A HYBRID AUGMENTED REALITY MODEL BASED ON INSTRUCTIONAL DESIGN AND USABILITY PRINCIPLES OF DIGITAL MEDIA ART

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UNIVERSITI UTARA MALAYSIA

2024

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Abstrak

Dengan perkembangan pesat seni media digital (DMA), pendidikan DMA menjadi bahagian penting dalam pendidikan seni di kolej dan universiti. Pengajaran DMA tradisional masih berdasarkan pengajaran bilik darjah, yang tidak mempunyai interaktiviti dan minat, dan sukar untuk merangsang minat dan semangat pelajar dalam pembelajaran. Akibatnya, penyepaduan teknologi realiti tambahan (AR) ke dalam persekitaran pendidikan menunjukkan potensi besar dalam meningkatkan pengalaman pembelajaran. Kertas kerja ini menggunakan reka bentuk kaedah hibrid berjujukan penerokaan, dan tujuannya adalah untuk mencadangkan teknologi AR berdasarkan prinsip kebolehgunaan untuk mereka bentuk model reka bentuk pengajaran DMA untuk menyediakan pelajar dengan persekitaran pembelajaran yang mengasyikkan. Kertas kerja ini mula-mula menganalisis teori teknologi AR yang relevan dan ciri-ciri aplikasi teknologi AR dalam pendidikan melalui penyelidikan sastera, dan kemudian menganalisis situasi semasa dan cabaran aplikasi pengajaran DMA. Kemudian, prinsip kebolehgunaan ditentukan melalui penilaian pakar dan pengguna, dan model reka bentuk pengajaran AR telah dibina. Akhir sekali, untuk mengesahkan keberkesanan model, DMA telah disiasat dan disahkan oleh pelajar sekolah rendah dalam reka bentuk buku bergambar projek AR. Keputusan menunjukkan bahawa menyepadukan prinsip kebolehgunaan ke dalam reka bentuk model pengajaran realiti tambahan DMA boleh meningkatkan penglibatan, kefahaman dan kreativiti pelajar dengan ketara, menghasilkan pengalaman pendidikan yang lebih berkesan dan mengasyikkan.

Kata Kunci: Realiti tambahan, Ujian kebolehgunaan, Reka bentuk pengajaran， Seni media digital

Abstract

With the fast-paced growth of digital media art (DMA), the inclusion of DMA education has now become a vital component of art education in colleges and universities.Still, traditional DMA teaching is often based on classroom teaching, which lacks interactivity and interest and makes it difficult to stimulate students' learning interest and enthusiasm. Therefore, integrating AR technology into educational environments shows great potential in enhancing the learning experience. in this thesis, an exploratory sequential mixed-method design is used to propose AR technology based on usability principles to design a DMA instructional design model to provide an immersive learning environment for students. This study firstly analyzes the relevant theories of process safety and characteristics of pedagogical applications with AR technology through document research and then analyzes the status and challenges of DMA instructional applications. Then, the AR instructional design model was constructed by determining the usability principles through expert and user evaluation. Finally, to validity and accuracy of proposed models, DMA is verified by a survey on AR project picture book design for elementary school students. The results show that integrating usability principles into the design of the DMA augmented reality instructional model can significantly improve learner engagement, comprehension, and creativity, resulting in a more effective and immersive educational experience.

Keywords: Augmented reality, Usability principles, Instructional design, Digital media art

Acknowledgment

I extend my deepest gratitude to all those who have supported me throughout the writing of this thesis. My sincere appreciation goes to my supervisor, Dr. Hammuzamer, for his invaluable guidance and unwavering encouragement. His insightful feedback on my drafts helped me refine my arguments and strengthen my conclusions. His unwavering belief in my abilities provided me with the confidence to overcome challenges and persevere. I am truly indebted to his patient support and mentorship, which have been instrumental in my academic growth and the completion of this thesis.

I am very grateful to the examiners of the proposal defense and viva sessions. Their comments, both during the sessions and the revision period, were insightful and greatly improved this work. I am grateful for their kind support throughout the process.I am deeply thankful to all the professors who have guided my academic journey.I appreciate your patience, your understanding, and your belief in me. I will miss your presence after graduation.

Finally, I would like to thank my parents, without their support, maybe I would not have had the chance to go out of the country, thanks to their love and trust in me over the years. I also would like to express my heartfelt thanks to all my friends who have encouraged me during my studies.

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CHAPTER ONE

INTRODUCTION

1.1 Overview

The objective of this research is to craft an AR-based instructional design model for DMA, adhering to usability principles, with the goal of improving student engagement and learning. This segment pinpoints existing usability challenges in DMA instruction, underscores the value of merging AR with DMA pedagogy, and delineates the structure of this research across nine core components: Research Background, Problem Statement, Research Gaps, Research Questions, Research Objectives, Research Hypotheses, Conceptual Framework, Research Significance, and Research Scope and Limitations, including key definitions, along with a brief overview of each chapter's content.

1.2 Research Background

In recent years, significant technological advances have facilitated the widespread use of AR in a variety of domains, and education is at the forefront of this revolution. AR fundamentally entails the superimposition of digital content, ranging from images and videos to complex 3D models, onto tangible reality, thereby enriching the observer's perceptual interfaces and interactions with his or her immediate physical environment (Milgram & Kishino, 1994). In education, AR is a strong contender to reshape traditional teaching methods by generating immersive and engaging learning experiences (Dünser, Grasset& Billinghurst, 2008).

The transformative potential of AR in education has found a particularly compelling niche in the field of DMA education. The discipline depends on developing creative skills, interactive exploration, and hands-on engagement in multimedia. Enhancing this pedagogical environment through AR technology heralds an area of possibilities for enhancing teaching strategies (Billinghurst, Kato & Poupyrev, 2001). The combination of AR and DMA education promises to transcend the boundaries of traditional learning, providing students with unprecedented access to merging their creative aspirations with the tangible digital dimension.

DMA education constitutes a dynamic field that strives to prepare students across a wide range of creative disciplines, including graphic design, animation, video production, and interactive media. However, traditional educational paradigms based primarily on static materials and traditional teaching techniques fail to encapsulate the complex and interactive nature that defines DMA (Hobbs & Moore, 2016). The innovative integration of AR technology into this educational arena offers a transformative solution to address this discrepancy and create immersive learning environments that resonate with the dynamic nature of DMA.

Traditional pedagogical approaches inherently tend to rely on static resources that often struggle to encapsulate the inherently fluid and dynamic nature of DMA. These approaches may inadvertently hinder students' holistic understanding and practical exploration of the subject matter (Delice & Türkkan, 2015). AR, as a bridge between the tangible and virtual worlds, has the inherent ability to revolutionize the field. By seamlessly blending virtual elements with real-world environments, AR transforms learning into a fascinating journey of discovery and creativity, closely aligned with the ethos of DMA education.

The convergence of AR and DMA education promises to spark a paradigm shift that resonates deeply with the aspirations of both educators and learners.AR enhances student learning by creating immersive environments where students can interact with virtual objects, promoting experiential learning and sparking creative thinking. When learners manipulate and immerse themselves in a virtual environment with objects that physical environment, the disconnect between theoretical knowledge and real-world applications is reduced, thus fostering a more holistic and authentic educational experience (Azuma, 1997).

However, a systematic and explicit approach is required to successfully integrate AR into instructional design. This is where the concept of usability principles comes into play. Rooted in human-centered design, usability principles emphasize creating products and systems simple to learn, quick to use, and designed to provide a satisfying user experience (Nielsen, 1994). Applying these principles to the design of AR-based instructional materials can increase their effectiveness by ensuring that learners can intuitively interact with the content, navigate through the AR environment, and achieve their learning goals.

The convergence of AR technology and usability principles can revolutionize DMA education (Bacca Acosta et al., 2014). Learners can interact with virtual elements related to real-world environments, enhancing their understanding of complex concepts and engaging in creative exploration. This approach to instructional design recognizes the importance educationsl technology while prioritizing the needs and experiences of learners.

As educators and instructional designers venture into this dynamic field, it becomes critical to establish an explicit instructional design model that harmonizes AR technology and usability principles with the unique requirements of DMA education. Such a model will provide educators with a structured framework for creating engaging, effective, and user-friendly AR-based instructional materials, ultimately fostering a new dimension of learning experience in the DMA field.

1.3 Problem Statement

In the current digital media art instructional design model, there are several outstanding problems to be solved. First of all, the teaching model often ignores the individual differences of learners' artistic background, interests, experience and creative potential, resulting in the failure of the general curriculum to meet the needs of different learners, affecting the learning outcomes and participation. Research has shown that personalized learning environments can enhance learner engagement and achievement (Johnson et al., 2021). Second, many courses, while emphasizing the transfer of basic knowledge and skills, lack cases and projects that integrate with practical applications in industry, making it difficult for students to integrate learning content with creative practice, whereas an effective education should combine theory with practice so that students are better prepared for the workplace (Brown et al., 2020). Third, teaching methods lack innovation, traditional teaching methods are dominant, lack interaction and practice, and it is difficult to stimulate learners' learning motivation and creativity, while innovative teaching methods such as project-driven learning and collaborative learning have not been paid enough attention and applied, and interactive and inquiry learning methods can promote students' creativity and critical thinking (Smith, 2019). Finally, the evaluation mechanism is often one-sided, relying on the final exam to evaluate the learning results, ignoring the continuous evaluation and development guidance in the learning process. This evaluation method is difficult to reflect the real level and development potential of students, nor can it help teachers timely adjust teaching strategies. Evaluation should be a continuous process to provide feedback for students' learning progress. Promoting improvement (Taylor, 2022). Therefore, addressing these issues requires the development of a digital media arts curriculum that prioritizes the needs of learners, combines theoretical knowledge with practical applications, and fosters creativity, thereby improving the overall quality and effectiveness of teaching.

1.4 Research Gap

Research into the assessment and confirmation of an augmented reality (AR) instructional framework for Digital Media Art (DMA), adhering to usability guidelines, is scarce. (Smith & Johnson, 2021) undertook a thorough examination of scholarly works concerning augmented reality within the realm of DMA education.While the review examined various aspects of augmented reality teaching models, including design and implementation, there was limited research addressing the verification and validation of such models based on usability principles. This research gap highlights the need for further investigation into the process of verifying and validating augmented reality teaching models for DMA, specifically focusing on their adherence to usability principles.

Although several AR instructional models have been proposed, systematic empirical studies are relatively scarce. This prevents many models from being effectively evaluated in real teaching and learning environments, thus limiting their practical application and popularization. Effective augmented reality instructional models should be evaluated for their educational effectiveness through rigorous validation studies (Chen & Tsai, 2021).

The success of augmented reality technology lies in its user experience and usability design (Huang et al., 2020). However, most current augmented reality instructional models lack user-centered usability evaluation in their design, resulting in a final system that may struggle to meet learners' needs.

When designing educational technologies, it is crucial to evaluate the effects of cognitive burden (Sweller, 2019). Many existing AR instructional models do not adequately assess the effects of mental workload, failing to balance the complexity of information presentation with cognitive abilities of students. This may result in students being confused or overwhelmed when using these technologies, which may affect learning outcomes.

In addition, many current studies use a single methodology (e.g., quantitative or qualitative research) and fail to combine the strengths of both, resulting in an incomplete understanding of the effectiveness of augmented reality instructional models. Utilizing a mixed-methods approach facilitates a deeper comprehension of the link between user experience and educational outcomes (Creswell & Plano Clark, 2018).

1.5 Research Questions

This research seeks to develop an AR teaching framework for DMA, grounded in usability principles, to boost student engagement and learning. Consequently, the subsequent inquiries must be explored:

RQ 1: What are the elements of a hybrid augmented reality model based on instructional design and usability principles of digital media?

RQ 2: How to construct a hybrid augmented reality model?

RQ 3: How to validate a hybrid augmented reality model?

1.6 Research Objectives

The research objectives are formulated as below:

RO 1: To identify the elements of a hybrid augmented reality model based on instructional design and usability principles of digital media art.

RO 2: To construct the hybrid augmented reality model based on instructional design and usability principles of digital media art.

RO 3: How to validate the hybrid augmented reality model through the expert review method.

1.7 Research Hypotheses

Aligned with the research questions and goals, the hypothesis of the study is proposed. The detailed presuppositions are outlined below:

Integration of usability principles into the design of augmented reality instructional models for DMA will significantly increase learner engagement, comprehension, and creativity, resulting in more effective and immersive educational experiences.

1.8 Conceptual Framework

Figure 1.1 below shows the conceptual framework of this study, illuminating the relationship between the incorporation of usability principles into an augmented reality instructional model for DMA education and the resulting impact on learner engagement, understanding, and creativity, resulting in a more effective and immersive educational experience.

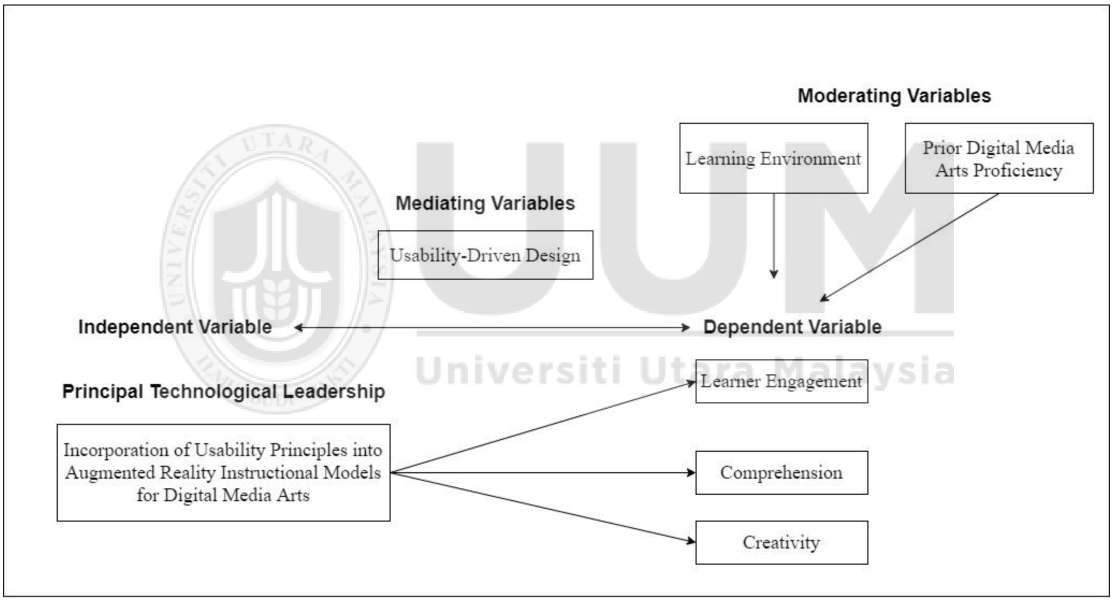

Figure 1.1 Conceptual Framework

(Picture Credit: Author's Self-Drawn)

The framework describes how the incorporation of usability principles into an augmented reality instructional model serves as the independent variable that influences learner engagement, comprehension, and creativity (the dependent variable). The application of usability-driven design is a mediator that facilitates this impact. Additionally, prior DMA proficiency and the learning environment were identified as moderating variables influencing the strength of these relationships. The interplay of these variables constructed a comprehensive view of how usability-enhanced augmented reality can enhance the educational experience in the field of DMA.

1.9 Research Significance

The importance of this research is demonstrated through its theoretical and practical contributions to the domain in question:

The theoretical significance of an augmented reality instructional design model for DMA based on usability principles lies in its potential to advance pedagogical theories and frameworks. By merging the realms of usability and augmented reality, this model introduces a novel perspective to instructional design theory.It adds to the expanding literature that connects educational technology with user-centered design, highlighting the significance of user experience in optimizing educational achievements.This integration has the potential to shape a new paradigm for designing immersive and effective educational experiences that meet the needs of the unique needs of DMA education. Furthermore, this aspect theoretical advancement can potentially influence broader educational practices by demonstrating the efficacy of combining technology, creativity, and usability principles in learning contexts.

The practical significance of an augmented reality instructional design model for DMA based on usability principles is manifold:

(1) Enhanced Learning Experience: This model offers educators a structured approach to creating AR-based instructional materials that are not only technically advanced but also intuitively navigable and engaging. Learners gain from a deeply engaging and interactive educational setting that mirrors real-world applications, thus fostering deeper engagement, comprehension, and creative expression.

(2) Optimized Creativity: By integrating usability principles, learners are empowered to explore and experiment creatively within the DMA domain. The model encourages a user-centered approach, allowing students to channel their creative energies toward content generation and experimentation rather than grappling with complex technology interfaces.

(3) Professional Readiness: As DMA fields require proficiency in utilizing advanced technologies, exposure to well-designed AR experiences equips learners with skills relevant to their future careers. They become adept at harnessing technology for creative expression, aligning with industry trends and demands.

(4) Educational Innovation: The model sets a precedent for innovative instructional practices that can inspire educators across disciplines to integrate emerging technologies like AR while adhering to user-centered design principles. This spurs the evolution of educational approaches beyond traditional boundaries.

(5) Research Implications: The model offers a platform for empirical research, enabling educators, researchers, and institutions to assess its efficacy in enhancing engagement, comprehension, and creativity. Insights gained from implementation and evaluation can contribute to the broader discourse on educational technology, pedagogical effectiveness, and human-computer interaction.

1.10 Research Scopes and Limitations

The study was limited due to the absence of analysis regarding students' perceptions as only 20 teachers were selected. Although the hypotheses of this study are partially valid, there are many shortcomings due to the limitations of one's level of research and the limitations of time and effort:

Firstly, the data was collected over at the same time and the degree of understanding from the learning environment and DMA expertise was incremental, therefore, absence of longitudinal data may affect the soundness of the findings to some extent.

Secondly, the survey method of this study is relatively single, and only the questionnaire is used for data collection. During the survey process, respondents may not fully understand the content of the questionnaire before answering, which may lead to bias in the collected data. In future studies, a variety of data collection methods (e.g., interview method and usability testing) can be adopted and combined with expert assessments (e.g., review panels and supervisors) to enhance the precision of the test results. Additionally, face-to-face communication with the respondents could be conducted before the questionnaire is administered so that they can complete their responses with a full understanding of the questions.

Finally, device limitations may hinder widespread implementation and equitable learning experiences. The ability of learners to access compatible AR devices is not universally available.

1.11 Clarifications of Terminology for This Research

The terms used in this study are AR Technology, Usability Principles, Instructional Design, and Digital Media Art with specific operational definitions as follows:

1.11.1 Augmented Reality (AR) Technology

AR technology refers to a cutting-edge field that blends the virtual and real worlds seamlessly.By superimposing digital elements,like images, videos, or 3D models, superimposed onto the real-world environment in real-time,AR technology enriches users' sensory perceptions and interactions within their immediate surroundings. Through the dynamic fusion of reality and virtuality, AR technology enhances the contextual understanding of information, augments human experiences, and opens new avenues for interactive engagement across various domains (Azuma,1997).

1.11.2 Usability Principles

Usability principles form a cornerstone of human-centered design, encompassing a collection of guidelines that prioritize the creation of interfaces, products, or systems with a user-centric focus. These principles emphasize crafting designs that are inherently intuitive, easy to learn, efficient to navigate, and capable of delivering a positive and satisfying user experience. By adhering to usability principles, designers seek to eliminate unnecessary complexities, streamline interactions, and cultivate a seamless connection between users and the designed artifacts, thereby enhancing overall usability and user satisfaction (Nielsen & Molich, 1990).

1.11.3 Instructional Design

Instructional design follows a structured approach to create effective learning experiences that enhance learning by analyzing learners' needs, developing instructional objectives, selecting appropriate instructional strategies, and assessing learning outcomes (Morrison et al., 2019). Bozarth, J. (2020) suggested that modern instructional design focuses not only on the delivery focusing not only on the content but also on the learner's involvement and experience.An effective instructional design needs to consider learners' backgrounds, motivations, and learning styles to ensure personalization of instruction (Lee & Lehto, 2020). Reiser & Dempsey,2018 suggest that the success of instructional design lies in its ability to assess learning outcomes through scientific methods and adjust based on feedback. In the digital age, instructional design needs to integrate technology and teaching strategies to enhance the interactivity and effectiveness of learning (Ally&Tsinakos,2021).

1.11.4 Digital Media Art (DMA)

DMA constitutes a multidisciplinary creative field that leverages digital technologies to conceptualize, design, and produce visual, auditory, or interactive content. This content creation spans a spectrum of artistic expressions, including graphic design, animation, video production, and interactive media. Rooted in the intersection of artistic vision and technological innovation, DMA serves both aesthetic and communicative functions, engaging audiences across various digital platforms and mediums (Manovich, 2001).

1.12 Thesis Structure

This study contains a total of six chapters. They are shown in Figure 1.2.

Chapter 1: Introduction.

This chapter highlights the importance of integrating AR technology with DMA education in terms of the background of the study, problem statement, research gaps, research questions, research objectives, research hypotheses, conceptual framework, significance of the study, research scope and limitations, operational definitions of the terminology used in the study, which highlight the importance of integrating AR technology with DMA education and outlines a summary of the chapters in this thesis.

Chapter 2: Literature Review.

This chapter outlines concepts related to usability principles in the context of DMA education, reviews relevant literature and research on DMA education, augmented reality, literature review related to instructional design, and usability principles, analyses the current state of the field, identifies limitations in existing approaches, and lays the theoretical foundation for the proposed pedagogical models and emphasizes their importance in improving learning outcomes and student engagement.

Chapter 3: Research Methodology.

This section details the research methodology, including participant criteria, data collection methods, and the integration of usability principles throughout the design process.

Chapter 4: Prototype Design and Development.

This section elaborates on the development of the AR Instructional Design Model and the detailed procedures for collecting and analyzing experimental data within an educational context to apply AR instruction.

Chapter 5: Results and Discussion.

