR'S PROFILE



Mohamad Saifuddin bin Rusli completed his bachelor's degree in Graphic Design (HONS.) Multimedia Major at the Faculty of Art and Design, Universiti Teknologi MARA. He also holds a Diploma in Graphic Design from Kolej Teknologi Timur (UiTM). Throughout his academic journey, he demonstrated exceptional dedication and excellence, earning the prestigious Vice Chancellor's Award in both 2013 and 2016. Professionally, Mohamad Saifuddin is a multifaceted Multimedia Designer and Digital Marketing Specialist with extensive experience in the industry. Since 2016, he has served as a full-time Multimedia Designer-cum-Digital Marketing professional at AEX System, where he integrates graphic design precision with functional website design to create cohesive brand experiences. His expertise spans user interface and user experience (UI/UX) design, 3D modeling, and the optimization of e-commerce platforms. Mohamad Saifuddin continues to deliver innovative, high-quality results that enhance brand visibility and drive engagement across digital channels.

LIST OF PUBLICATION

Rusli, M. S., & Ibrahim, Z. (2022). Augmented Reality (AR) for Deaf and Hard of Hearing (DHH) for animation. e-Academia Journal, 11(2), 175-186. https://ir.uitm.edu.my/id/eprint/88957/