This chapter presents the results of the evaluation of the augmented reality teaching model. By analyzing the data collected, the results are discussed and their implications for DMA education are explained.

Chapter 6: Findings and Conclusions.

This chapter summarizes the main findings of the study and their implications for DMA education. It mainly discusses the contributions of the study, highlights the benefits of the augmented reality teaching model, and suggests future research directions for the field.

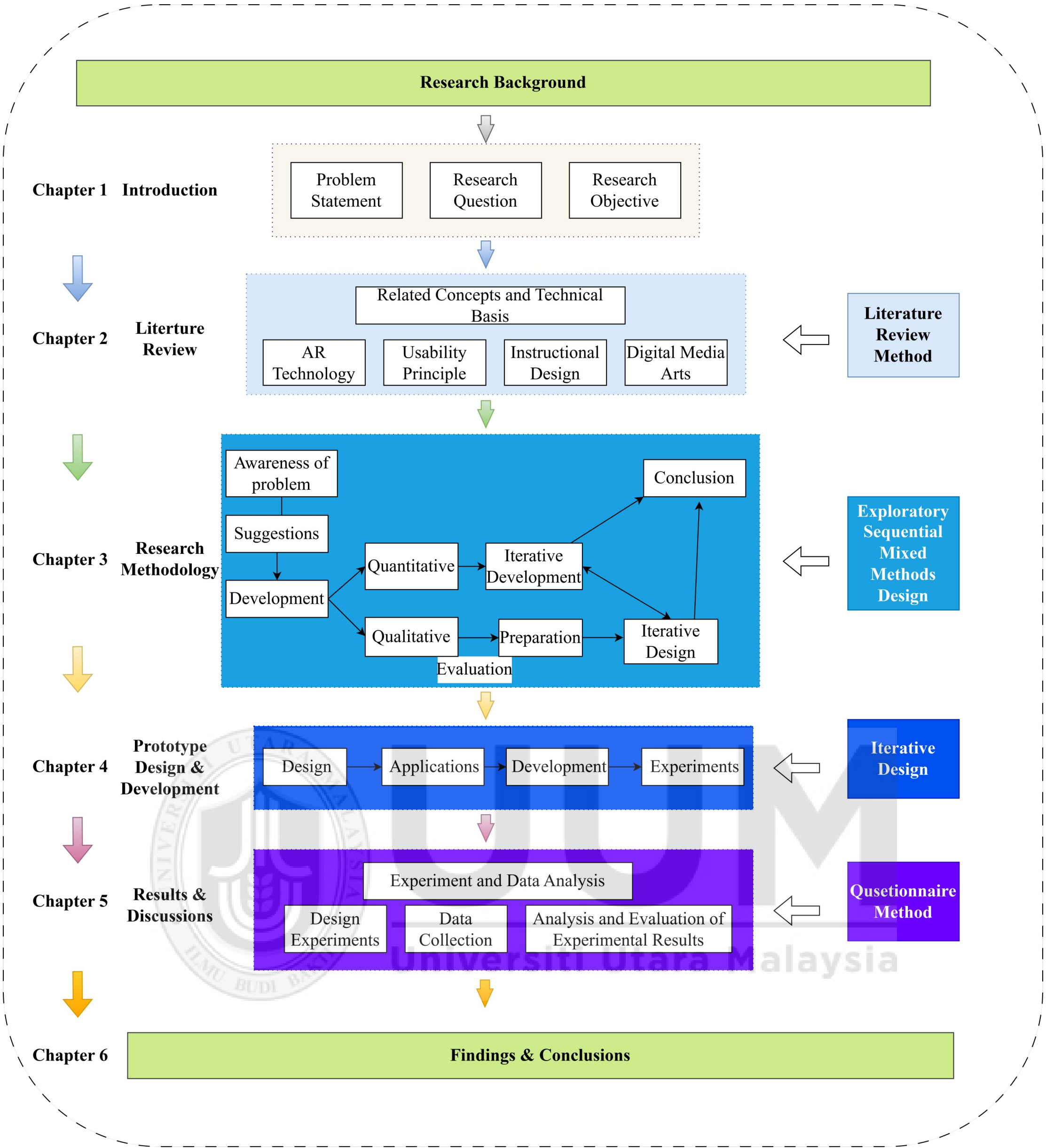

Figure 1.2 Research Framework

(Picture Credit: Author's Self-Drawn)

1.13 Summary

In conclusion, this section addresses the research problem and questions, objectives, methodologies, hypotheses, scope, anticipated results, and the potential impact of the proposed solutions, as outlined in Table 1.1. The topics covered serve as key foundational principles for the study, essentially framing it as a conceptual overview.

Table 1.1

Summary of This Research Study

Research Problem
Research on the verification and validation of an AR teaching model for DMA, grounded in usability principles, is scarce. Smith & Johnson (2021) conducted a systematic review of literature on augmented reality in DMA education. While the review examined various aspects of augmented reality teaching models, including design and implementation, there was limited research addressing the verification and validation of such models based on usability principles. This research gap highlights the need for further investigation into the process of verifying and validating augmented reality teaching models for DMA, specifically focusing on their adherence to usability principles.
Research Question
(1) What are the elements of a hybrid augmented reality model based on instructional design and usability principles of digital media are? (2) How to construct a hybrid augmented reality model? (3) How to validate a hybrid augmented reality model?
Research Objectives
(1) To identify the elements of a hybrid augmented reality model based on instructional design and usability principles of digital media art. (2) To construct the hybrid augmented reality model based on instructional design and usability principles of digital media art. (3) How to validate the hybrid augmented reality model through the expert review method.
Research Methodology
Start → Quantitative Research Phase → Data Collection → Data Analysis → Results Interpretation Decision Point (Is Qualitative Research Needed?) → Qualitative Research Phase → Qualitative Data Collection → Qualitative Data Analysis → Results Interpretation → Results Integration → Draw Conclusions → Report Research Findings → End

Research Hypothesis

Integration of usability principles into the design of augmented reality instructional models for DMA will significantly increase learner engagement, comprehension, and creativity, resulting in more effective and immersive educational experiences.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

It is important to examine previous literature related to the topic to observe the perspectives of the selected research, refer to Chapter 3.2.2.The subsequent literature survey offers context knowledge related to the construction of an augmented reality instructional design model for DMA based on usability principles. The focus is to review the techniques used within educational processes. Identify the challenges in the realm of education DMA, review other technologies previously used to enhance DMA learning, and identify usability issues students face when learning DMA using AR technologies.

2.2 Review of Research Related to AR Technology

2.2.1 Principles of AR Technology

The basic components of the AR system include five parts: a high-resolution camera, high-performance processor, high-capacity storage, high-pixel display, and human-computer interaction terminal to achieve an immersive AR experience.

Combined with the relevant principles summarized and produced, as shown in Figure 2.1, AR schematic diagram. Among them, CPU performance is the key factor that determines the real-time rendering of AR scenes. High-performance CPUs are needed to ensure smooth real-time rendering of virtual content, which contributes to the realism of augmented reality rendering (Schmalstieg & Hollerer, 2016). Memory storage in an AR system is responsible for storing data that must be converted and displayed shown. This includes media assets such as 3D models, textures, audio and video files.

The location of memory storage can be categorized into two types: local and cloud-based. Local storage refers to the storage capacity available on the device itself, such as RAM or removable storage. Cloud storage, on the other hand, involves storing media information on remote servers that can be accessed via the Internet (Billinghurst & Kato, 2002).

The screen or display plays a vital role in delivering virtual reality content to the user. The screen presents the combined view to the user after the processor uses algorithms to superimpose the digital content superimposed onto the actual environment. The quality and characteristics of the screen, such as resolution, color reproduction, and refresh rate, significantly affect the visual fidelity and immersion of the augmented reality experience (Azuma et al. 2001). The human-computer interaction (HCI) aspect of an AR system is responsible for facilitating user interaction and enhancing the overall AR experience.

Through input devices such as touchscreens, gestures, voice commands, or motion sensors, users can interact with virtual content superimposed on the physical environment for an immersive and interactive experience(Billinghurst & Duenser, 2012).

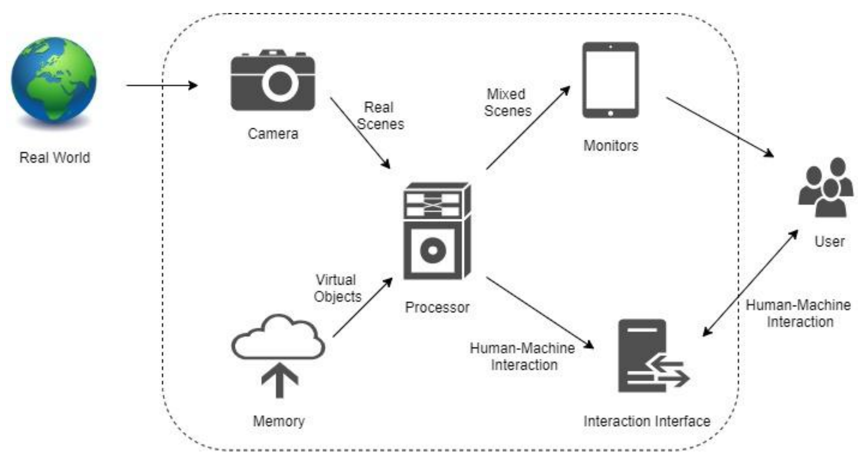

*Figure 2.1.*AR System Schematic

(Picture Credit: Author's Self-Drawn)

2.2.2 Elements of Augmented Reality

One of the elements of designing an augmented reality AR instructional design model for DMA based on usability principles is the incorporation of intuitive and user-friendly interaction design. This element focuses on creating interactive technologies and user interfaces that enhance the usability and user experience of AR applications. By designing interactions that are intuitive, efficient, and satisfying to learners, AR instructional design models can facilitate effective engagement and learning in the context of DMA.

To support this element, research by Billinghurst, (Kato & Poupyrev,2001) highlights the importance of intuitive interaction design in AR systems. They discuss the concept of a natural interface that strives to align user interactions with their expectations and a priori knowledge. By designing AR interactions that mimic real-world actions or utilize familiar gestures, users can quickly understand and navigate DMA content in AR environments. This intuitive interaction design enhances usability and reduces the learning curve associated with AR instructional design models. In addition, MacIntyre, Mynatt & Voida's (2001) research highlights the importance of the user interface in AR applications. They argue that the user interface plays a crucial role in enhancing efficient interaction among users and digital content in realistic environments. User interfaces should be attractive visually, user-friendly, and offer explicit guidance for engaging with the virtual elements within the DMA model. These interfaces should also consider the particular requirements and inclinations of the intended audience audience to ensure an inclusive and user-centered design.

The specific elements are shown in Table 2.1. By integrating the findings and principles of these studies, an AR instructional design model for DMA can be designed with a focus on usability and user-centered interaction design. The model can provide learners with intuitive and engaging interactions that enhance the learning experience and improve educational outcomes in the field of DMA.

Table 2.1

Elements of Augmented Reality

Elements	Explanation	Citation
Virtual Objects	Digital content overlaid on the real world to create an augmented experience.	Azuma, (1997)
Tracking Systems	Technologies used to track the position and orientation of the user and objects in the real world.	Milgram & Kishino, (1994)
Display Devices	Hardware devices that present the augmented reality content to the user, such as headsets, smartphones, or tablets.	Billinghurst & Kato, (2002)
Interaction Techniques	Methods for users to interact with and manipulate the virtual objects in augmented reality environments.	Bowman, LaViola Jr& Poupyrev, (2004)
Environmental Context	The physical surroundings in which the augmented reality experience takes place.	Azuma, (1997)

2.2.3 Types of AR Technology

There are several types of AR technology, each form suitable for different applications and use cases. The main types include the following:

First, marker-based AR uses visual markers as a foundation (also known as fiducials) as reference points for AR content. These markers are typically two-dimensional patterns that, when recognized by an AR device or application, trigger the display of numeric information above the marker location (Azuma et al.2001). Often used for teaching DMA to improve student learning experiences. In this approach, markers or visual cues are used to trigger the display of virtual content related to the art topic. Students can scan the marker using an AR-enabled device (such as a smartphone or tablet) and immediately view an interactive 3D model, animation, or multimedia element superimposed on the marker (as shown in Figure 2.2). By monitoring the marker's location and alignment, virtual objects or information can be superimposed precisely on the marker's location. This type of AR technology allows students to explore and interact with DMA in a more immersive and engaging way (Smith, 2016).

In contrast to marker-based AR, markerless AR doesn't require predefined markers. Instead, it uses computer vision techniques to detect and track objects or surfaces in the real world, enabling digital content to be superimposed seamlessly （Hsiao et al.2018).

Figure 2.2. Marker-Based AR
(Picture Credit: Internet)

Secondly, Projection-based AR involves projecting digital content directly onto physical objects or surfaces, creating an interactive augmented experience. This type of AR is often used for art installations, entertainment, and interactive displays (Billinghurst, Kato & Poupyrev,2001). In the context of teaching DMA, projection-based AR can be used to display large-scale interactive artworks, create immersive visual installations, or enable students to experiment with digital media elements in real-world spaces (as shown in Figure 2.3). This type of AR technology enhances students' understanding of and engagement with DMA concepts and allows for creative exploration (Cruz-Neira, Sandin & DeFanti, 1993).

There are wearable AR devices (e.g., smart glasses or headsets) that tracking the marker's position and orientation. These devices can display digital content immediately within the user's line of sight, enhancing applications ranging from industrial tasks to consumer experiences (Azuma & Ronald, 1997).

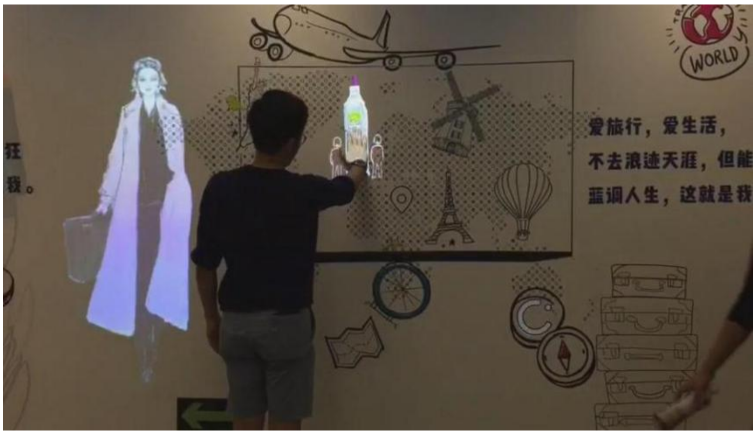

Figure 2.3. Projection-Based AR
(Picture Credit: Internet)

Finally, handheld AR, also known as mobile AR, is an AR experience delivered through handheld smartphones, tablets, and similar devices. Users can view the real world through the device's camera and see digital content superimposed on the screen (Schmalstieg & Hollerer, 2016). In the context of DMA, mobile AR applications accessible through portable devices such as smartphones or tablets provide a portable and accessible platform for teaching DMA. These apps use the mobile device's built-in camera and sensors to superimpose virtual content onto the real world, allowing students to interact with DMA elements in their immediate environment (as shown in Figure 2.4). Mobile AR applications can be used to demonstrate artistic concepts, provide visual references, or facilitate collaborative projects, enabling students to actively participate in DMA anytime, anywhere (Damala, 2009).

Figure 2.4. Mobile-Based AR
(Picture Credit: Internet)

The various types of AR provide unique opportunities to enhance student learning experiences, encourage creativity, and facilitate hands-on exploration of DMA concepts. By utilizing these AR technologies, educators can create dynamic, immersive learning environments that promote active student engagement and deepen understanding of DMA principles. To address the shortcomings in teaching DMA, I have selected, in this study, mobile device-based AR technology.

2.2.4 Features of Mobile AR Technology

Mobile device-based AR technology utilizes smartphones and tablets as AR platforms and can be a good solution to the challenges faced by traditional teaching methods. It has the following characteristics, as shown in Figure 2.5:

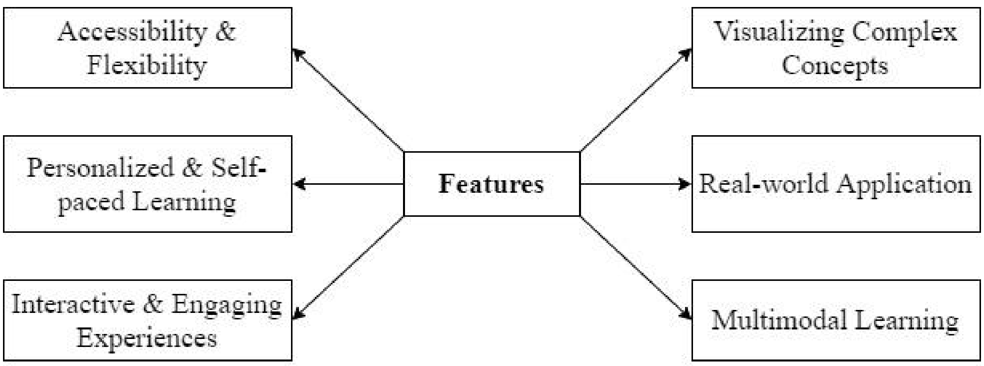

Figure 2.5. Features of Mobile AR Technology
(Picture Credit: Author's Self-Drawn)

In real life, mobile devices are ubiquitous and easily accessible to most students. By using mobile-based AR, educators can overcome the barriers associated with limited access to specialized or dedicated AR devices. Students can participate in AR experiences using devices they already have, thus fostering inclusivity and flexibility (Klopfer et al., 2009).

Secondly, mobile device-based AR applications can be designed to allow students to learn at their own pace and explore topics that interest them. This self-directed approach allows students to take control of their learning journey and delve deeper into areas of DMA that resonate with them (Pivec & Dziabenko, 2015).

The next, mobile device-based AR provides an interactive and engaging learning experience by overlaying digital content onto the real world. This hands-on engagement allows students to directly manipulate and interact with AR elements, making abstract concepts in DMA more concrete and accessible (Dünser, Grasset& Billinghurst, 2008). At the same time, visualization of complex concepts such as 3D modeling, animation, and spatial arrangement can be achieved. Students can see and understand intricate details that may be difficult to convey through traditional methods (Billinghurst, Clark& Lee, 2015).

The next, mobile device-based AR can bridge the gap between classroom learning and real-world applications. Students can use AR applications to superimpose digital elements onto physical space, fostering creativity and helping them conceptualize how to integrate digital media projects into real environments (Höllerer & Feiner, 2004).

Finally, mobile devices can support multimodal learning experiences by combining visual, auditory, and tactile elements. Students can explore multiple forms of DMA, including graphics, audio, video, and interactive simulations, thus enhancing their understanding and skills (Gee, 2003).

Therefore, in this study by choosing mobile-based AR, educators can leverage the power of technology to overcome the limitations of traditional teaching methods and create immersive, interactive, and personalized learning environments that meet the unique needs and challenges of teaching DMA.

2.2.5 Features of Education Applications of AR Technology

Augmented reality technologies for DMA education, grounded in usability principles, exhibit the characteristics listed in Table 2.2.,including aspects of interactivity, visualization, personalization, collaboration, and gamification, which provide the basis for developing effective and engaging educational experiences. Leveraging these attributes, educators can develop immersive and impactful educational settings tailored to students' varied requirements.

Table 2.2
Characteristics of Educational Applications of AR Technology

Feature	Description	Citation
Interactive Learning	AR provides interactive learning experience by overlaying digital content onto the real world.	Klopfer, Osterweil, & Salen, (2009)
Visualization & Simulation	AR enables visualization and simulation of complex concepts in DMA.	Billinghurst & Duenser, (2012)
Personalized Learning	AR offers personalized and adaptive learning experiences tailored to individual learners' needs.	Chen & Huang，(2019)
Collaboration & Social Learning	AR facilitates collaborative learning experiences in shared AR environments.	Dede, (2009)
Gamification & Motivation	AR can be gamified to enhance learner engagement and motivation in DMA education.	Lee, (2011)

Firstly, AR technology offers interactive learning experiences that go beyond traditional textbooks and lectures. Students can actively engage with virtual objects and environments, manipulating them, and exploring their characteristics in real-time.

This interactivity promotes hands-on learning, enhances student engagement, and deepens their understanding of educational content (Klopfer, Osterweil, & Salen, 2009).

The next, AR technology enables students to visualize complex concepts by superimposing virtual objects onto the real world.AR enables the visualization and simulation of complex concepts and processes in DMA, enabling learners to explore and understand abstract or spatially complex ideas through interactive visual representations (Billinghurst & Duenser, 2012). Such visualizations and simulations can improve comprehension and make abstract or challenging concepts easier to understand and remember (Milgram & Kishino, 1994).

The next, AR applications can be customized to cater to individual learners' needs, preferences, and skill levels. Through adaptive algorithms, AR programs can provide personalized content and tailored feedback, enabling students to progress through the material at their own speed. This individualization fosters a personalized learning experience, where students can focus on areas they find challenging and receive targeted support, promoting better learning outcomes（Chen & Huang，2019).

Then secondly, AR technology facilitates collaborative learning experiences among students. By interacting with virtual objects and sharing their experiences, students can collaborate on problem-solving activities, conduct virtual experiments together, or participate in group projects. This fosters collaboration, dialogue, and analytical abilities, while also encouraging social interaction and peer learning (Dede, 2009).

Finally, AR-based educational applications often incorporate gamification elements to enhance student motivation and engagement. By incorporating game-like features like incentives, accomplishments, and progress monitoring, and challenges, AR technology transforms the learning process into an enjoyable and immersive experience. These elements encourage students to actively participate, persevere through challenges, and achieve their learning goals (Lee, 2011).

2.2.6 Relationship between AR Technology and Usability Principles

Arezoo Shirazi et al. (2013), incorporating mobile context-aware visual simulations into STEM education, they concluded that their platform, leveraging visual mobile AR technology, enhances textbook content with computer-generated virtual multimedia and graphics. This approach enables more interactive engagement with context-aware simulation animations than conventional teaching methods.

In addition, the experiments of Ernest Redondo, Francesc Valls, and others (2014) also proved that the use of a visualization system can stimulate students' learning interest and improve the quality of their graduation design and final academic performance.

Kunyanuth Kularbphettong et al. (2019) Employing AR in classroom instruction, they observed an increase in student concentration on learning activities. Jun Lee et al. (2012) used AR technology to create a veterinary education simulator. A veterinary education simulator based on augmented reality technology was made. The performance assessments indicate that the system enhances academic achievement over conventional approaches.

On the other hand, Iulian Radu (2014) found that users are still significantly more motivated. It was found that users of AR systems (compared to non-real-time augmented reality systems) were much more motivated. After examining 26 comparative AR studies, she determined the necessity for guidelines to create effective educational AR experiences.

Other research, by Phil Dingman et al. (2015), argues that AR qualifies for use in educational Settings. Every application must be implemented thoroughly to prevent abuses in user interaction. Afshan Ejaz et al. (2019) argue that there are many differences between traditional graphical user interfaces and AR-based user interfaces. To address some of the challenges of integrating AR technology into DMA learning environments, usability principles provide a systematic framework to address these challenges and create user-centered, effective, and engaging AR learning experiences. Applying usability principles ensures that AR interfaces are intuitive and efficient and enhances the overall learning process by reducing cognitive load, minimizing errors, and increasing user satisfaction. By focusing on usability, educators, and developers can unlock the full potential of AR technology in education and provide learners with a seamless and meaningful experience that supports their learning goals. Therefore, we should better understand the existing usability principles.

2.3 Review of Research Related to Usability Principles

2.3.1 Overview of Ten Usability Principles

Usability principles are a set of guidelines and best practices for designing and evaluating user interfaces, systems, and products to optimize their effectiveness, efficiency, and user satisfaction (Nielsen & Molich, 1990). These principles focus on creating interfaces that are intuitive, user-friendly, and offer a satisfying experience.Specific quantitative data collection is explained in more detail in Table 4.9. Widely used, recognized, and general usability principles are the ten usability Principles (Nielsen, 1994) (Figure 2.6). Here is an overview of Nixon's ten usability principles:

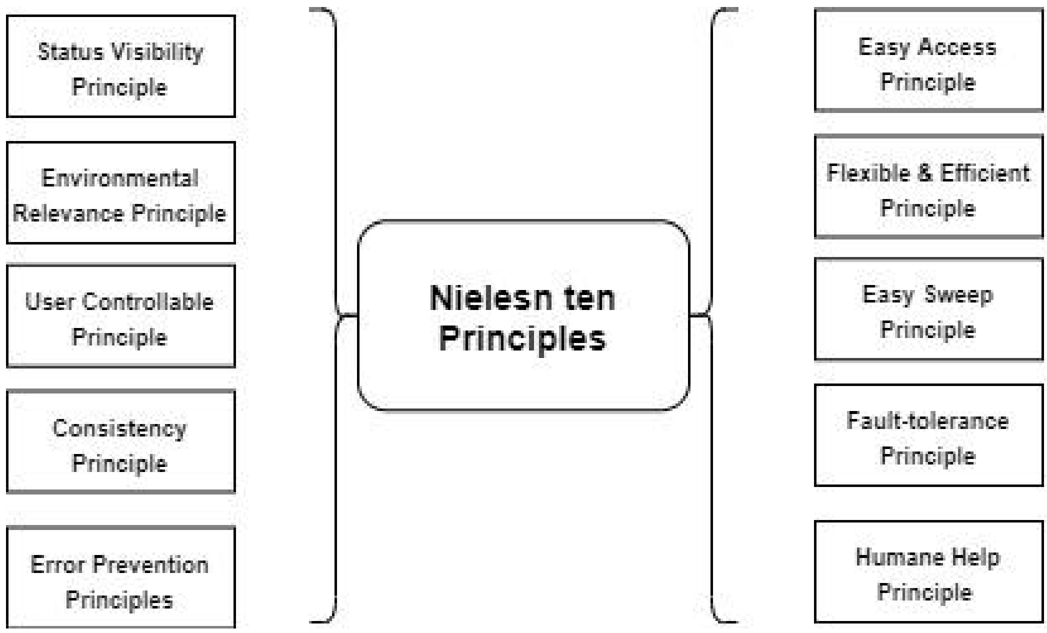

Figure 2. 6. Usability Principles
(Picture Credit: Author's Self-Drawn)

(1) State visibility principle: Users should be aware of what is happening in the system by providing clear and timely feedback on what they are doing. Users should always be aware of the current state of the system and understand how their input is being processed.

(2) Principle of contextual relevance: Use language, concepts, and representations that are familiar to users to make the system more intuitive and easier to learn. The system should reflect the user's mental model and use their existing knowledge to facilitate smooth interaction.

(3) The principle of user control: This allows users to easily navigate and undo actions, providing them with a sense of control and the ability to recover from mistakes. Users should have the freedom to explore and experiment without fear of irreversible consequences.

(4) Principle of Consistency: Ensure consistency in interface design, following

established standards and conventions to minimize cognitive burden and enhance usability. Consistent design patterns and interactions make it easier for users to learn and navigate the system.

(5) Error-proofing principles: Design interfaces in a way that minimizes the occurrence of errors, for example by providing clear error messages, validation checks, and confirmation dialogues. Error prevention focuses on proactive measures to guide users and prevent them from making mistakes.

(6) Ease of access principle: Minimize the need for users to recall information from memory by providing visible and easily accessible prompts, labels, and instructions. The system should present information in a way that prompts recognition, rather than requiring users to recall information from their memory.

(7) Principle of flexibility and efficiency: Meet the needs of novice and expert users by providing shortcuts, customizable options, and efficient workflows. The system should allow users to tailor their experience to their specific needs and provide shortcuts for experienced users to perform tasks faster.

(8) Easy-to-scan principles: Aim for simplicity and clarity in design, removing unnecessary elements that may distract or confuse users. Aesthetic design focuses on creating visually pleasing interfaces, while minimalist design aims to eliminate clutter and simplify the user experience.

(9) Error tolerance principles: Provide informative error messages, recovery advice, and guidance to help users resolve errors and continue to perform tasks. When an error occurs, the system should provide clear explanations and actionable instructions to help the user resolve the error.

(10) Human help principles: Provide easily accessible and contextually relevant help

resources to help users understand and navigate the system. Help and documentation should be readily available and provide relevant information when users need help or seek additional guidance.

These usability principles, when applied effectively, contribute to the overall usability and user experience of digital products and systems, increasing user satisfaction and successful interactions.

2.3.2 Elements of Usability Principle

Usability principles are essential to creating effective and engaging learning experiences in the field of DMA. These principles guide the design and implementation of intuitive, efficient, and user-centered instructional materials. Effectiveness, efficiency, ease of learning, error-proofing, and user satisfaction were extracted through a review of the overview of Nielsen's ten usability principles, as shown in Table 2.3. It can enhance learner engagement, comprehension, and creativity.

Table 2.3

Elements of Usability Principle

Elements	Explanation	Citation
Learnability	The ease with which users can learn to use the system or interface.	Nielsen, J, (1993).
Efficiency	The speed and efficiency with which users can perform tasks using the system or interface.	Shneiderman, B, (1998).
Memorability	The ease with which users can remember how to use the system or interface after a period.	Norman, D. A, (2013).
Error Prevention	Designing systems or interfaces that minimize the occurrence and impact of user errors.	Preece, J., Rogers, Y., & Sharp, H, (2002).
User Satisfaction	The overall satisfaction and positive user experience with the system or interface.	Tractinsky, N, (1997).

The first is effectiveness, (Nielsen,1993) introducing the concept of the usability heuristic, which incorporates several elements related to AR instructional design models. According to their research, effectiveness is the degree to which users can accurately and completely accomplish their goals using AR instructional design models. The model should help learners achieve their desired learning outcomes in DMA by ensuring that content and interactions are aligned with their educational goals. In the augmented reality teaching model of DMA, effectiveness largely promotes successful learning outcomes in DMA. Assess the model's ability to communicate key concepts, promote creativity, and enhance understanding of the principles of DMA.

The second is efficiency, which, as described by Nielsen (1993), refers to the resources that learners spend to achieve their goals. In the context of the AR teaching model, efficiency can be achieved by providing intuitive navigation, simplified interaction, and minimizing unnecessary steps or cognitive load. Learners should be able to navigate and effectively access DMA content in an AR environment to optimize their learning experience. In the DMA augmented reality teaching model, efficiency is a measure of the speed and resource efficiency of users in achieving learning goals in an augmented reality environment. Analyze the time and effort required by users to browse teaching content, complete tasks and achieve teaching goals.

Then there is learnability, as Shneiderman (1998) said, learnability is another essential element. It focuses on how easily learners can understand and use AR instructional design models of DMA without extensive training or prior knowledge. The model should be designed with clear instructions, intuitive interactions, and an easy-to-follow structure that enables learners to quickly master functions and navigate the AR environment with minimal obstacles. In the DMA augmented reality teaching model, the intuitiveness and simplicity of the design enable users to quickly learn how to interact with and navigate the augmented reality teaching model. Evaluate the learning curve for teachers and students in seamlessly adopting and leveraging AR capabilities.

Secondly, error prevention, Pulis, Rogers, and Sharp (2002). Referring to error prevention involves designing AR instructional design models in a way that minimizes errors and supports error recovery. A combination of clear visual cues, feedback on information, and error-prevention mechanisms should be used to guide learners and prevent them from making mistakes that may hinder their progress or understanding of DMA concepts. In the augmented reality teaching model of DMA, the ability of the augmented reality teaching model to minimize user error during interaction. Examine functional and design elements to prevent misinterpretation, misreading, or accidental manipulation for a more accurate, error-free learning experience.

Finally, user satisfaction focuses on learners' subjective perception of the AR instructional design model. Learners should find this model enjoyable, attractive, and satisfying, which will encourage them to continue using it and motivate them to study DMA (Tractinsky.1997). In the DMA augmented reality teaching model, teachers and students' overall positive cognition and satisfaction with the augmented reality teaching model. Gather feedback on user experience, preferences, and perceived benefits to understand the overall satisfaction and acceptance of the teaching model.

The above five indicators provide a framework for evaluating the usability of augmented reality teaching models in the specific context of DMA education, with specific qualitative data collection set out in Table 4.10. Applying these usability principles to DMA teaching fosters a user-centered learning environment that increases student engagement, understanding, and creativity. By focusing on ease of learning, efficiency, and other factors, educators can create impactful instructional materials that enable learners to excel in the DMA.

2.3.3 Usability of AR Technology Applications

We analyzed current literature on AR applications, categorizing the identified issues into four groups, as depicted in Table 2.4. The research pertains to location-based smartphone AR apps and their associated usability challenges.

Table 2.4

Usability Features of AR Applications

Usability Feature	Description	Citation
AR Interacting with a Small Display Device	Designing interfaces optimized for smaller screens of devices like smartphones or smart glasses.	Bimber, O., & Raskar, R. (2005)
Multimodal Interface	Integrating multiple modes of interaction (voice commands, gestures, touch) for flexibility and inclusivity.	Billinghurst, M., & Kato, H. (2002)
Limited Manipulation	Providing simplified and intuitive controls for effective interaction in scenarios with restricted physical movement.	Dünser, A., Grasset, R., & Billinghurst, M. (2009)
User on the Go	Delivering concise and easily accessible information for users who are mobile or engaged in other activities.	Reitmayr, G., & Schmalstieg, D. (2007)

Swan et al (2005) studied usability principles for AR. In the domain of human-computer interaction (HCI), they discovered that a mere 14.3% of studies embraced user-centered design, with 7.9% focusing on general application. Subsequently, the researchers categorized user-centered AR studies into three categories: the first explored understanding how users perceive and recognize AR operations, and evaluating user performance on tasks, and the third involved communication with AR users. They identified a scarcity of research on user interfaces and interactions from a user-centered viewpoint.

Another researcher, Dünser et al (2009), extended Swan and Gabbard's research. Until 2007, they worked on AR research and discovered that merely 10% had carried out user-driven AR experiments. It was also found that there were only 41 studies of actual usability, excluding performance and perceptual studies, views, and endorsements.

2.3.4 AR Application Usability Principles of Smartphone Environments

According to Gasiorowski et al. (2015), the usability principles of AR applications in smartphone environments include ease of use, smoothness, realism and alignment, context-awareness, adaptability, exception handling, and privacy protection, which are as follows:

First, ease of learning and use: AR applications should have simple and intuitive user interfaces and operations so that users can quickly get started and naturally interact with virtual content.

Second, smoothness and fluency: AR applications should provide smooth image and animation rendering, avoid buffering and delays, and ensure a lag-free user experience.

Third, realism and alignment: AR apps should be able to accurately track and align virtual content with the real environment so that it seamlessly blends with the surrounding objects and scenes to provide a more realistic feel.

Fourth, context-awareness: AR applications should leverage smartphone sensors (e.g., cameras, gyroscopes) and data (e.g., GPS, accelerometers) to achieve perception and understanding of the user's environment, providing a personalized and interactive AR experience.

Fifth, adaptability: AR applications should be able to adapt to different devices, scenarios, and network conditions, with adaptability and flexibility to ensure normal operation in various situations.

Sixth, abnormality handling ability: AR applications should have good error handling and abnormality handling mechanisms, timely feedback to the user, and provide solutions to avoid users losing trust in the application.

Seventh, privacy protection: AR apps should comply with privacy norms, clearly inform users of the purpose of data collection and use, provide the necessary authority control and data protection, and safeguard the security of users' personal information.

2.3.5 Usability Testing

Usability testing is a crucial aspect of the design process and development process, especially when creating digital products or applications. It involves assessing the usability and UX of a system or interface by observing and collecting feedback from users as they interact with the product. This is shown in Table 2.5. Usability testing helps to pinpoint potential usability concerns, understand user behavior, and make informed design decisions to enhance the overall user experience.

Table 2.5
Usability Testing Essentials

Points	Explanation	Citation
Purpose	The primary purpose of usability testing is to assess how well users navigate, understand, and complete tasks within a system or interface.	(Lazar et al,2017)
User Engagement	Usability testing involves recruiting representative users who match the characteristics of the target audience and observe their interactions and feedback.	(Nielsen,1993）
Testing Environments	Usability testing can be conducted in controlled laboratory settings or natural environments based on research objectives, resources, and constraints.	(Tullis&Albert,2008）
Methods & Techniques	Usability testing employs methods like think-aloud protocols, observation-based studies, questionnaires, and performance metrics for data collection.	(Rubin&Chisnell,2008)

Therefore, in this study, usability testing will be combined with the contents of the questionnaires in Appendix A and Appendix B to evaluate the model developed by experts and users.

2.4 Review of Research Related to Instructional Design

2.4.1 Theoretical Foundations of Instructional Design

In recent years, the theoretical underpinnings in educational design have continued to evolve, covering a wide range of aspects such as behaviorism, constructivism, epistemology, pragmatism, engagement theory, and cognitive load theory, as shown in the following paragraph of the specific literature review overview. These theories provide rich views on educational design and facilitate the optimization of the learning experience.

First, behaviorist theory emphasizes the relationship between external stimuli and responses. Landers&Callan,2019 explored the application of behaviorism in online and gamified learning, for example, the use of feedback mechanisms and reward systems to enhance learning motivation. Second, constructivist theory remains an important foundation for instructional design. Hwang&Chen,2019 explored how collaborative learning and project-oriented learning can be used to promote the co-construction of knowledge. Epistemological theory focuses on the cognitive process of learners and emphasizes the construction of knowledge. In recent years, studies have concentrated on how to support the management of cognitive load and the effective organization of knowledge through technology (Kalyuga, 2020). Pragmatism theory emphasizes the combination of learning and practical application. In recent years, research has focused on improving student learning experiences and application through real-world problems and projects (Garrison & Anderson,2020). Then secondly, engagement theory emphasizes the active participation of learners.

Veletsianos & Shepherdson, in their 2016 study, explored how to promote learner interaction facilitated teamwork and interaction via digital channels and web-based tools. Finally, the application of cognitive load theory in instructional design has received increasing attention. Plass & Pawar, in their 2021 study, explored how to optimize learning outcomes through multimedia design and information presentation.

Currently, many studies have combined both theories, behaviorism and constructivism, to develop more effective instructional strategies (Huang & Liaw, 2018).

2.4.2 Learner-Centered Instructional Design

In recent years, the theory of learner-centered instructional design has received increasing interest from educational scholars and professionals. In learner-centered instructional design, it is crucial to promote the active participation of learners. According to Huang and Seng (2020), classroom activities need to should be crafted to be emphasizes active student participation and enhances learning through interaction and collaboration. Customizing instruction based on learners' interests and needs can significantly improve motivation and effectiveness (Aguirre et al., 2021). Freeman et al. (2021) stated that the design of blended and online educational settings must make full use of technological aids for enhancing flexibility and convenience in learning. Meanwhile, collaborative learning not solely boosts learning outcomes yet also fosters the development of social skills (Dillenbourg, 2019).

2.4.3 Advantages of Augmented Reality in Instructional Design

AR technology provides learners with an immersive experience by overlaying digital data onto the actual surroundings (Azuma, 1997). In recent years, the use of AR technology in education has increased and can provide an interactive platform for science, math, art, and other disciplines to enhance the overall quality of students (Martínez et al., 2021). This interdisciplinary integration provides teachers with more opportunities for creative teaching, especially in art and design courses (Fowler &

Dineva, 2020). A study by Wu et al. (2019) discovered that learners who participated in AR activities showed significant increases in both motivation and engagement. Through hands-on practice, students achieved a more profound grasp of the process and principles of creating artwork, thus enhancing their creativity. Kumar et al. (2021) found that when learners used AR tools for self-directed learning, they were able to achieve higher knowledge retention and satisfaction with their learning.AR technology can assess students' performance through real-time data collection and analytics, which provides teachers with more feedback (Huang & Liaw, 2022).

2.4.4 Usability Principles in Instructional Design

2.4.4.1 Usability Definition and Importance

Usability usually refers to the efficiency, effectiveness, and satisfaction of a user in using a product or system in each context. Nielsen (2018) suggests that usability relates to an individual's capacity to understand, learn, and operate a system's interface, highlighting the significance of improving the user experience. As per the ISO 9241-11 guidelines standard, usability is characterized as "the performance, productivity, and contentment of the user in achieving a goal in a given context".

Furthermore, Garrett (2019) emphasizes the importance of usability design, stating that it not only affects the actual operation of the user as well as the user's psychological perception and overall experience, particularly within educational contexts. With the creation of technology, especially within AR applications, the usability of user interfaces is increasingly emphasized. In instructional design, good usability can ensure that learners get started quickly, increasing learning efficiency and satisfaction (Shneiderman & Plaisant, 2010).

2.4.4.2 Usability Relevance and Importance

According to research, usability has a direct impact on learner effectiveness and motivation. Zhang et al. (2020) stated that in educational technology environments, systems with high usability are more appealing to learners and increase their engagement and knowledge acquisition. If the usability of the system is low, learners will be frustrated, which in turn affects learning outcomes.

Meanwhile, Alcántara et al. (2021) discussed the impact of usability on educational equity, arguing that usability design can provide equal learning opportunities for learners from different backgrounds and help them overcome technological barriers. In courses related to digital media arts, there is a particular need to focus on usability to enhance the creative experience and promote students' creativity.

2.4.4.3 Connection between Usability and Learning Outcomes

Several studies have found that higher usability tends to be associated with better learning outcomes. First, Ho and Lee (2017) noted that in digital learning environments, the greater the usability of the system, the more elevated the actual usage and engagement of learners. User-friendly interfaces and intuitive navigation designs enable learners to retrieve and manipulate information more efficiently, thus facilitating deeper learning. For example, online courses with well-designed interfaces accelerate learners' digestion and understanding of content.

Second, Zhang et al. (2020) examined how usability impacts learning motivation. They found that a learning platform with high usability can increase learners' intrinsic motivation and make them more actively involved in learning activities. This positive engagement attitude further enhances the effectiveness of learning.

In addition, Chen et al.'s (2021) study of usability in mixed reality technology showed that users who use augmented reality learning tools with well-designed and easy-to-use interfaces will significantly increase learners' knowledge retention rate and application ability. This finding emphasizes the importance of well-designed usability in teaching digital media arts. In digital media art courses, user-friendly interfaces and simple operation processes can help learners focus more on learning content rather than technical details, thus enhancing the learning experience.

2.4.5 Evaluation and Feedback Mechanisms for Instructional Design

2.4.5.1 Importance of Evaluation

The importance of assessment in instructional design is reflected in several ways, especially in digital media arts and mixed augmented reality environments. Assessment is not only used to measure learners' learning outcomes but also provides feedback to the instructional design for appropriate adjustment and optimization.

First, Wang et al. (2019) argued that effective assessment promotes learners' self-awareness and increases their engagement in the learning process. Through timely feedback, learners can understand their strengths and weaknesses, which motivates them to self-regulate and improve. This self-regulation ability is especially crucial for the learning of complex skills, especially in the field of art and design.

Second, Huang et al. (2020) emphasized the real-time nature and flexibility of assessment in digital learning environments. Their study shows that real-time assessments (e.g., adaptive tests and interactive feedback) reflect learners' true level better than traditional final exams and enable rapid adjustment of teaching strategies, thus improving learning outcomes.

In addition, for the application scenario of mixed augmented reality, Koh et al. (2021) pointed out that assessment should not only focus on knowledge acquisition but also on learners' attitude changes and skill development when using new technologies. Their study showed that a more comprehensive understanding of learners' performance in emerging environments can be achieved through effective assessment frameworks.

Therefore, assessment becomes a vital component of feedback on the effectiveness of instruction and education (Garrison & Ehringhaus, 2007). Effective assessment tools can help teachers make timely adjustments to their teaching strategies to improve learning outcomes.

2.4.5.2 Feedback and Learner Reflection in Real-Time

Real-time feedback is widely recognized as an important factor in enhancing learning outcomes. Real-time feedback not only provides the necessary information to help learners make immediate adjustments to their learning strategies but also provides a basis for learner reflection. Reflective learning is the process through which students can understand their educational journey status more fully by thinking about and evaluating what they have learned.

Hattie and Timperley's (2020) study showed that timely feedback significantly improves learners' self-efficacy and academic achievement. Dunn et al. (2019) noted that real-time feedback is particularly important in digital learning environments because it can quickly correct learners' errors and reduce misunderstandings. In mixed augmented reality environments, learners can experience a more vivid and intuitive learning process through interactive feedback. This type of immediate feedback encourages learners to think deeply about the learning content, which promotes reflection.

Meanwhile, Zhang et al.'s (2021) study emphasized the link between real-time feedback and learner self-regulation. They found that when learners have access to real-time feedback, they are more likely to engage in self-assessment, which in turn triggers reflective behavior. Such reflection involves not only understanding of knowledge but also assessment of the learning process, which promotes persistence and depth of learning.

In addition, Li et al. (2020) investigated feedback mechanisms in digital environments, noting that timely feedback can significantly increase learners' motivation and engagement, which in turn enhances learners' reflective skills. Their study showed that the immediacy and interactivity of feedback when using augmented reality further enhanced learners' learning outcomes and reflective skills.

2.5 Review of Research Related to DMA

2.5.1 Current Teaching Practices

As shown in Table 2.6, each example of DMA instruction is illustrated with its corresponding citation. These examples highlight the diverse range of DMA instruction, including digital painting and illustration, 3D modeling and animation, video production and post-production, and interactive media design.

Table 2.6

Current Teaching Practices

Example	Explanation	Citation
Digital Painting and Illustration	Digital media painting provides students with more creative freedom and room for experimentation, allowing them to better express their creativity and ideas.	（Lowe, 2019）
3D Modeling and Animation	Spatial thinking, creativity, and teamwork skills can be developed through the study of 3D modeling and animation in DMA.	（Chiang et al., 2020）
Video production & post-production	Video production and post-production in DMA develop students' editing skills, storytelling skills, and visual expression.	（Nagata & Sugiyama, 2018）
Interactive Media Design	Through interactive media design in DMA, students can develop their user experience design skills and technology implementation skills.	（Lee & Liu, 2019）

2.5.2 DMA Teaching and Learning Approaches

As shown in Table 2.7, each example of DMA teaching and its corresponding citation is described. These examples highlight the multiple methods used in teaching DMA, including workshops, online courses, critique sessions, exhibitions, and academic courses. These teaching methods provide opportunities enabling students to cultivate technical skills, engage regarding critical analysis skills, explore creative concepts, and gain insight into DMA.

Table 2.7

Examples of DMA for Current Teaching

Example	Explanation	Citation
Workshops	Hands-on learning experiences in various aspects of DMA through practical exercises and collaborations.	Humphreys, L. (2016)
Online Courses	Flexible and accessible instruction through online courses covering various DMA topics.	Bishop, R., & Yancy, T. (2018)
Critique & Analysis	Examination and discussion of digital artworks to develop analytical skills and expand visual literacy.	Smith, B., & Schreiber, B. (2019)
Exhibitions	Platforms for students to showcase their digital art creations, gain exposure, and receive feedback.	Manovich, L. (2016)
History & Theory Classes	Exploration of the historical development and theoretical frameworks of DMA.	Paul, C. (2018)

Workshops at the DMA provide students with hands-on learning experiences in various aspects of DMA, such as digital photography, graphic design, video production, or animation, according to the table above. These workshops typically include hands-on exercises, demonstrations, collaborative projects, and guest artist sessions. Students learn technical skills, explore different tools and techniques, and engage in creative expression under the guidance of experienced faculty (Humphreys, 2016).

Secondly, Online DMA programs offer flexible and convenient instruction in DMA for students at all levels. These classes encompass various subjects, including digital ones. image editing, web design, multimedia narratives, 3D modeling, and digital art theory. Through video lectures, interactive assignments, forum discussions, and personalized feedback, students learn on their own, increase technical proficiency, and explore creative concepts in the digital realm (Bishop & Yancy, 2018).

The critical and analytical courses in DMA instruction focus on the examination and discussion of digital artworks created by students or professional artists. These courses include interpretation and evaluation of artistic techniques, aesthetic choices, conceptual ideas, and cultural contexts. Through guided discussion, peer feedback, and critical reflection, students develop their analytical skills, expand their visual literacy, and gain a deeper understanding of the nuances of DMA (Smith & Schreiber, 2019).

DMA exhibitions provide a platform for students to showcase their creative work in a physical or virtual gallery. These exhibitions can be organized within an educational institution or in collaboration with external venues. Students showcase their DMA projects to a wider audience, allowing them to gain exposure, receive feedback, and build professional networks. Exhibitions foster a sense of accomplishment, encourage students to refine their artistic vision, and develop their confidence as DMA (Manovich, 2016).

Finally, the DMA Theory class explores the theoretical frameworks and critical perspectives of DMA. Students learn about the evolution of digital art, influential artists and movements, and the sociocultural impact of technology on artistic practice. Through lectures, readings, discussions, foundations, and conceptual foundations of DMA (Paul, 2018).

2.5.3 DMA Teaching and Learning Technology

The DMA field is inherently intertwined with technology, and the field utilizes a variety of technological tools and platforms in its instruction. Below is a review of some of the key technologies used to teach and learn DMA:

First are some of the design tools like Adobe Creative Suite (Photoshop, Illustrator, InDesign) and CorelDRAW, which are widely recognized in the industry. graphic design software is an important tool for teaching graphic design concepts (Adobe, 2021). Students will learn how to manipulate images, create visual compositions, and design layouts that communicate information effectively.

Secondly, animation software such as Adobe Animate and Toon Boom Harmony allow students to animate their creations (Toon Boom Animation, 2021). They learn animation principles, character design, and storytelling techniques, which are crucial for both 2D and 3D animation. Software for video editing like Adobe Premiere Pro and Final Cut Pro provides students with the capabilities to process and refine video content (Apple, 2021). Students learn video compositing, editing techniques, and post-production processes.

For students who delve into 3D DMA,applications like Autodesk Maya, Blender, and Cinema 4D enable them to create 3D models, scenes, and animations. They learn modeling, texturing, lighting, and rendering in 3D space (Blender Foundation, 2021). Several interactive media tools such as platforms like Unity and Unreal Engine facilitate the creation of interactive digital media experiences (Unity Technologies, 2021). Students learn to build immersive environments, games, simulations, and interactive applications that engage users in novel ways.

Digital drawing boards, such as Wacom devices, replicate the traditional drawing experience while enabling students to create digital illustrations, sketches, and conceptual art directly on the screen (Wacom, 2021).

For students exploring VR and AR, tools such as Oculus Medium, Tilt Brush, and ARKit provide a platform for designing and developing virtual and augmented experiences (Oculus, 2021). These technologies enable students to create immersive worlds and superimpose digital elements onto real-world environments.

These technologies form the technological cornerstone of teaching the dynamic field of DMA. By incorporating these tools into the curriculum, educators can equip students with the technical prowess and creativity needed to thrive in the diverse world of digital media.

2.5.4 Application of AR in DMA

AR technology offers a wide range of applications in the DMA, transforming the way art is created, presented, and experienced. By overlaying digital content onto actual settings, AR offers artists and audiences the unique opportunity to interact with art in innovative and immersive ways, blurring the boundaries between boundaries between the tangible and digital worlds. In this section, we explore several relevant applications of AR technology in DMA, which include interactive art installations, virtual exhibitions, immersive storytelling, collaborative art making, and digital visualization, as shown in Table 2.8. Their significance and impact on the art world is highlighted.

Table 2.8

Augmented Reality in DMA

Application	Description	Citation
Interactive Art Installations	AR is used to create interactive installations where viewers can engage with digital artworks in real-time, using gestures or object recognition.	Schnädelbach et al,.2008)
Virtual Exhibitions	AR creates virtual gallery spaces, enabling viewers to remotely explore digital art collections and interact with artworks through mobile devices.	Gosling & Turner, (2012)
Immersive Storytelling	AR enhances storytelling experiences by overlaying virtual elements onto physical objects or spaces, creating narratives that seamlessly blend the real and virtual worlds.	Brade et al. (2016)
Collaborative Art Creation	AR facilitates real-time collaboration among multiple artists, enabling them to work together on shared virtual canvases or sculptures, fostering artistic collaboration.	Billinghurst et al. (2002)
Digital Visualization	AR enhances the visualization of DMA in physical spaces by overlaying virtual elements onto physical artworks or exhibition spaces, providing an immersive and interactive viewing experience.	Encinas et al. (2019)

Firstly, a crucial application of AR in DMA is interactive art installations. As shown in Figure 2.7, Landon International's Rain Room: is an engaging artistic exhibit in which visitors can traverse simulated environments rainfall without becoming wet.Motion-detecting sensors detect the presence of the viewer and create localized rain-free zones, enabling them to navigate through falling water. Also shown in Figure 2.8, is Chris Mielke's Betrayal in the Shelter: an interactive installation that combines motion capture technology with projection mapping. Visitors can position oneself before a sizable display and experience a journey of transformation from human to bird by controlling virtual wings through arm movements. Also shown in Figure 2.9. is the abstract landscape by Adrien M and Claire B.: visitors can interact with the projected image by touching or blowing on it, thus creating a dynamic visual transformation and an interesting and immersive environment.

Secondly, Schneiderbach et al. (2008) discuss the use of AR to create interactive installations that allow viewers to interact in real-time with digital artworks through real-time interaction. By utilizing AR, these installations provide viewers with a dynamic and an immersive artistic encounter, allowing them to manipulate and engage with virtual elements using gestures or object recognition. This level of interactivity enhances the engagement and connection between the viewer and the artwork, creating a more immersive and memorable experience.

Figure 2.7. Rain Room

(Picture Credit: Internet)

Figure 2.8. The Treachery of Sanctuary

(Picture Credit: Internet)

Figure 2.9. XYZT: Abstract Landscapes
(Picture Credit: Internet)

The other, another notable application of AR in DMA is virtual exhibitions. The Louvre Museum in Paris, as shown in Figure 2.10, offers virtual tours that allow users to explore iconic artworks and galleries. Users can browse the museum's floor plan, zoom in on artworks, and access audio and text descriptions to learn more about the masterpieces housed within the museum. Also shown in Figure 2.11, The Metropolitan Museum of Art: 360° Project. allows users to virtually visit and explore the Metropolitan Museum of Art in NYC. Through a series of high-resolution panoramic images, users can browse through the different galleries, see artworks up close, and access more information about the works and artists. Examples such as the Museum of Modern Art (MoMA) Virtual View and the British Museum Virtual Experience showcase virtual exhibitions, offering patrons an immersive and informative encounter that allows them to explore prestigious museums and access a vast array of art and cultural artifacts from around the world.

Meanwhile, Gosling and Turner (2012) explore the use of AR to create virtual gallery spaces in which viewers can explore digital art collections remotely. Through AR technology, viewers can utilize their smartphones to tap into the virtual exhibition, view and interact with the artworks, and gain more information about the work or artist. The virtual exhibition extends the accessibility of DMA, allowing a wider audience to interact with the artworks wherever they are. It also provides a personalized and customizable exhibition experience, allowing viewers to navigate the virtual space at their own pace and explore the artworks according to their interests.

Figure 2.10. The Louvre Virtual Tour
(Picture Credit: Internet)

Figure 2.11. The Met: 360° Project
(Picture Credit: Internet)

The other, Immersive storytelling is another compelling application of AR in DMA. As shown in Figure 2.12, 'Tree' is a VR experience that places the viewer in the heart of a rainforest, witnessing first-hand the effects of deforestation and climate change. Through a combination of VR visuals, spatial audio, and physical interaction, the audience can engage with the narrative and become immersed in the story. Breed et al. (2016) discuss leveraging AR to boost the storytelling interaction by superimposing virtual elements onto physical objects or spaces. By incorporating AR into storytelling, artists can create narratives that seamlessly blend the real and virtual worlds. AR-driven storytelling opens new possibilities for artists to engage and captivate audiences, providing a unique and memorable narrative experience.

Figure 2.12. Tree

(Picture Credit: Internet)

Collaborative artmaking is another important application of AR in DMA. Billinghurst et al. (2002) highlight the use of AR technology to enable multiple artists to collaborate in real time, regardless of their physical location. Collaborative AR art systems allow artists to work together on a shared virtual canvas or sculpture, thereby enhancing communication and facilitating artistic collaboration. As shown in Figure 2.13, Phillip Schütte and Christian Mio Loclair's Shadow Monsters, the silhouettes of participants are transformed into colorful animated creatures. Multiple participants can engage in a shared creative experience by interacting with their own and each other's shadows, resulting in a collaborative and dynamic visual display. This use of AR breaks down barriers and enables artists to collaborate on DMA projects, pushing the boundaries of creativity and opening new avenues for artistic expression.

Figure 2.13. Shadow Monsters

(Picture Credit: Internet)

In addition, AR technology can be used for the digital visualization of art exhibitions. Encinas et al. (2019) discuss the application of AR in augmenting DMA visualization in physical space. By superimposing virtual elements onto a physical artwork or exhibition space, AR technology enriches the viewer's experience by providing additional layers of information, animation, or interactive elements. It allows the viewer to explore the artistic process in greater depth, gain insight into the artist's intentions, and explore DMA in a more immersive and interactive way.

These applications of AR technology in DMA demonstrate its potential to transform the art world. By adopting AR, artists and audiences can engage in new forms of artistic expression, collaboration, and storytelling. AR enriches the art experience by increasing interactivity, immersion, and accessibility, redefining the boundaries of traditional art practices, and inviting audiences into the fascinating and dynamic world of DMA.

2.5.5 DMA Teaching and Learning Challenges

Education within DMA offers exciting opportunities for creative exploration and technological innovation. However, this dynamic field also presents several challenges that educators, students, and institutions must address to ensure effective education and meaningful skill development. The following is a review of some of the current challenges to teaching DMA:

First, technology in the field of DMA is rapidly evolving, and teachers and students need to constantly keep up with the latest technological trends and tools. As Hsu et al. (2021) pointed out, "Technology in the field of digital media is changing rapidly, and educators must constantly refresh their expertise and competencies to provide students with the latest teaching content."

Secondly, DMA involves multiple fields and students need to acquire diverse skills. According to Jiang and Lin (2019), teaching DMA involves multiple fields such as image processing, animation production, audio production, programming, etc., and students need to develop a variety of skills comprehensively.

The other, the software and hardware resources required for DMA are relatively expensive, limiting the learning opportunities for some students. According to Wang et al. (2018), DMA education faces the problem of insufficient resources, especially in economically disadvantaged areas where schools often struggle to provide adequate equipment and tools.

The other, DMA emphasizes creativity and personal expression, but for some students, finding the right way to be creative and express themselves can be a challenge. According to Zhou and Wu (2020), DMA teaching needs to equip students sufficiently with guidance and assistance for help them explore their creative potential.

Finally, DMA works are usually multimedia, and providing teachers with timely and effective feedback and conducting assessments can be a challenging task. According to Lee and Shu (2017), DMA teaching needs to explore effective feedback and assessment methods to help students develop their multimedia skills holistically.

2.5.6 Aspects of DMA

When designing an AR instructional design model for DMA based on usability principles, several aspects ought to be considered to guarantee a productive and user-friendly educational journey. These aspects include content delivery, interaction design, feedback mechanisms, adaptability, and customization options, as shown in Table 2.9. By incorporating these usability principles into the AR instructional design model, learners can seamlessly engage with DMA content and enhance their understanding and creativity in the field.

Chen and Chen's (2013) research highlights the importance of content delivery in AR systems for DMA education. They highlight the need for clear and well-organized content presentation to make certain that learners can easily access and understand the data. Designing visual representations that effectively communicate DMA concepts, such as 3D models or interactive animations, can increase engagement and learning outcomes. In addition, research conducted by Martín-Gutiérrez et al. (2015) highlights the significance of interaction design in the AR instructional design model. They argue that intuitive and user-friendly interaction techniques, such as gesture-based control or touch interaction, can facilitate active engagement and promote the exploration and manipulation of DMA elements in AR environments. These interaction design principles help to increase the usability and effectiveness of AR instructional design models.

In terms of feedback mechanisms, Dalgarno and Lee's (2010) research suggests that timely and informative feedback is essential in AR learning environments. Feedback can include visual cues, audio cues, or performance indicators that guide learners' actions, correct misconceptions and enhance their understanding of DMA concepts. Combining effective feedback mechanisms supports the usability of AR instructional design models and enhances the learning experience.

The adaptability and customization options in the AR instructional design model are in line with the research of Zhang and Patel (2006). They emphasize the need to consider individual learner preferences, abilities, and learning styles. Providing adaptive options, such as adjustable difficulty levels or personalized content recommendations, enables learners to customize their learning experience and ensures that the AR instructional design model is inclusive and user-centered in its design.

By integrating these aspects based on usability principles, the AR instructional design model for DMA can provide learners with an immersive, engaging, and effective learning experience. These aspects promote usability, learner-centered design, and the integration of DMA concepts with AR environments.

Table 2.9

Aspects of DMA

Aspects	Explanation	Citation
Visual Imagery	The use of visual elements, such as images, graphics, and animations, to convey artistic expression.	Manovich, L, (2002).
Sound & Music	Incorporation of audio elements, including music, sound effects, or ambient sounds, to enhance the artistic experience.	Collins, K, (2008).
Interactivity	Interaction between the artwork and the viewer, enabling engagement and participation.	Paul, C, (2011).
Narrative & Storytelling	The use of storytelling techniques to convey a message or evoke emotions through digital media.	Ryan, M. L, (2004).
Multimodality	Integration of different media forms, such as images, text, sound, and video, to create a cohesive artistic experience.	Kress, G., & van Leeuwen, T. (2006).

2.6 Summary

This chapter offers a conceptual foundation for the design of the subsequent model by reviewing the current pedagogical challenges of DMA, the technology used, and the types of AR technology and usability principles.

Overall, Many users remain unacquainted with AR technology, and without substantial gaming experience, they might struggle with the icons and interfaces utilized for AR features. Therefore, the caliber of educational interactions in the field of digital media arts can be significantly enhanced by combining learner-centered pedagogical theories, the advantages of augmented reality technology, an emphasis on the principles of usability, and effective assessment and feedback mechanisms. Subsequent studies may further investigate the incorporation of these factors into a mixed augmented reality model to innovate teaching methods in digital media arts.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter mainly summarizes the specific methods of this research and collects the criteria of target users (experts and users) through interviews and questionnaire design, as well as the needs, pain points, and expectations of digital media art and augmented reality applications and clarifies the usability principles that have a greater effect on the user interaction quality.

3.2 Background

The integration of AR in instructional design for digital media art presents a promising avenue for immersive and effective learning experiences. This study aims to develop a comprehensive AR instructional design model grounded in usability principles to enhance the learning outcomes in the realm of digital media art.

3.3 Research Methodology

This study was designed using an exploratory sequential mixed methods approach as shown in Figure 3.1.

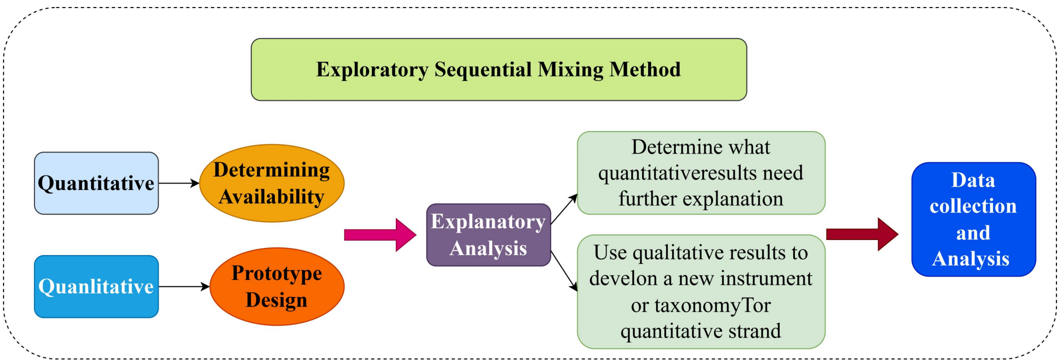

Figure 3.1 Exploratory Sequential Mixing Method

(Picture Credit: Author's Self-Drawn)

The exploratory sequential mixed methods approach was bifurcated into dual stages. During the initial phase, gathering and interpreting qualitative data were prioritized, followed by a second phase that focused on numerical data gathering and examination to validate and refine the emerging AR instructional design model.

Phase 1: QUALITATIVE PHASE

3.4 Preparation Phase

3.4.1 Background Analysis

Based on the content analysis of usability principles, AR technology, and DMA-related principles in Chapter 2, the main challenges and gaps in existing DMA augmented reality teaching models based on usability principles were identified, as shown in Table 3.1.

Table 3.1

Key Challenges and Gaps

Key Challenges & Gaps	Description	Citation
Lack of teacher training and technical support	Limitation of the effectiveness of innovation and implementation of instructional design.	García & García, (2021)
Adaptation of content and methodology	The current AR apps lack personalized adaptation to different learners' needs.	Freeman et al., (2020)
Absence of assessment mechanisms	The current AR education model lacks systematic assessment tools and standards, which affects subsequent instructional improvement.	Wu et al., (2019)
Limitations of technology penetration	Limited diffusion and popularization of AR technology due to lack of technological infrastructure and high cost of equipment.	Kumar et al., (2022)
Users experience design flaws	Ineffective user interface design reduces learning motivation and effectiveness.	Liu et al., (2021)

By comprehensively identifying these challenges and gaps in existing models, educators, instructional designers, and researchers can address these issues when developing augmented reality instructional models for DMA and can implement appropriate strategies and solutions to improve the usability, effectiveness, and accessibility of AR instructional models in DMA education.

For the main challenges and gaps in usability principles can be addressed, the specific needs and requirements of learners in DMA education, as shown in Table 3.2, were analyzed through the literature review method.

Table 3.2
Specific Needs and Requirements

Specific Needs &Requirements	Description	Citation
Immersive & Engaging Experiences	Learners seek immersive and engaging experiences that enable them to interact with DMA concepts in a meaningful way. The AR model should provide dynamic and interactive content for a realistic and engaging learning experience.	Chen et al., (2017)
Visual & Spatial Understanding	DMA involve visual elements and spatial design. Learners need opportunities to develop their visual and spatial understanding. The AR model should facilitate the exploration of visual elements, 3D models, and spatial relationships.	Fonseca et al., (2018)
Collaboration & Feedback	Collaborative work and feedback exchange are important in DMA. The AR model should support collaborative projects, peer-to-peer feedback, and real-time interactions to foster a sense of community and provide valuable input from peers and instructors.	Hsu et al., (2016)
Flexibility & Customization	Learners have diverse learning styles and preferences. The AR model should offer flexibility and customization options, allowing learners to adjust the pace, explore content through multiple pathways, and receive adaptive feedback tailored to their individual needs.	Johnson & Giorgi, (2017)
Integration with Real-World Contexts	DMA education should prepare learners for real-world application. The AR model should incorporate practical instances, research findings, and sector standards into bridge the gap between classroom learning and	Akçayır & Akçayır, (2017)

professional application.

By considering these specific needs and requirements of learners in DMA education, the AR teaching and learning model can address key challenges and gaps in usability principles. It can provide immersive and engaging experiences, support visual and spatial understanding, facilitate collaboration and feedback, offer flexibility and customization, and integrate with real-world environments. These considerations contribute to the development of effective, learner-centered AR pedagogical models in DMA education.

3.4.2 Content Analysis

In the content analysis, the model of the DMA background is comprehensively sorted out, and then the model is compared and analyzed. In the context of DMA, the existing AR instructional design model and usability framework are shown, as outlined below.

The first is a synthesis and organization of frameworks for usability, which in brief has the following five elements（As shown in Figure 3.2）:

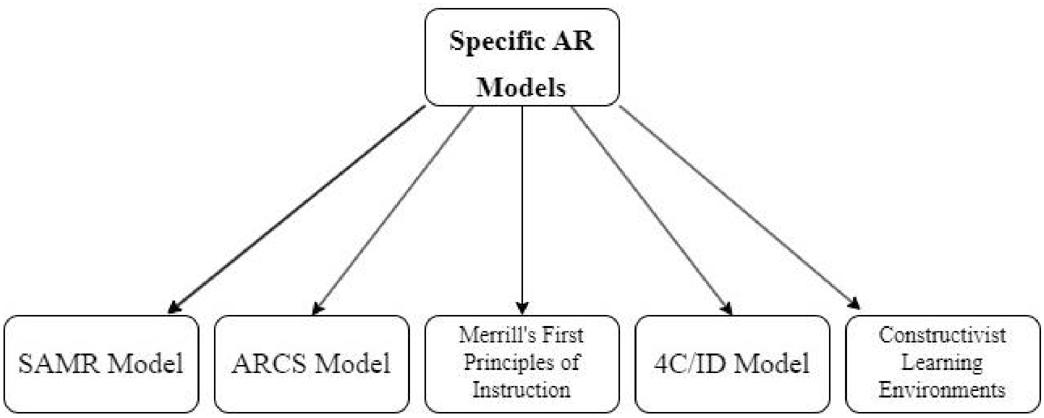

Figure 3.2. Specific AR Models
(Picture Credit: Author's Self-Drawn)

First, Nielsen's Heuristics: It is the application of Jakob Nielsen's usability heuristics to evaluate the efficacy, productivity, and contentment regarding AR instructional design. Second, User Experience (UX) Design Principles: It is to incorporate UX principles such as clarity, simplicity, and consistency into the design process. Finally, ISO 9241-11 standard: It is to evaluate usability concerning ISO standards, emphasizing effectiveness, efficiency, and user satisfaction. Fourth, accessibility standards: It is to ensure that AR instructional design follows accessibility standards so that it can be inclusive of users with different abilities. Fifth, Cognitive Load Theory: It is about managing cognitive load and optimizing learning and understanding by presenting data presented in a manner that is consistent with the human cognitive architecture.

Secondly, the specific AR model has the following five elements in brief（As shown in Figure 3.3）:

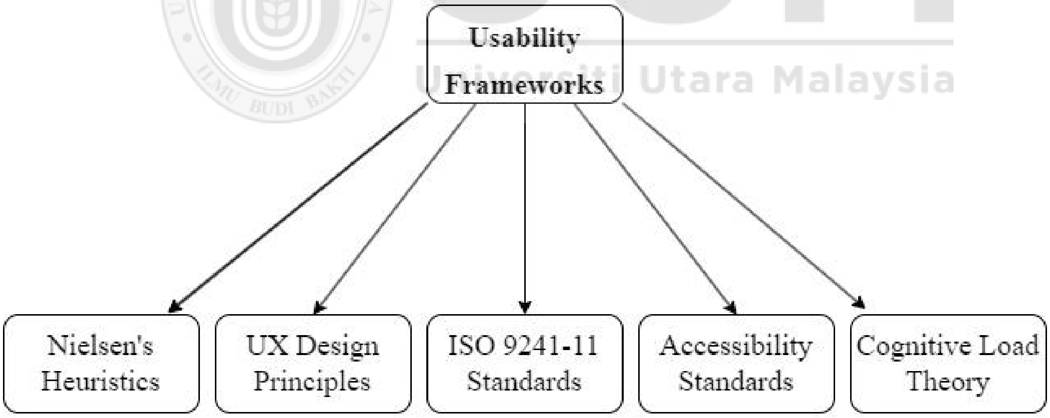

Figure 3.3. Usability Frameworks
(Picture Credit: Author's Self-Drawn)

First, the SAMR model (Substitution, Augmentation, Modification, Redefinition): Categorizes AR applications according to their impact on learning tasks, from basic substitution to transformative redefinition. Secondly, the ARCS framework (Engagement, Pertinence, Assurance, Contentment):Focuses on capturing and maintaining the attention of the learner, emphasizing the relevance of the content, building the confidence of the learner, and ensuring satisfaction with the learning experience. Thirdly, Merrill's First Principle of Teaching: It is emphasizing problem-solving, activating prior experiences, demonstrating, applying, and integrating effective learning experiences using AR. Fourth, the 4C/ID model (Four-Component Instructional Design): Integrates learning tasks that include acquiring, processing, applying, and integrating knowledge through AR applications. Fifth, Constructivist Learning Environment: It implements constructivist principles and encourages learners to actively construct knowledge acquired through exploration and interaction in the AR environment.

3.4.3 Comparative Analysis of Models

In this research, we present a framework for evaluating the usability of smartphone AR applications by considering their properties discussed in section 2.4.4. Our approach involves synthesizing existing studies to develop relevant and appropriate usability principles.

Our goal is to establish usability principles specific to AR app services on smartphones tailored to users' geographic data. We sourced established usability guidelines originating from the works of Atkinson, Bennett, Bahr, & Nelson (2007); Dünser, Grasset, Seichter, & Billinghurst (2007); Gong & Tarasewich (2004); and Kim et al. (2007) (see Table 3.3). Atkinson et al. (2007) focused on heuristic assessment techniques proposed by renowned researchers such as Nielsen, Shneiderman, Tognazzini, and Tufte. They consolidated overlapping concepts and simplified a comprehensive set of heuristics, which we considered a valuable preliminary study for heuristic evaluation in the context of augmented reality on smartphones and usability guidelines. From their work, we identified dozen usability guidelines, such as user-software engagement, ease of learning, and cognitive enhancement(Atkinson et al., 2007).

Table 3.3

Collected Usability Principles

Usability Principles	References
Enhancing cognitive processes, Uniformity, Preset options, Mistake handling, Visual design, Assistance and manuals, Ease of learning, Navigability and exit strategies, Interaction between software and user, Alignment with real-world concepts, Integration of system and software, User autonomy and software adaptability.	Atkinson et al. (2007)
Utility, Fault resilience, Adaptability, Ease of learning, Minimal physical exertion, Cognitive load reduction, Interactive responsiveness and communication, Contentment.	Dünser et al. (2007)
Customization options, Uniformity, Dialogs with clear conclusions, Interaction flow from general to specific, Pleasurable experience design, Attention management for limited focus, Multimodal interface design, Adaptability to various contexts, Quick operation and error recovery, Shortcuts for experienced users, Error avoidance and straightforward handling, Feedback that enhances understanding, Minimizing cognitive load, Action reversibility, Encouraging self-directed control.	Gong & Tarasewich（2004）
Preciseness, Organization, Aesthetics, Uniformity, Manageability, Immediate Interaction, Robustness, User Comfort, Functionality, Productivity, Error Notification, Recognition, Responsiveness, Endurance, Accessibility, Real-world Alignment, Enjoyability, Anticipation, Preventative Measures, Security, Clarity, User Autonomy.	Kim et al. (2007)

Dünser et al. (2007) explored broad human-computer interaction principles pertinent to the design of AR applications. They observed that previous AR studies had predominantly emphasized technological aspects, sometimes overlooking principles focused on user-centric design. To ensure the successful development of AR systems, they advocated for balancing technical issues with user-centered design principles. They examined a range of principles and guidelines for human-computer interaction design leading to enhance AR usability and selected appropriate ones based on their findings. To validate their approach, they presented current research and case studies that demonstrate the link between design principles and the characteristics of AR systems. Consequently, the Dünser et al. (2007) study furnishes valuable initial findings for scholarly investigation interested in studying the user-friendliness of augmented reality apps. From their work, we identified eight usability guidelines, such as cost-effectiveness and minimizing mental effort, and low physical effort (Dünser et al., 2007).

Gong and Tarasewich (2004) examined the characteristics the constraints of mobile device interfaces in comparison to desktop environments. They put forth recommendations for portable mobile device use interfaces based on research on desktop and mobile interfaces and usability. Such design principles are beneficial for human-computer interaction (HCI) experts and professionals focusing on mobile usability and interface design.

Their study serves as a precursor to our investigation into the user-friendliness of AR applications on smartphones within a mobile context setting. For our study, we identified 15 usability goals, including "enabling frequent users to utilize shortcuts," "providing informative feedback," and "designing dialogues for closure" (Gong & Tarasewich, 2004).

Tangible User Interfaces (TUIs) emulate fundamental human senses and behaviors, such as tactile interaction and sensory perception (Ishii, 2008). Augmented Reality overlays digital data onto physical items,bridging the gap between physical and virtual spaces, and leverages real objects for controlling digital information. Given these characteristics, TUIs prove to be suitable interfaces for AR. An example of TUI interaction is the gesture of expanding or reducing objects on a touch screen.

Kim et al. (2008) proposed Guidelines for usability and a structured assessment method for TUIs aim to enhance user interaction assess their Principles for user-friendliness and a process for recognizing design elements considerations.Within the scope of their research, they reviewed existing studies related to usability and retrospectively derived principles adequate for TUIs. Their study provides pertinent preliminary data for comprehending characteristics of TUIs in the context of smartphone-based AR applications. In our research, we identified 25 key usability guidelines, encompassing user autonomy, operability, and responsive feedback (Kim, Kim, Chio, & Ji, 2008). We then held a consultation with experts to deliberate on the criteria for 61 usability principles sourced from Atkinson et al. (2007), Dünser et al. (2007), Gong and Tarasewich (2004), and Kim et al. (2008). We specifically selected these 61 usability principles as they have a direct influence on the characteristics and functionality of mobile AR applications.We employed the following criteria to determine the final set of usability principles.

In line with our criteria for exclusion, we carefully selected and integrated usability principles based on their objectivity, subjectivity, and repetition (refer to Table 3.4). Through the analysis of the relationships between these principles, we ultimately identified 22 key usability principles. For instance, in the context of error management, the prevention of predictable errors allows users to easily perform supported tasks. As error management directly impacts work performance, it was deemed essential and included as a selection criterion.

Table 3.4
Deleted and Integrated Usability Principles

Accessibility, Consistency, Context Sensitivity, Default Settings, Interactive Manipulation, User Engagement, Error Prevention and Resolution, Termination, Intuitiveness, Feedback Mechanisms, Support and Documentation, Organizational Structure, Ease of Learning, Minimal Physical Demand, Multisensory Interaction, Navigability, Customizability, Anticipatory Design, Recognition Over Recall, Speed of Response, User Autonomy, Clarity of System Status.

To further organize these usability guidelines, we constructed an interrelation matrix for demonstrate the connections among the various principles. A value of 2 indicated a clear relationship, 1 indicated an ambiguous relationship, and 0 indicated no relationship. Ten experts, each with a minimum of 2 years of expertise in UI and UX, took part in this process. The results of this analysis are presented in Table 3.5.In this research, each element encompassed guidelines with a factor loading no less than 0.6. Although the principle of minimal physical exertion had a factor loading below 0.28, most participants agreed that it ought to be incorporated as a result of the nature of AR applications, which are controlled by smartphone users.

Table 3.5

Results Obtained from a Principal Component Analysis with Varimax Rotation

	Factors				
Principles	1	2	3	4	5
Multimodality	0.884				
Enjoyment	0.819				
Familiarity	0.817				
Visibility	0.789				
Hierarchy	0.681				
Defaults	0.619				
Recognition		0.905			
Predictability		0.886			
Learnability		0.88			
Consistency		0.853			
Error management			0.87		
Help and documentation			0.853		
User control			0.744		
Personalization			0.652		
Feedback				0.925	
Direct manipulation				0.707	
Responsiveness				0.701	
Low physical effort				0.282	
Context based					0.822
Exiting					0.816
Navigation					0.603
Availability					0.603

＊ Remaining principles after adjustment.

Based on the examination of the primary elements, we categorized the usability guidelines categorized into five distinct groups: user-information, user-cognitive, user-support, user-interaction, and user-usage (see Figure 3.4). Here are the characterizations of these categories.

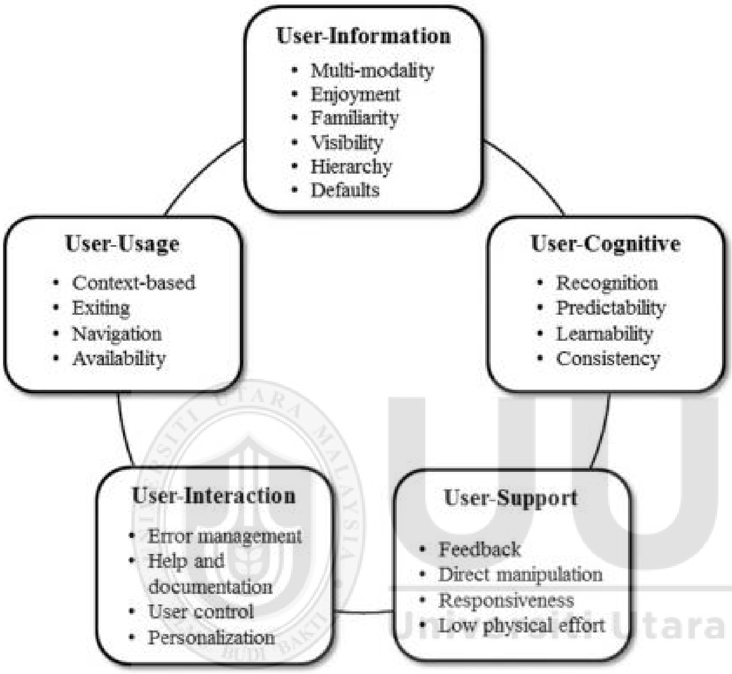

Figure 3.4. Screening Usability Principles
(Picture Credit: Author's Self-Drawn)

1. User-information: The set of principles within user-information pertains to delivering information to users effectively, encompassing visual representation, organized menu structures, and familiar expressions.
2. User-cognitive: The principles within the user-cognitive focus on mental faculties essential for users, aiming to reduce memory burden, enable expected reactions, and facilitate easy application learning.
3. User-support: The user-support category encompasses principles that aim to assist users, encompassing the provision of useful information, error reduction, and handling, as well as personalization.

4. User interaction: The set of principles within user interaction relates to facilitating seamless engagement between end-users and software, including supplying responses through minimal effort.

5. User-usage: The user-usage category involves principles about practical application usage, encompassing appropriate reactions to various situations and methods that allow users to effortlessly utilize or terminate the applications.

The categorization structure of usability principles is shown in Table 3.6.

Table 3.6

Usability Principles Developed for the Evaluation and the Development of AR Application

Principles		Definition
User-Information	Defaults	The initial setup should be user-friendly. Additionally, the framework indicating the input area, and examples concerning the type of input should be furnished.
	Enjoyment	A visually appealing design, inclusive of color schemes, should be employed to deliver engaging experiences for users.
	Familiarity	Familiar metaphors and icons, along with language that is user-centric, should be utilized.
	Hierarchy	When dealing with a substantial amount of information, a phased design should be presented to users to facilitate ease of use.
	Multi-modality	When presenting information, both auditory cues and visual displays should be incorporated.
	Visibility	The visual elements should be meticulously crafted.
User-Cognitive	Consistency	Commonly accepted terminology and interfaces should be consistently applied to avoid confusion.

User-Support	Learnability	The application's functions and features should be both efficient and straightforward for users to master.
	Predictability	The application's capabilities and attributes should be intuitive and facile for users to acquire.
	Recognition	Essential information should be adequately presented to minimize the reliance on users' short-term memory.
	Error management	The application should incorporate preventive measures and solutions for errors that may arise during use.
	Help and documentation	Adequate assistance should be furnished to facilitate user application.
	Personalization	The interface should be customizable to accommodate users' preferences and unique requirements.
User-Interaction	User control	It should instill in users a sense of control over the system, with the system reacting to their inputs.
	Direct manipulation	As users manipulate the device, the screen's feedback and the users' actions should correspond in an intuitive manner.
	Feedback	The progression of tasks and the system's status should be consistently communicated to users.
User-Usage	Low physical effort	It should reduce the operational strain on the application and the fatigue experienced by users.
	Responsiveness	It should respond swiftly to user actions.
	Availability	The application should exhibit swift startup times, and the previous operational state and choices should be preserved upon reactivation.
	Context-based	The user interface should be crafted with a variety of settings in mind, ensuring compatibility with diverse usage contexts.
	Exiting	Exiting or reverting to prior operational segments should be straightforward.

Navigation	Users should be empowered to move around the application freely while executing their tasks.

3.5 Iterative Design Phase

3.5.1 Prototype Development

In this research, we established usability guidelines for a mobile AR app and performed a heuristic assessment to pinpoint usability concerns. Subsequently, we crafted a prototype and carried out usability trials to verify the effectiveness of the usability guidelines. The research structure of this study encompasses shown in Figure 3.5. The research framework is bifurcated into two stages.

During the initial phase, we gathered usability guidelines through a literature review and held a consultative session where experts deliberated on the gathered usability guidelines. Second, the usability principles are categorized through principal a dissection of the components.

In the second phase, we performed a heuristic assessment of a mobile AR application, applying the categorized usability guidelines established in the first phase. Subsequently, we developed an enhanced version of the mobile AR application prototype, followed by usability testing.

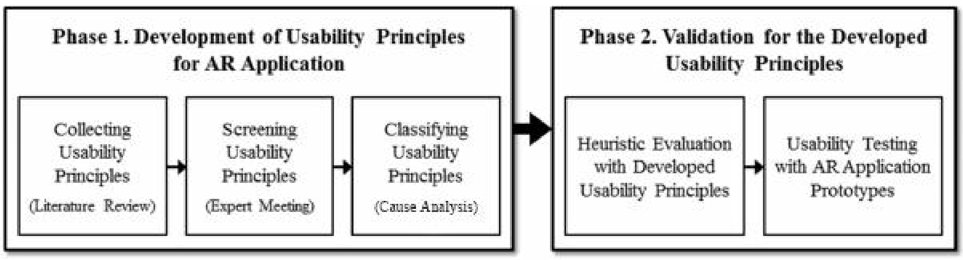

Figure 3.5. Research Framework
(Picture Credit: Author's Self-Drawn)

3.5.2 Development of the Research Model

Through the literature review in Chapter 2, the specific elements of research objective 1 are expounded. The display elements of this research are summarized, including user interface design, content adaptation, interactivity, situational relevance, and technical stability. The specific description, instructional design principles, and usability principles are shown in Table 3.7. From the summarized elements, a research model known as the hybrid augmented reality model based on instructional design and usability principles of digital media art is generated that can guide anyone to create AR applications, as shown in Figure 3.6, which fulfills research objective 2.

Table 3.7

The Elements of a Hybrid Augmented Reality Model Based on Instructional Design and Usability Principles of Digital Media Art.

Element	**Describe**	**Instructional design principles**	**Usability principles**	**Citation**
User interface design	Including the layout of virtual objects, interaction mode and so on.	Easy to understand and use, in line with the student's cognitive level.	The interface is simple and clear, and the operation is intuitive.	（Lee,H.,&Cho,Y.2022）
Content fit	Adjust the depth and breadth of the content according to the learning objectives.	It is closely related to the curriculum objectives and promotes the internalization of knowledge.	Clear information layers to avoid information overload.	（Zhang, L., & Xu, J.2023)
Interactivity	The degree of interaction between the user and the virtual environment.	Encourage active exploration and practical operation.	Timely and accurate feedback improves user engagement.	（Chen, Z., & Li, M.2022)

Situational correlation	Relationship between virtual scenarios and actual application scenarios.	Enhance situational awareness and problem-solving skills.	The scene is authentic and believable, improving immersion.	（Kim, Y., & Park, S.2023)
Technical ability	The smoothness and reliability of system operation.	Ensure that the teaching process is not disturbed by technical faults.	Fast response and reduced waiting time.	（Li, M., & Chen, Z.2022)

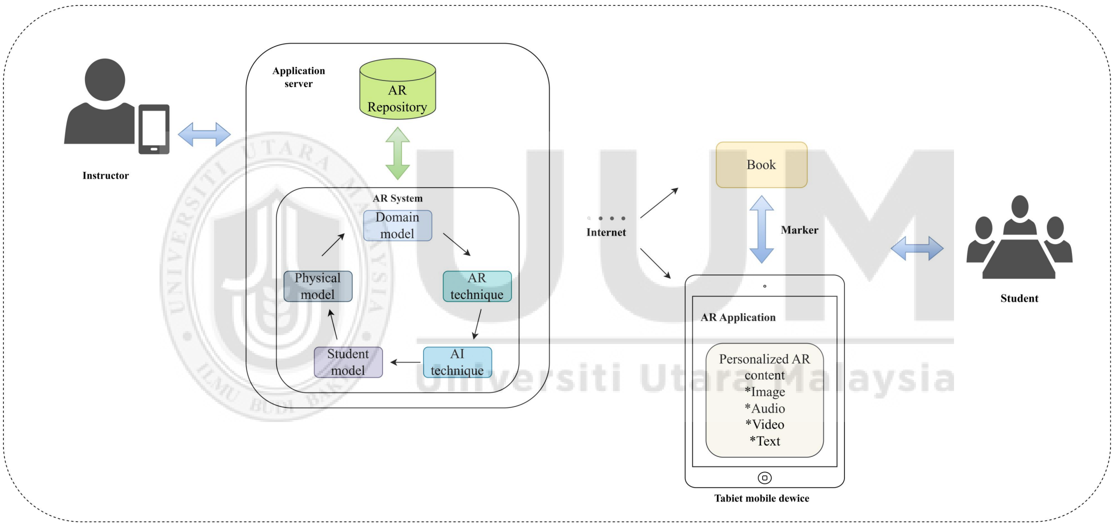

Figure 3.6. The Hybrid Augmented Reality Model Based on Instructional Design and Usability Principles of Digital Media Art
(Picture Credit: Author's Self-Drawn)

3.5.3 Expert Review

At this stage, qualitative analysis methods (thematic examination, content analysis) are used to extract themes, strengths, and weaknesses from expert reviews. Use this information to refine the prototype. The specific qualitative content of the specific expert evaluation and user evaluation is shown below.

There exist two categories of heuristic or expert evaluations, namely, content evaluation, functional assessment, including system assessment and user interface assessment.In the case of content assessment, where the experts participated in the evaluation were faculty members who teach DMA courses at universities. They were asked for the confirmation of the content of the prototype to guarantee that it was appropriate for professional courses and student use. For the functionality and interface assessment, with experts engaged were lecturers involved in educational and developmental contexts augmented reality applications. They necessitate validate the prototype to spot any issues pertaining to the prototype's functionality and user interface.

The development and validation of the System Usability Scale (SUS) according to Lewis & Sauro (2009) assessed the usability of the software interface, including the prototype functionality. and Sauro & Lewis (2012) for practical guidance on the use of statistical methods for analyzing and interpreting user experience data. It includes examples and techniques for analyzing questionnaire responses about the interface design and prototype functionality. There is also Bangor et al. (2009) who suggest adding an adjective rating scale to the SUS survey was employed to furnish a more nuanced understanding of user perceptions of interface design and functionality.

Therefore, this evaluation will take the form of a questionnaire survey of relevant experts in the field of DMA specialization. The details of the survey were developed as shown in Table 3.8. This assessment will enable the designers to identify and address issues relating to the interface design and functionality of the prototype.

Table 3.8
Expert Evaluation Questionnaire

Questions
1. What is your assessment of the usability of the AR Instructional Design Model for DMA in your area of expertise?

2. Please rate the effectiveness of the model in delivering rich AR media content.

3. What room for improvement do you see in the design model's compliance with usability principles?

4. Please comment on whether the model provides sufficient guidance and support in the teaching and learning process.

5. Please give your comments and suggestions on the user interface design, operability and user experience of the model.

6. In your area of specialization, how effective do you think the model is in fostering students' creativity and innovation?

7. Please evaluate the effectiveness of the model in stimulating students' interest in learning and keeping them engaged.

8. How flexible do you think the model is in catering for different learning styles and individual differences?

9. Please provide what you consider to be the strengths and weaknesses of the model and give suggestions for improvement.

10. In what areas or scenarios do you think the model could be more widely used?

After the heuristic assessment was completed, the Reality Composer the application underwent evaluation by the intended user group. Tullis & Albert's (2013) comprehensive guide to measuring and evaluating the user experience in research covers a variety of usability evaluation methods and provides practical advice on questionnaire design and data analysis. Rubin & Chisnell (2008) in a comprehensive guide covers the basics of usability testing, including questionnaire design and validated evaluation methods.

Therefore, in this study, a target user was developed, whose target users were students majoring in DMA from Xihua University in Sichuan, China. A series of surveys served as an instrument for ascertaining the users' responses to the Reality Composer application as shown in Table 3.9. The user evaluation consisted of a perception analysis, along with a correlational examination, and regression analysis. The purpose of the purpose of the perception study is to ascertain the role of user opinions in using the Reality Composer application to optimize the learning experience, increase user engagement, and foster creativity among students in the field of DMA. In addition, correlation analyses will be conducted to ascertain the relationship among the independent and dependent variables. Finally, regression analyses will be conducted to elucidate the impact of the independent variables on the outcome variables.

Table 3.9
Users Evaluation Questionnaire

Questions
1. How usable did you find the AR Instructional Design Model for DMA while you were using it for your studies?
2. Please rate the effectiveness of the model in helping you understand and learn art concepts and techniques.
3. Do you think the model provides enough real-time feedback and guidance to help you with your learning tasks?
4. Please rate the user interface design, operation and interaction of the model.
5. How do you think the use of the model has affected your learning outcomes?
6. Did you find the learning process more interesting and interactive when using the model?
7. Please rate the effectiveness of the model in motivating and actively engaging you in learning.
8. Do you think the model meets your learning needs and personalized learning preferences?

3.5.4 Usability Testing

Use end-user samples for usability testing to collect quantitative data on user interaction, efficiency, and satisfaction. Adopt standardized usability metrics. Usability is a key aspect of any instructional design model, especially in the context of AR in DMA. To evaluate and improve the usability of AR instructional design models, standardized usability indicators are adopted. These indicators provide a structured framework for assessing the effectiveness, efficiency, and satisfaction of models in facilitating learning experiences.

The first is standardized usability metrics, which mainly refers to the ability of users to achieve specific learning goals accurately and comprehensively. The criterion is the task success rate, that is, the percentage of successful completion of the learning task. Learning outcomes are the degree to which knowledge is acquired and retained by the user from the content taught. This instructional design model evaluates the rate at which participants finished interactive exercises and gauges the improvement of users' DMA skills.

The second is the task completion time, which mainly refers to the resources consumed as executed by the user to finalize the learning task. Simply speaking, it is the average time required for the user to accomplish a specific learning activity. The criterion is interaction efficiency, that is, the number of interactions required to complete the learning goal. This instructional design model analyzes the time spent by users browsing AR content and completing interactive exercises.

Finally, from the user's perspective, the overall comfort and acceptability of the AR instructional design model to collect user feedback through standardized satisfaction surveys. The judgment metric is the user's self-reported satisfaction score based on their overall experience. In this instructional design model, a post-interaction survey is mainly managed to measure user contentment regarding the comprehensibility of instructions and the overall user interface.

The selection of these standardized usability indicators is based on established principles pertaining to human-computer interaction, along with instructional design. These metrics are aligned with widely recognized usability assessment frameworks, including Jakob Nielsen's Heuristic Assessment and ISO 9241-11 Usability Metrics. Jakob Nielsen's Heuristic Evaluation: Metrics take inspiration from Nielsen's heuristics to ensure that AR instructional design models follow principles such as system transparency, alignment with real-world contexts, user agency, and flexibility.
ISO 9241-11 Standard: The indicators selected are consistent with ISO 9241-11, emphasizing efficiency, effectiveness, and satisfaction as core dimensions of usability. This standard guides the evaluation of interactive systems and ensures an extensive assessment of the user experience.

To implement these indicators, quantitative data collection methods were used. Use user test sessions, surveys, and performance analytics to gather data on task success, task completion time, user satisfaction, and other relevant metrics.

Standardized usability metrics provide a powerful framework for evaluating and improving the usability of AR instructional design models in DMA education. By systematically measuring effectiveness, efficiency, and satisfaction, models can be continually improved to meet the changing user requirements. This section Outlines the importance of standardized usability metrics, provides examples of specific metrics, and explains their references in existing usability evaluation frameworks. Next, quantitative data will be used to collect the above usability evaluation indicators.

3.5.5 Data Collection

To validate the usability and effectiveness of the AR instructional design model for

DMA based on usability principles, the validation in this research was grounded in the improvement of previous research methods that focused on heuristic and user-based evaluation (Allen, Currie, Bakken, Patel, & Cimino, 2006; Rau & Liang, 2003). The following is a comprehensive evaluation of an augmented reality instructional design model for DMA based on usability principles. It includes both expert and user evaluations.

In this study, 15 experts in AR, DMA, and instructional design from 10 universities in Sichuan Province were randomly recruited to conduct a thorough review of the prototype. Collect qualitative feedback on usability, instructional effectiveness, and overall design. The specific sample size is shown in Table 3.10.

Table 3.10
Name of Schools and Number of Samples

Name of the school	Teacher Enrolment	Number of Sample
Southwest Jiaotong University	8	1
Xihua University	10	2
Sichuan Normal University	9	2
Southwest University	6	2
Chengdu Neusoft University	12	1
Jili University	6	1
Sichuan Arts University	15	2
Sichuan Media University	12	1
Sichuan Music University	5	2
Sichuan Agricultural University	8	1

3.6 Experiments Settings Phase

This experiment uses expert assessment and user assessment to validate an augmented reality instructional design model for DMA based on usability principles. The two phases have different data collection contents; in the expert evaluation phase, data collection is mainly conducted on usability content and application effectiveness. In the user evaluation phase, data are collected on the users' realization of satisfaction and user experience in the process of using the model. The specific experimental process and data collection are delineated within detail in the subsequent sections detail.

3.6.1 Experimental Subject

In the expert evaluation phase, the main objective is for assessing the effectiveness of the DMA teaching model based on augmented reality technology in terms of usability and application effectiveness. Therefore, according to the standard that I have been engaged in DMA instructional design for more than 3 years, I invited 5 experts within the domain of DMA instructional design, focusing on our city to participate in this review; Publish more than 2 relevant studys; He also teaches at an art school. Essential details regarding the five experts is summarized, as shown in Table 3.11.

Table 3.11

Expert General Information

Number	Name	Sex	Age	Title	Workplace
1	Li XX	M	25	Associate Professor	Sichuan Arts University
2	Wang X	M	30	Tutors	Xihua University
3	Liu XX	F	35	Assistant Professor	Southwest University
4	Ji X	M	40	Assistant Professor	Sichuan Normal University
5	Liang XX	F	45	Tutors	Sichuan Music University

3.6.2 Experimental Methods

In the study of the augmented reality teaching design model for DMA based on usability principles, the expert evaluation adopted a practical assessment method, including usability content assessment and application effectiveness assessment.

Responses were gathered using a 5-point Likert scale, which was employed to design the question items from three aspects: interface friendliness, interaction fluency, and clarity of language expression.

After setting up the interview questions, individual face-to-face interviews were used, with each expert arranging about 1 hour of interview time. According to the above criteria, I printed out the questionnaire content in Table 3.8 and visited the 5 experts selected one by one for review. First, I visited Li XX from the DMA Lab, as shown in Figure 3.7. Two experts were invited to the coffee shop for a face-to-face interview, as shown in Figure 3.8 and Figure 3.9. Finally, I interviewed two senior professors in the DMA Teaching and Research Department, as shown in Figures 3.10 and 3.11.

Figure 3.7. Experts Evaluation Interview A

Figure 3.8. Experts Evaluation Interview B

Figure 3.9. Experts Evaluation Interview C

Figure 3.10. Experts Evaluation Interview D

Figure 3.11. Experts Evaluation Interview E

Feedback from experts can serve as a means for more effectively spot potential issues within instructional applications, thereby optimizing design and improving usability

(Alhalabi, 2021). Therefore, in the expert review study, an interview questionnaire was designed to assess experts' opinions regarding the efficacy and usability of mixed augmented reality modeling in teaching digital media arts. Successful mixed-reality learning environments require a combination of effective instructional strategies and user-friendly design to achieve optimal learning outcomes (Liu & Shih, 2023).

The content of the questionnaire is based on relevant literature and best practices to ensure coverage of key metrics such as user experience Hsieh, P. P., & Tsai, C. C. (2020), learning effectiveness Kim, S., & Lee, Y. (2020), usability Wu, H. K., & Chang, Y. S. (2022). etc.

The content of the interviews was designed to ask the experts for their opinions and suggestions on the course program, including its strengths, weaknesses, and possible improvements as shown in Table 3.12.

Table 3.12
Statistics on Expert Review Interviews

Serial No.	Core Issues	Score
EQ1	Usability assessment	
		Excellent (5 points) Good (4 points) Fair (3 points) Inadequate (2 points) Very poor (1 point)
EQ2	Assessment of effectiveness	
		Very effective (5 points) Effective (4 points) Average (3 points) Limited effectiveness (2 points) Ineffective (1 point)
EQ3	Room for improvement	
		Provide user training and support (5 points) User interface optimization (4 points)

		Simplification of operation (3 points) Feedback mechanism improvement (2 points) No need for improvement (1 point)
EQ4	Provide guidance and support	Very adequate (5 points) Adequate (4 points) General (3 points) Limited (2 points) Inadequate (1 point)
EQ5	User interface, operability and user experience	Excellent (5 points) Good (4 points) Average (3 points) Inadequate (2 points) Very poor (1 point)
EQ6	Fostering creativity and innovation	Very effective (5 points) Effective (4 points) Average (3 marks) Limited effectiveness (2 points) Ineffective (1 point)
EQ7	Stimulates interest in learning and keeps students engaged	Very successful (5 points) Successful (4 points) Average (3 points) Limited success (2 points) Unsuccessful (1 point)
EQ8	Accommodates different learning styles and individual differences	Very flexible (5 points) Flexible (4 points) Average (3 points) Not flexible enough (2 points) Very inflexible (1 point)
EQ9	Strengths, weaknesses and suggestions for improvement	

		Advantages (list) Weaknesses (list) Suggestions for improvement (list)
EQ10	Areas of application or scenarios	(list)

3.6.3 Qualitative Data Analysis

The qualitative data analysis focuses on insights obtained from expert reviews of the AR instructional design model tailored for DMA. The analysis aims to identify strengths, weaknesses, and areas for improvement in the model, with a particular emphasis on usability principles. (see Table 3.13).

Table 3.13
Qualitative Expert Reviews Insights.

Opinion	Strengths	Explain	Areas for Improvement	Explain
User-Centered Interface	Acknowledged User-Centered Design Philosophy	Experts appreciated the evident user-centered design philosophy, recognizing the consideration of user needs and preferences.	Enhancement of Visual Cues	Experts suggested further enhancements to visual cues for navigation, emphasizing the reduction of cognitive load.
	Positive Feedback on Interface Elements	The interface elements were commended for their intuitiveness, clear instructions, and accessible controls.	Simplification of On-Screen Instructions	Recommendations were made to simplify on-screen instructions to ensure better user understanding.

Progressive Scaffolding	Well-Structured Learning Pathways	The learning pathways were praised for their well-structured approach, effectively guiding users from fundamental to advanced concepts.	Smooth Progression in Learning Pathways	Experts observed that certain learning pathways may benefit from a smoother progression to prevent users from feeling overwhelmed.
	Effective Use of Interactive Modules	Experts recognized the positive impact of interactive modules in introducing and reinforcing key concepts.	Consideration of Additional Interactive Exercises	Recommendations were made to consider introducing more interactive exercises for effective reinforcement.
Interactive Content	Effective Use of AR Technology	Experts commended the effective use of AR to overlay interactive DMA content, enhancing user engagement.	Diversification of Interactive Content	Experts recommended further diversification of interactive content to engage users with a broader range of preferences.
	Diverse Media Types	The inclusion of various media types, such as 3D models, videos, and audio, was recognized for catering to different learning styles.	Alignment of Interactive Elements with Learning Objectives	Suggestions were made to ensure seamless alignment between interactive elements and learning objectives.
Real-World Context Integration	Realistic Applications of Concepts	Experts acknowledged the successful integration of real-world applications of DMA concepts	Enhancement of Realism in Virtual Studios	Recommendations were made to enhance the realism of simulations within virtual studios, making practical

		within instructional content.		applications more authentic.
	Practical Simulations in Virtual Studios	The virtual studios were praised for simulating practical scenarios, allowing users to apply theoretical knowledge.	Introduction of More Complex Scenarios	Consideration was given to incorporating more complex scenarios to challenge and engage advanced users.
Feedback Mechanisms	Immediate Feedback Loops	The immediate feedback loops were recognized for providing users with timely information on their interactions and performance.	Consistency in Immediate Feedback	Experts suggested ensuring that feedback mechanisms are consistently immediate across all interactive elements.
	Effective Progress Tracking	Progress tracking features were appreciated for allowing users to monitor their advancement through instructional content.	Fine-Tuning of Progress Tracking Features	Recommendations were made to fine-tune progress tracking features for a more user-friendly experience.
Usability Considerations	Clarity in Instructions	Experts recognized the clarity of instructions throughout the model, contributing to overall usability.	Enhancement of Accessibility Features	Recommendations were made to enhance accessibility features further, providing better support for users with visual impairments.

	Integration of Accessibility Features	The integration of accessibility features, such as voice-guided instructions, was positively acknowledged.	Continuous Monitoring of Accessibility Standards	Experts emphasized the importance of continuous monitoring and updating of accessibility standards to ensure inclusivity.

The qualitative data analysis reflects a positive overall impression of the AR instructional design model. Acknowledging strengths in user-centered design, progressive scaffolding, and effective feedback mechanisms, the analysis identifies key areas for improvement. The iterative design process, guided by expert feedback, is expected to contribute significantly to the model's overall usability and effectiveness in DMA education. This qualitative data analysis provides a detailed examination of the expert-reviewed insights, offering valuable information for the ongoing refinement and development of the AR instructional design model for DMA.

3.6.4 Experimental Subject

In the user evaluation phase, the main objective was to assess the Augmented Reality-based DMA teaching model in terms of realization satisfaction and user experience. Therefore, I invited 10 in-service DMA teachers in the 25-45 age group in our city to participate in the user evaluation according to the criteria that they must have at least 2 years of DMA teaching experience, as well as a certain degree of computer operation ability, and they must be open to new technologies and teaching methods. The basic profiles of specific users are shown in Table 3.14.

Table 3.14

Users General Information

Number	Name	Sex	Age	Title	Workplace
1	Wang X	M	25	Tutors	Southwest Jiaotong University
2	Li XX	F	28	Assistant Professor	Xihua University
3	Dai XX	F	30	Assistant Professor	Sichuan Normal University
4	Huang XX	M	32	Tutors	Southwest University
5	Sun XX	F	35	Assistant Professor	Chengdu Neusoft University
6	Tian x	M	38	Assistant Professor	Jili University
7	Zhang X	M	40	Assistant Professor	Sichuan Arts University
8	Zhang XX	F	42	Tutors	Sichuan Media University
9	Wu XX	F	44	Assistant Professor	Sichuan Music University
10	Li X	M	45	Tutors	Sichuan Agricultural University

3.6.5 Experimental Methods

User evaluation is a critical step in ensuring that educational applications meet the needs of learners. Through questionnaires, researchers can collect valuable data on user experience and usability (Zhou & Li, 2021).

In the user evaluation stage, after identifying the evaluation target as teachers in the DMA teaching field, a questionnaire form was created based on the list of user evaluation questions and evaluation indicators designed in 3.6.2, and data collection was conducted through a questionnaire survey to evaluate their experience of using the instructional design model and their perceptions, and to collect data on the young teachers' evaluation of the instructional design model's ease of use, teaching effectiveness, and students' responses (Chen & Huang, 2022). Statistics and descriptions of young teachers' overall attitudes and perceptions of the instructional design model were collected (Wang et al., 2023). The specific questionnaire format is shown in Table 3.15.

Due to the inconsistency of the subjects' workplaces, the created questionnaire form was finally sent to the group of DMA teaching teachers who used Questionnaire Star to participate in user evaluation online, and they were instructed to fill in and fill out the survey form within a certain period.

Table 3.15
Statistics on User Review Interviews

Serial No.	Core Issues	Score
UQ1	Usefulness to DMA	
		Very useful (5 points) Useful (4 points) Average (3 points) Not very useful (2 points) Useless (1 point)
UQ2	Help to learn the effectiveness of artistic concepts and techniques	
		Very effective (5 points) Valid (4 points) Average (3 points) Limited effect (2 points) Invalid (1 point)
UQ3	Provide real-time feedback and guidance	
		Very good (5 points) Sufficient (4 points) Average (3 points) Not enough (2 points) Insufficient (1 point)
UQ4	User interface design, operation and interaction	
		Excellent (5 points) Good (4 points) Average (3 points) Need improvement (2 points) Very poor (1point)
UQ5	Influence on learning effect	

		Very positive (5 points) More positive (4 points) Average (3 points) Negative (2 points) Very negative (1 point)
UQ6	Whether the learning process is more fun and interactive	Strongly agree (5 points) Agree (4 points) Average (3 points) Disagree (2 points) Strongly disagree (1 point)
UQ7	The effectiveness of motivating learning and active participation	Very effective (5 points) More effective (4 points) Average (3 points) Limited effect (2 points) Invalid (1 point)
UQ8	Meet learning needs and individual preferences	Very consistent (5 points) More consistent (4 points) Average (3 points) Not quite (2 points) No (1 point)

Phase 2: QUANTITATIVE PHASE

3.7 Iterative Development Phase

3.7.1 Refinement of Prototype

This phase incorporates feedback from expert reviews to refine the AR instructional design model, address identified weaknesses, and improve usability.

First, in the case of qualitative data collection, expert feedback on the user-centric interface highlighted the need for clearer visual cues to enhance navigation and reduce cognitive load. On-screen instructions are considered slightly complex and may affect user understanding. As a result, on-screen guidance is simplified at this stage, making the experience much simpler to use. More prominent visual cues, such as intuitive animations, have been added to guide users through navigation.

On the progressive stand, experts feedback that certain learning paths are considered abrupt, causing some users to feel overwhelmed. Experts recommend introducing additional interactive exercises to better reinforce knowledge. Therefore, complementary interactive exercises are added at this phase for bolstering key concepts and enhance the learning experience. The order of learning modules has been adjusted to ensure smoother progress and reduce user discomfort.

In terms of interactive content, experts recommend further diversification of interactive content to meet a wider range of learning styles.
The alignment of interactive elements with specific learning objectives needs to be improved. Therefore, a seamless alignment between interactive elements and learning objectives is ensured at this stage to achieve a coherent teaching flow. Additional interactive elements were introduced, including quizzes and 360-degree immersive experiences, to appeal to users with different preferences.

Second, on real-world background fusion, experts report that simulations in virtual studios are considered effective but could benefit from being more realistic. It is recommended to introduce more complex scenes in the virtual studio. Thus, more complex scenarios are introduced at this stage, challenging users and promoting deeper engagement with the concept of DMA. It enhances the realistic sense of simulation in the virtual studio and provides users with more realistic actual scenes.
On the feedback mechanism, the expert feedback progress tracking feature works, but needs to be tweaked slightly to provide a more user-friendly experience. Therefore, fine-tune the progress tracking feature at this stage to ensure a smoother and more user-friendly experience. Implement real-time feedback mechanisms for all interactive

elements to provide immediate responses.

In terms of usability considerations, the experts emphasized the continuous monitoring and updating of accessibility standards. Accessibility features need to be further enhanced, especially for visually impaired users. Therefore, a continuous monitoring process is established at this stage to ensure compliance with the latest accessibility standards. Additional accessibility features such as screen reader compatibility and enhanced voice-guided instructions are integrated.

Finally, in the iterative design process, the integration of user test sessions was carried out to verify the impact of improvements on user experience. Direct user feedback is actively integrated to address specific pain points and usability issues. Quantify the impact of improvements using usability metrics, including task success and interaction efficiency. Analyze metrics to identify areas for further improvement and verify the usability of the model.

The improved augmented reality instructional design model is expected to demonstrate improved usability, enhanced user engagement, and smoother learning experience progression. An iterative design process guided by expert feedback, user testing insights, and usability metrics aims to create a model that effectively addresses the weaknesses identified in the initial prototype.

3.7.2 AR Software Suitability Evaluation

This summary builds an AR instructional design prototype based on the identification of usability principles, focusing on the evaluation of AR software suitability, outlining the process of incorporating usability principles into the prototype, the experimental subjects, the experimental process, as well as the results and analysis of the experiment.

This research first evaluates three AR software platforms, Unity+Vuforia (SAROSA M, et al., 2019), Zapworks Designer (SEELYB J, et al., 2019), and Kivicube (CAO Zhi & DING Xiao-e, 2019), within the realm of digital media design art picture book course Applicability was evaluated. The assessment indicators covered functions and features, editing tools and interface design, resource library and community support, and ease of technology operation. The designers' experience was quantitatively analyzed by constructing an assessment scale, and the performance and ease of use of the three platforms were comprehensively evaluated, as shown in Table 3.16. During the evaluation process, considerable emphasis was placed on the technical support and service response of the platforms to ensure the objectivity and practicality of the evaluation results.

Zapworks Designer is a full-featured online AR software platform for a variety of AR application scenarios; Vuforia stands out as a widely-used Augmented Reality (AR) software development kit (SDK) that combines with the AR features of the Unity engine to form the Unity+Vuforia solution, which can support cross-platform operation and is used to develop complex AR applications and games (HE Rui-ling, et al. 2022); Kivicube is an online AR software platform developed in China and favored by beginner users for its simple and convenient operation.

Each of these three platforms is unique in terms of functions and features, editing tools and interface design, resource library and community support, and ease of technical operation. According to the comprehensive evaluation results in Table 4.1, the Zapworks Designer platform has comprehensive functions, no code, and drag-and-drop features, and supports designers and developers to create AR illustrated books efficiently and intuitively with moderate difficulty. Meanwhile, its operation interface is simple and beautiful, and it fits well with the design process of the advertising and publishing industry; Unity+Vuforia platform, with its powerful functions and complex tools, is more suitable for users with technical foundation and programming experience; Kivicube platform is simple to operate and is suitable for beginners, but it has relatively weak functions and limited support for resource libraries.

Table 3.16
Evaluation Results of AR Software Applicability

	Functions & Characteristics	Edit tools & Interface design	Resource library & Community support	Technical operation difficulty
Unity+ Vuforia	Supports cross-platform operation and provides comprehensive AR technology for developing complex AR applications	With learning costs and programming knowledge requirements, providing visual programming interfaces	Alive Resource Library with comprehensive plugins/models/materials and tutorials	More difficult
Zapworks Designer	Supports multi-platform operation and provides world/image/face tracking for various AR application scenarios	No need for programming knowledge, AR scenes can be created by drag and drop and configure parameters to provide animation.	As above	Moderate Difficulty
Kivicube	Provides basic functions such as image/world/physical AR for beginners	As above	Limited Resource Library with limited selection of plug-ins and models	Moderate Difficulty

Taking all these factors into consideration, this study chooses the Zapworks Designer platform for prototyping and development of the AR illustrated book "Elephant Mountain Sacrifice to the Sea", which was created as a project of the digital media art course.

3.7.3 Zapworks-Based AR Project Design

The flow of Zapworks-based AR technology in this study is shown in Figure 3.12.

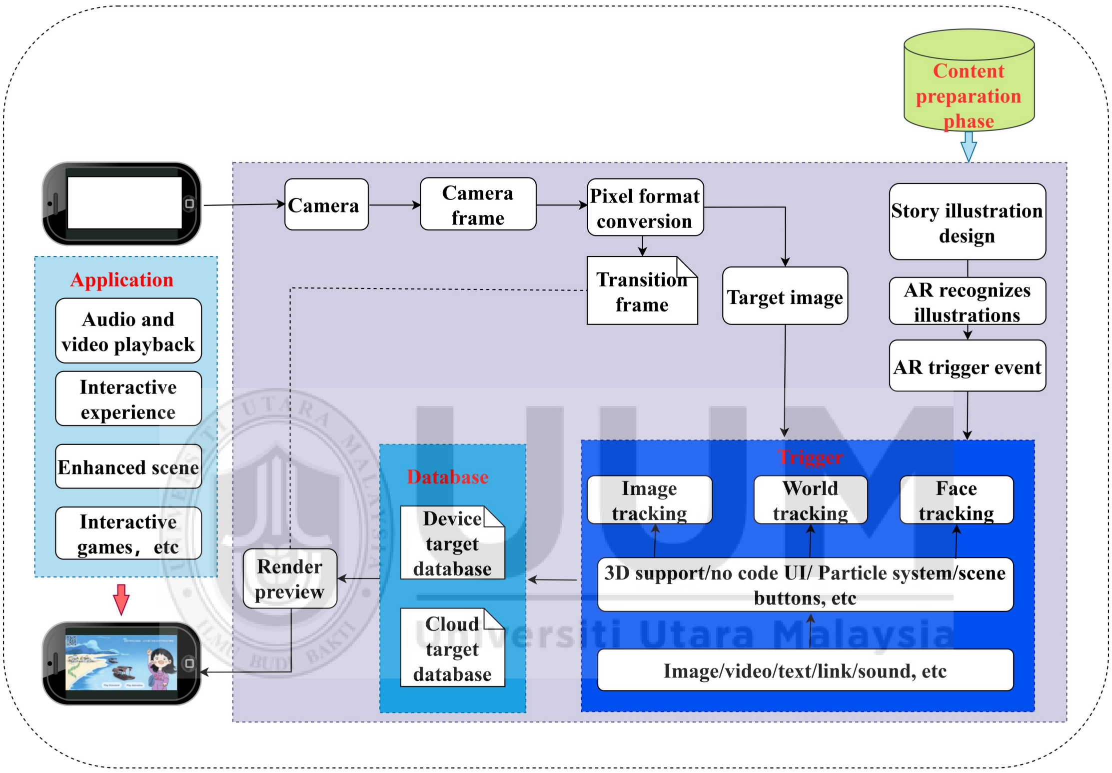

Figure 3.12.AR Technology Flow

(Picture Credit: Author's Self-Drawn)

3.7.4 AR Prototype Design

The prototype design and development of the AR illustrated book project "Elephant Mountain Sacrifice to the Sea" created for the Digital Media Arts course used Zapworks as the technical implementation tool. The key elements of the design include digital processing of illustration pages, design of AR trigger elements, illustration elements for interactive events, implementation of image tracking functions, and integration of 3D models or audio video. The whole design process is divided into three main parts: content preparation, design and implementation of interactive functions, and effect demonstration and evaluation. The design process is shown in Figure 3.13.

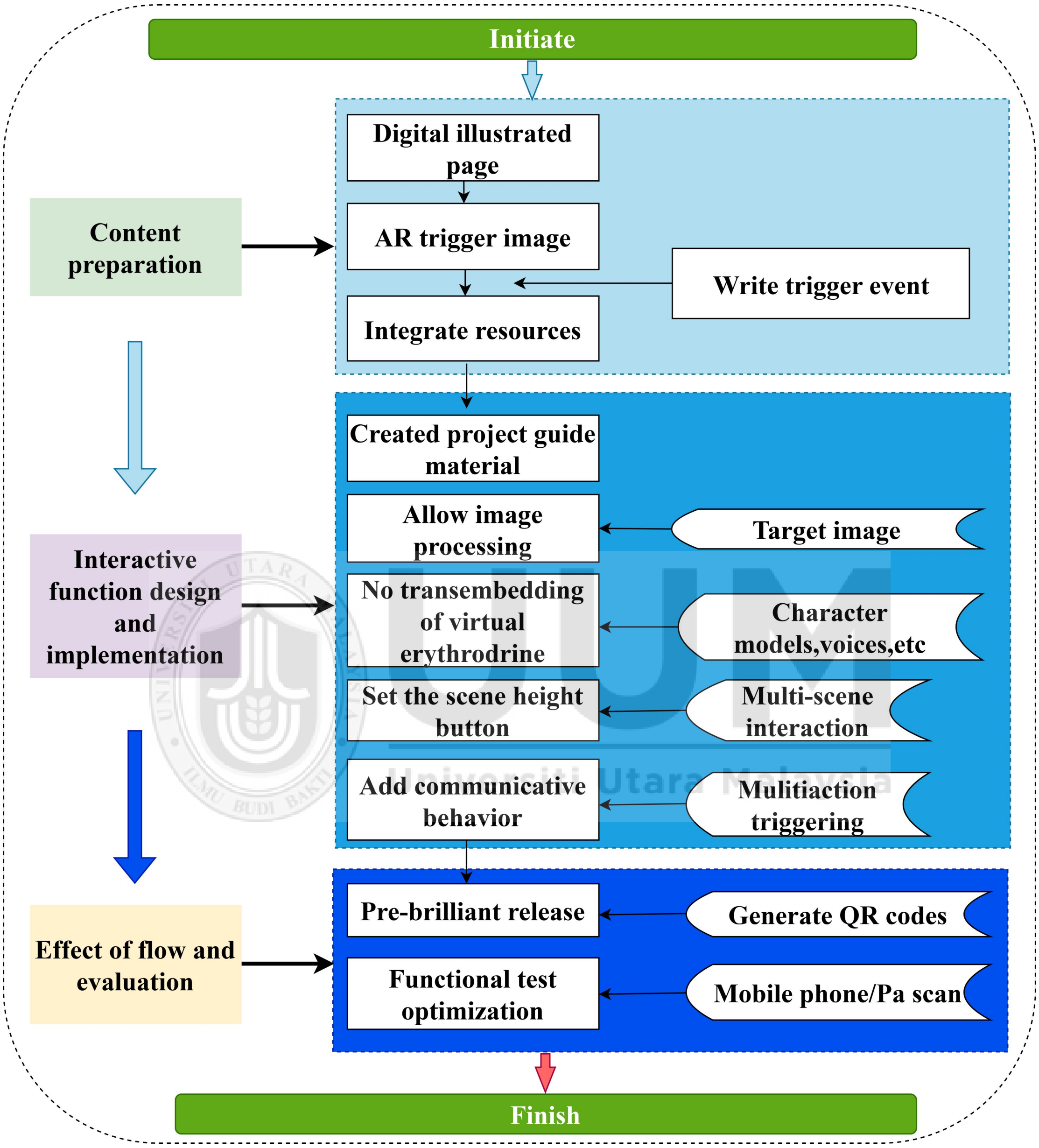

Figure 3.13.AR Design Framework

(Picture Credit: Author's Self-Drawn)

Content Preparation: Digitize images of the illustration pages designed for the "Elephant Mountain Sacrifice to the Sea" AR illustrated book course to ensure compatibility with AR technology. This session involved selecting and optimizing images to be used as images for AR triggering elements, ensuring that these images could be accurately recognized by Zapworks. It was also determined which image elements would trigger interactive events and predefined the corresponding behaviors and feedback. Gathering the required digital resources, such as 3D models, video, and audio, in preparation for the subsequent design and development phases.

Interaction Function Design and Implementation: Import relevant digital resources into Zapworks and set up the image tracking function of the illustrated pages so that the system can accurately match the images. As shown in Figure 3.14, 3D models or video resources are embedded into the scene according to the preset events to give the illustrated pages vivid dynamic effects. Design the scene transition logic and user interface control to establish the user's interaction interactions using the interface elements through touch or swipe operations.

Figure 3.14. Scenes and Functions

(Picture Credit: Author's Self-Drawn)

Effect of flow and evaluation: Use the preview function to check the AR effect and release the final product, generating QR codes that can be used by testers. As shown in Figure 3.15, the QR code is scanned by different mobile devices to test and experience the AR effect and collect feedback. Optimize the function according to the user experience test results to provide a better reading experience.

Figure 3.15. Testing Effect
(Picture Credit: Author's Self-Drawn)

3.8 Evaluation of Test Effectiveness Phase

3.8.1 Participants

Putting the prototype in digital media art AR program design, we chose experimental participants, all thirty-eight participants from the third grade of an thirty-eight participants Chengdu City, Sichuan Province, spanning ages from 9~10 years old. These participants possessed equal reading ability with no significant difference and were able to read and retell simple stories on their own. In the pre-experimental survey, about 86.1% of the participants indicated that they had used digital devices, mainly for learning (80%), entertainment (50%), and social contact (25%). Also, all experimental participants owned a cell phone or tablet. Parental consent was secured for the study and the participants before the start of the experiment.

Individuals were assigned at random to the respective groups the test group (n1=18) as well as the comparison group (n2=18). The final effective sample size was reduced to 33 participants, with n1=16 in the experimental group (10 at 9 years old and 6 at 10 years old) and n2=17 in the control group (9 at 9 years old and 8 at 10 years old), due to the unavailability of data from five participants' recordings due to poor quality.

3.8.2 Experimental Strategy and Procedure

For the credibility of the findings, the principle of random grouping according to the school number was adopted, and the students in the same class of the third grade with similar reading levels were assigned to either the experimental or control group. The variables were controlled by strictly controlling the consistency of the content of the reading materials and the standardization of the testing environment.

The experimental group, after receiving training on the use of AR project picture books, read AR project picture books produced by the subject group of digital media art students, while the control group read traditional printed picture books of the same story. The selected reading materials, which are suitable for 9–10-year-olds, are designed to attract the interest of this age group with moderate difficulty, which can effectively reflect their reading comprehension level.

Morrow's (1986) 10-point Story Retelling Rating Scale has high reliability and validity and focuses on assessing the elements of story setting, theme, plot, ending, and sequence. Participants' retelling scores can reflect the level of reading comprehension of the retellers, and thus Morrow's Story Retelling Rating Scale was used as the primary assessment method in this experiment. The design of the retelling questions is shown in Table 3.17.

Table 3.17
Retelling Questions Design

Retelling questions design		
Background	1. One or more central characters appear in the story 2. The time in which the story takes place 3. Where the story takes place	3 pts.
Themes	1. Theme(s) shown in the story 2. Hidden themes or meanings of the story	2 pts.
Endings	1. provides one or a series of events related to the protagonist 2. An event or series of events that occurs that leads the protagonist to solve a problem or achieve a goal	2 pts.
Episodes	1. The protagonist solves a problem or achieves a goal 2. The ending has implications	2 pts.
Sequence	1.The sequence in which the story is told	1 pt.

After the participant read the picture book, the researcher captured the participant's retelling of the story through audio recording; the participant was also guided according to the method proposed by Morrow to encourage the experimental participant to retell the story as completely as possible. A posttest quasi-experimental design was used to ensure that participants were not exposed to the material before testing. All retelling scores were employed for compare the disparities between the experimental and control cohorts. Participants' retellings were scored according to a retelling scoring scale. The final sequence of scores for each participant was obtained for each of the five elements, including setting, theme, plot, ending, and sequence, with the highest value of the sum of the scores for each element being 10, i.e., the maximum composite score was 10. The scores d1 and d2 of each element for each participant in the two groups are noted as $\{O_1(i,j), i=1, n_1; \; j=1,6\}$, $\{O_2(i,j), i=1, n_2; \; j=1,6\}$, respectively. The detailed study procedure is shown in Figure 3.16.

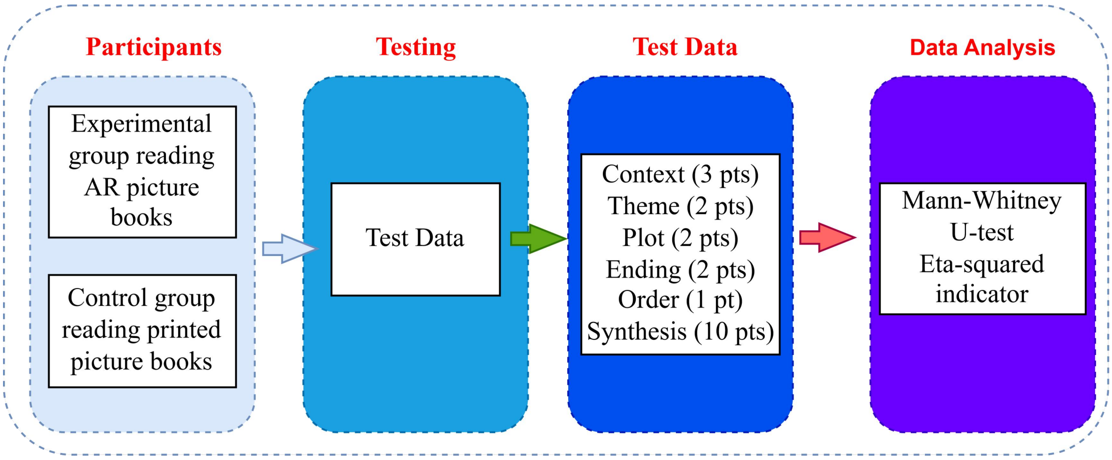

Figure 3.16. Experimental Strategy

(Picture Credit: Author's Self-Drawn)

3.9 Data Analysis

In the data analysis stage, through expert review and user evaluation, statistical methods are used to analyze quantitative data and usability indicators, and user survey feedback and learning outcomes are collected and compared. The specific data analysis content will be explained in Chapter 4.

3.10 Limitations and Future Directions

Both qualitative and quantitative findings highlight the importance of user engagement in effective AR instructional design for DMA. At the same time, models that go through the iterative design phase based on user feedback demonstrate higher usability and learning outcomes.

According to the results review, it is also necessary to build a reinforcement learning experience to gradually guide users through complex concepts of DMA. The feedback loop is also standardized and optimized to provide users with consistent and meaningful information during the learning process. And prioritizing accessibility standards to ensure inclusiveness for users with diverse abilities.

Therefore, a continuous iterative design process based on user feedback should be encouraged to refine and enhance the AR instructional design model. Engage experts from the fields of DMA, instructional design, and accessibility to ensure a holistic and inclusive approach. Large-scale user testing is conducted to gather different perspectives and ensure that the results are generic. By addressing these findings, focusing on strengths, mitigating weaknesses, and implementing the recommendations outlined, AR instructional design models for DMA can evolve to furnish an additional effective, engaging, and accessible educational encounter.

3.11 Conclusion

Here, we condense the results of the qualitative and quantitative stages, highlight the strengths and weaknesses of AR instructional design models for DMA, and highlight key insights, areas for improvement, and suggestions for improving AR instructional design models for DMA.

The advantages found in the qualitative phase are user-centered design, interactivity and engagement, and integration of real situations. The specific content of design focused on user needs is that the AR instructional design model emphasizes user-centered principles, combining user needs and preferences. In terms of interactivity and engagement, qualitative analysis emphasizes the successful integration of interactive elements, which improves users' participation in DMA content. In terms of real context integration, the model effectively combines teaching content with practical application and promotes the relevance of the learning experience.

Summarizing the qualitative stage, it was found that some models showed limitations in providing progressive support, suggesting a need for more comprehensive scaffolding teaching during the educational experience. Simultaneously, the qualitative feedback reveals inconsistencies in the implementation of the feedback loop, indicating the need for improvement in this aspect.

In the quantitative phase, the advantage is that the quantitative data confirms positive usability indicators, indicating that users find the AR instructional design model intuitive and easy to navigate. At the same time, users demonstrated improved learning outcomes, demonstrating the effectiveness of the model in conveying concepts of DMA. Quantitative data, in turn, highlights the challenges of meeting accessibility standards, highlighting the need for improvements to meet the capabilities of different users. Some users reported higher cognitive load, suggesting that some design elements may need to be simplified to improve comprehension.

3.12 Summary

This study utilizes the questionnaire method with an eye to the approach to conducting the current study. In other words, the organization of this study was clarified to determine the target group and the subjects studied size of the study. In addition to the method of sampling, data gathering processes, and the preliminary research, and data analysis system were also considered.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Overview

This chapter will focus on the implementation and data analysis process of the DMA augmented reality instructional design model based on usability principles. Evaluate the effect and feasibility of the design model in practical teaching, find out the problems and improvement points in the implementation of the model, and provide guidance and support for better application and development of the DMA augmented reality teaching design model based on the principle of usability.

4.2 Data Analysis

A combination of statistical inference and descriptive inference was employed for data analysis in this research. Employing SPSS version 23.0 for the analysis, a descriptive assessment was conducted to provide a general comprehension of the participants' characteristics and demographics factors. In addition to this, in the descriptive inference, the collected data were analyzed to extract useful information and conclusions to explain the effectiveness of the model and room for improvement. Descriptive statistics (e.g., standard deviation and mean) are used to describe all structures. And learner engagement, understanding, and creativity are compared to the results of use, also known as analysis of variance.

4.3 Survey Data Collection

According to the contents of the questionnaire in Table 3.11 (Refer to Appendix A for detailed questionnaire content), the questionnaire star was distributed to 5 experts in DMA for investigation and evaluation, and the specific data results were sorted out, as shown in Figure 4.1.

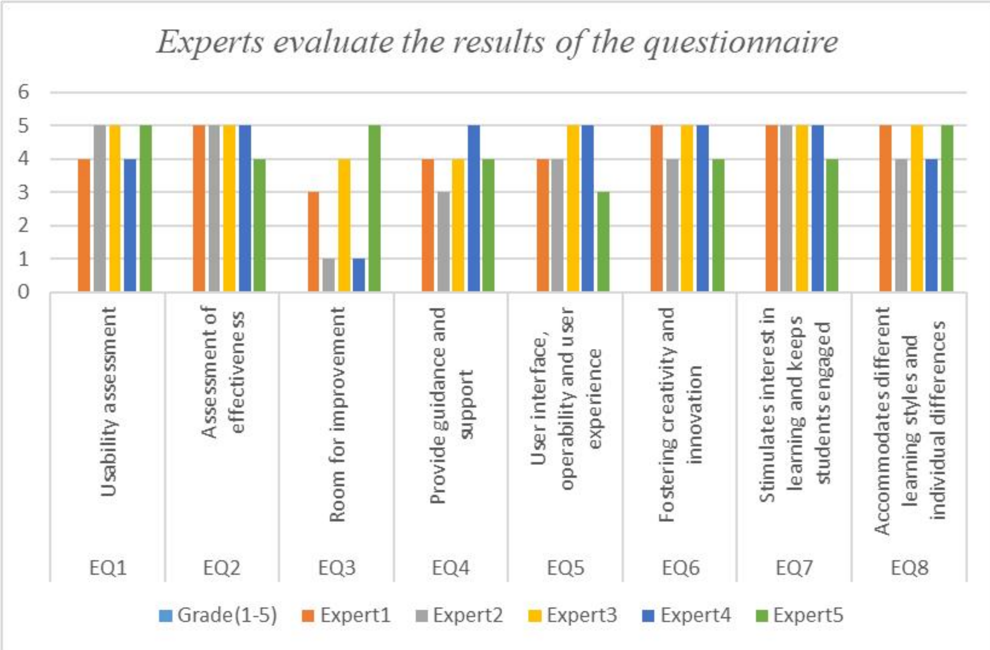

Figure 4.1. Experts Evaluation of the Questionnaire Results
(Picture Credit: Author's Self-Drawn)

According to the contents of the questionnaire in Table 3.14 (Refer to Appendix B for detailed questionnaire content), questionnaire stars were distributed to 10 teachers in the field of DMA for investigation and evaluation, and specific data results were sorted out, as shown in Figure 4.2.

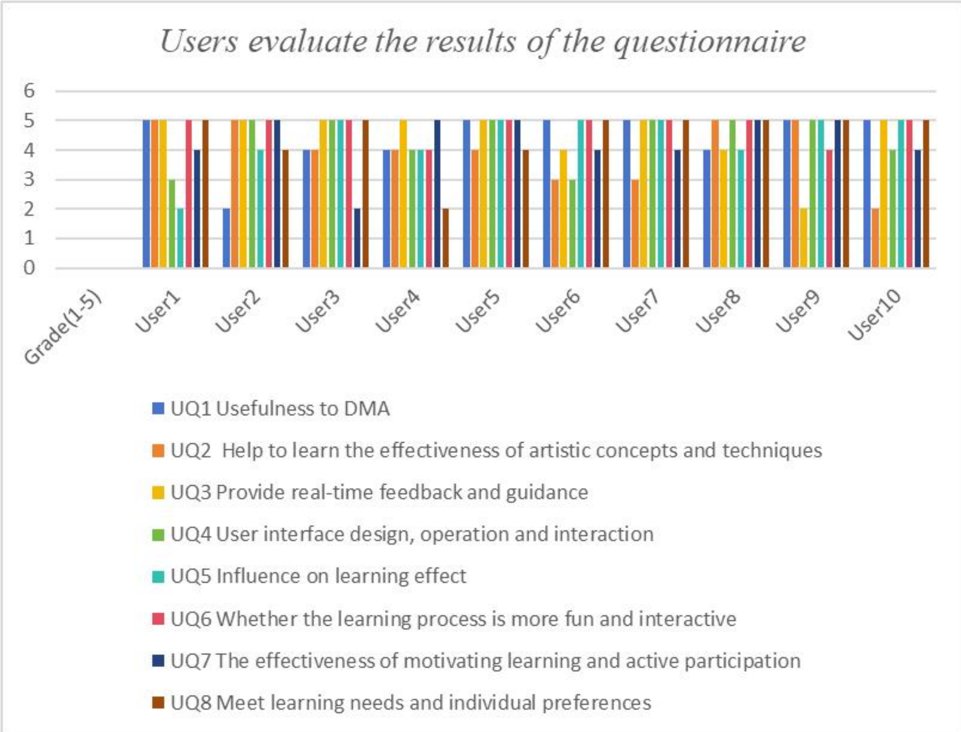

Figure 4.2. User Evaluation of the Questionnaire Results
(Picture Credit: Author's Self-Drawn)

After collecting questionnaires from experts and users, data analysis was conducted using SPSS. The above charts and graphs to offer a benchmark for the improvement of the model.

4.4 Descriptive Analysis

4.4.1 Expert Evaluation

The results of the expert assessment questionnaire data in Table 3.11 were statistically analyzed using SPSS data statistics for the minimum, maximum, mean, standard deviation, median, IQR, variance, standard error, kurtosis, skewness, and coefficient of variation for each of the assessment metrics, and the results are shown in Table 4.1.

Table 4.1
Expert Evaluation of Numerical Indicators

Evaluation Indicators	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6	EQ7	EQ8
Minimum Value	4	4	2	3	4	4	4	3
Maximum Value	5	5	5	5	5	5	5	4
Average Value	4.4	4.8	4	4.2	4.8	4.2	4.8	3.6
Standard Deviation	0.55	0.45	0.55	0.84	0.45	0.45	0.45	0.55
Median	4	5	4	4	5	4	5	4
IQR	1	0	1	1.25	0	0	0	0.5
Variance	0.3	0.2	0.3	0.71	0.2	0.2	0.2	0.3
Standard Error	0.25	0.2	0.25	0.36	0.2	0.2	0.2	0.25
Kurtosis	-1.2	-2	-1.2	-1.15	-2	-2	-2	-1.2
Skewness	0.37	-0.67	0.37	0.33	-0.67	-0.67	-0.67	0.37
Variation Coefficient	0.125	0.938	0.125	0.2	0.938	0.107	0.938	0.152

Based on the numerical characteristics of the statistical indicators in Table 3.14, it was found that the mean value of the usability assessment was 4.40, indicating that the AR instructional design model had overall high usability in the field of digital media arts specialization, and the standard deviation was 0.55, which indicated that the scoring results varied to some extent. The median is 4.00, indicating that most of the experts consider the model to be better in terms of usability. The kurtosis is -1.20, indicating that the distribution of ratings is relatively flat and close to normal. The coefficient of variation was 0.125, indicating a large variation in usability scores.

On the assessment of the effectiveness of rich AR media content, the mean value of this assessment metric is 4.80, indicating that most of the experts think that the model is very effective in providing rich AR media content. The standard deviation was 0.45, indicating that the ratings were relatively consistent. The median is 5.00, indicating that most experts consider the model to be very effective in providing rich AR media content. The skewness is -0.67, indicating that the distribution of ratings is slightly skewed to the left, i.e., the ratings are generally higher. A coefficient of variation of 0.938 indicates that there is less variation in the ratings.

On the assessment of room for improvement in compliance with usability principles, the mean value of this assessment metric was 0.40,suggesting that enhancements can be made and some suggestions for improvement. The median was 0.00, indicating that half of the experts found the model problematic in terms of compliance with usability principles. A skewness of 0.37 suggests that the dispersion of ratings is slightly skewed to the right.

In the assessment of guidance and support, the mean was 4.20, indicating that the model was able to provide better guidance and support throughout the educational process. The standard deviation was 0.84, implying that there was a large variation in the results of these ratings. The median was 4.00, indicating that most of the experts considered the model to be at an adequate level in terms of guidance and support.

On the other hand, for evaluating UI design, operability, and user experience, the mean value of this assessment metric was 4.80, indicating that most experts were very satisfied with the model's user interface design, operability, and user experience. The standard deviation is 0.45, indicating that the ratings are relatively consistent. The median is 5.00, indicating that most experts gave high ratings to the UI design, maneuverability, and UX.

As for the assessment of the effectiveness of developing creativity and innovation, it shows a mean value of 4.20, indicating that most of the experts considered the model to be very effective in developing students' creativity and innovation. The standard deviation was 0.45, indicating that the ratings were relatively consistent. The assessment of the effectiveness of stimulating students' interest in learning and keeping them engaged showed a mean of 4.80, indicating that most experts considered the model to be very efficient in igniting students' curiosity about learning and keeping them engaged. The standard deviation was 0.45, which describes the relative consistency of the scoring results.

In the assessment of flexibility in adapting to learning styles and individual differences, the mean value of the assessment metrics was 3.60, indicating that the model is flexible in adapting to different learning styles and individual differences. The standard deviation was 0.55, describing a wide variation in the scoring results.

In summary,drawing from the preceding evaluation, the AR instructional design model performs well in terms of usability, rich AR media content effectiveness, guidance and support, user interface design, operability, and user experience, fostering creativity and innovation, stimulating students' interest in learning and keeping them engaged, and adapting to learning styles and individual differences flexibility, according to the survey assessment by five experts specialized in digital media arts. However, there is still some room for improvement, such as improving the guidance and feedback mechanism and adding personalized learning features. The model has a broad spectrum of application prospects in areas and scenarios such as digital media art teaching, art exhibitions, and virtual art creation. Evaluating the expert assessment with questionnaires and analyzing these statistical indicators, can offer a comprehensive grasp of the survey data and a reference basis for the improvement of the model in question.

4.4.2 User Evaluation

In the numerical analysis of user assessment, the outcomes of the user assessment questionnaire data in Table 4.6 were also statistically analyzed using SPSS data statistics for the minimum, maximum, mean, standard deviation, median, IQR, variance, standard error, kurtosis, skewness, and coefficient of variation for each of the assessment metrics, and the results are shown in Table 4.2.

Table 4.2
Users' Evaluation of Numerical Indicators

Evaluation Indicators	UQ1	UQ2	UQ3	UQ4	UQ5	UQ6	UQ7	UQ8
Minimum Value	1	1	1	1	1	1	1	1
Maximum Value	3	3	3	2	3	2	2	3
Average Value	1.6	1.83	1.78	1.7	1.83	1.9	1.8	1.78
Standard Deviation	0.89	0.87	0.88	0.48	0.87	0.31	0.4	0.88
Median	1.5	2	2	2	2	2	2	2
IQR	1	1	0.75	0.75	1	0.25	0.75	1
Variance	0.79	0.76	0.77	0.23	0.76	0.09	0.16	0.78
Standard Error	0.31	0.33	0.32	0.15	0.33	0.1	0.13	0.3
Kurtosis	-2.12	-1.18	-1.07	-1.26	-1.18	-1.89	-2.06	-1.04
Skewness	-0.74	-0.43	-0.41	-0.1	-0.43	0.68	0.24	-0.39
Variation Coefficient	0.55	0.47	0.49	0.28	0.47	0.16	0.22	0.49

According to the numerical characteristics of statistical indicators in Table 4.8, when 10 participants were surveyed on their feelings about AR instructional design model in DMA learning, according to the values of mean value, standard deviation, and median value, overall, participants believed that AR instructional model was useful in DMA learning. In terms of IQR, variance, kurtosis, and skewness, participants' evaluation of the AR instructional design model has a certain degree of dispersion, and the coefficient of variation shows that the relative dispersion is moderate.

In the numerical value of the survey participants' evaluation of the potency of AR instructional design models understand and learn art concepts and techniques, overall participants believe that the models are effective in helping to understand and learn art concepts and techniques. There is also a degree of dispersion, but it is relatively moderate.

The median value of survey participants' evaluation of the immediate responses and guidance offered by the model is 2, indicating that overall, participants believe that the model provides a certain degree of instantaneous responses and direction.. The kurtosis is -1.07, indicating that the distribution of participants' evaluation of the immediate responses and guidance offered by the model presents a flat distribution. With a skewness of -0.41, the distribution of participants' evaluations of the immediate responses and guidance offered by the model skews slightly to the left. The coefficient of variation is 0.49, indicating that participants' evaluation of the immediate responses and guidance offered by the model is relatively discrete.

The average value of the survey participants' evaluation of the UI design, operation, and interaction of the model is 1.7, indicating that the participants believe that the model is effective in user interface design, operation, and interaction overall. The IQR is 0.75 and the variance is 0.23, indicating that there is a certain degree of dispersion in participants' evaluation of the model's user interface design, operation, and interaction. The coefficient of variation is 0.28, indicating that participants' evaluation of the UI design, operation, and interaction of the model is relatively less discrete.

Among the values evaluated on the impact of this model on the learning effect, the average value is 1.83, indicating that the participants believe that employing this model has a certain impact on the learning effect overall. The error range of participants' evaluation of the learning effect using this model is roughly 0.33, which is relatively small. The coefficient of variation is 0.47, indicating that participants' evaluation of the learning effect using this model is relatively discrete.

At the same time, in the numerical analysis of the participants' evaluation of the fun and interaction of the learning process using this model, the average value is 1.9, indicating that overall, the participants believe that the use of this model can make the learning process more interesting and interactive. Participants' ratings of the fun and interactivity of the educational journey using the model generally had a margin of error of 0.1 from the mean. The kurtosis value is -1.89, indicating that participants' evaluation of the fun and interactivity of the learning process using the model presents a flat distribution. The skewness value of 0.68 indicates that the distribution of participants' evaluation of the fun and interactivity of the learning process using the model is slightly skewed to the right. The coefficient of variation value was 0.16, indicating that participants' evaluation of the interest and interactivity of the learning process using the model was relatively less discrete.

The mean of the survey participants' evaluation of the effectiveness of the model in stimulating and actively engaging in education is 1.8, indicating that the participants believe that the model is effective in stimulating and actively engaging in the learning process overall. The standard deviation value is 0.4, indicating that there are some differences in participants' evaluation of the model in terms of motivation and active participation in learning. The error range of participants' evaluation of the model on motivation and active participation in learning is roughly 0.13.

In addition, in the numerical analysis of participants' evaluation that the model meets the learning needs and personalized learning preferences, the average value shows 1.78, indicating that overall, the participants believe that the model meets the learning needs and personalized learning preferences to a certain extent. The standard deviation is 0.88, indicating that there is some difference in the model, but the evaluation has a margin of error of 0.3 from the mean value. The coefficient of variation value is 0.49, indicating that participants' evaluation of the model to fulfill their educational requirements and tailored learning experiences preferences is relatively discrete.

In summary, grounded in the examination of the survey results, most of the participants perceived some usefulness about the degree of usefulness of the AR instructional design model in DMA learning. In terms of effectiveness ratings in helping to understand and learn art concepts and techniques, participants overall perceived the model to be effective. Participants also generally felt that the model provided real-time feedback and guidance to assist with learning tasks. Users rated the model's user interface design, operation, and interaction highly. Most evaluations of the learning effectiveness of using the model were positive and believed that it improved learning. Most participants also felt that using the model rendered the educational process more engaging and participatory. The model was considered effective in motivating and actively participating in learning. Finally, participants also gave positive comments on the model's compliance with learning needs and personalization preferences.

4.5 Confirmatory Factor Analysis

The design pattern is verified and evaluated comprehensively from two dimensions of theory and practice, and different verification factors and evaluation indexes are set up.

Expert evaluation focuses on theoretical rationality and practical feasibility, while user evaluation focuses on implementation satisfaction and user experience. Therefore, in terms of the rationality of the verification factor theory, the evaluation index is the conformity between the design model and the teaching theory, the internal logic of the design model and the concept clarity; regarding the practical availability of the verification factor, the evaluation index is the operability, the scope of application and the reusability. The data analysis results are shown in Table 4.3.

Table 4.3

Expert Evaluation (5 experts)

Evaluation Indicators	Theoretical Reasonableness	Practical Feasibility
Conformity to pedagogical theory	0.85	0.12
Internal logic	0.79	0.24
Conceptual clarity	0.83	0.19
Operability	0.13	0.91
Scope of Application	0.26	0.84
Reusability	0.21	0.88

In terms of satisfaction with the implementation of the validator, the evaluation indicators are the smoothness of the implementation process, satisfaction with the implementation results, and learning effect for students; in terms of the use experience of the validator, the evaluation indicators are ease of use, practicality, and compatibility of the design pattern. The data analysis results are shown in Table 4.4.

Table 4.4

User Evaluation (10 users)

Evaluation Indicators	Implementation Satisfaction	Usage experience
Smoothness of the implementation process	0.72	0.32
Satisfaction with the implementation results	0.86	0.21
Learning effect on students	0.79	0.29
Ease of use of the design model	0.22	0.85
Practicality of the design patterns	0.16	0.91
Compatibility of design patterns	0.28	0.78

The above data show the degree of contribution of different evaluation indicators to the confirmatory factors to reflect the basic process of confirmatory factor analysis.

4.6 Hypotheses Testing

In the previous section 1.7 of Chapter 1, the hypothesis of this study was presented as the integration of usability principles into the design of augmented reality instructional models for DMA will significantly increase learner engagement, comprehension, and creativity, resulting in a more effective and immersive educational experience.

Based on the above hypotheses, I will conduct a correlation analysis to test the validity of the hypotheses. First, I will conduct an analysis of correlation to explore the interconnection between the principle of usability and learner engagement, understanding, and creativity. Pearson's r was utilized to gauge the linear correlation between the two variables. The results of the correlation analysis will show the intensity and orientation of the link between usability principles and these learner variables.

By correlation analysis, if a robust positive association exists between usability principles and learners' engagement, understanding, and creativity, therefore it will validate this hypothesis.

On the contrary, if the results of the correlation analysis do not endorse the supposition of no substantial connection or influence between the principles of usability and the learner variables, the hypothesis needs to be reassessed or adjusted to further explore other possible factors that may influence these learner variables.

Therefore, before the correlation analysis, expectations were set for the assumptions assessed by the experts, as shown in Table 4.5. Expectations were set for the assumptions assessed by the users, as shown in Table 4.6.

Table 4.5

Expert Evaluation Hypothesis Expectations

	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6	EQ7	EQ8
Average Value	4.3	4.9	3.9	4.3	4.9	4.2	4.8	3.5

Table 4.6

Users Evaluate Hypothetical Expectations

	UQ1	UQ2	UQ3	UQ4	UQ5	UQ6	UQ7	UQ8
Average Value	1.6	1.75	1.8	1.6	1.8	2.0	1.7	1.8

To explore the relationship between an augmented reality instructional design model for DMA based on usability principles and learner engagement, comprehension, and creativity, I used the Pearson's r to assess the linear association between them.

Using the Pearson coefficient of correlation function, the following code was run:

```
import numpy as np
def pearson(x, y):
    """
    计算 Pearson 相关系数
    """
    x_mean = np.mean(x)
    y_mean = np.mean(y)
    numerator = np.sum((x - x_mean) * (y - y_mean))
    denominator = np.sqrt(np.sum((x - x_mean) ** 2) * np.sum((y - y_mean) ** 2))
    return numerator / denominator
if __name__ == '__main__':
    expert_evaluations = np.array([4.4, 4.8, 4, 4.2, 4.8, 4.2, 4.8, 3.6])
    expert_avr = np.array([4.3, 4.9, 3.9, 4.3, 4.9, 4.2, 4.8, 3.5])
```

```
user_evaluations = np.array([1.6, 1.83, 1.78, 1.7, 1.83, 1.9, 1.8, 1.78])
user_avr = np.array([1.6, 1.75, 1.8, 1.6, 1.8, 2.0, 1.7, 1.8])

print(" Yuxiao_Liu-expert_corr:\n",pearson(expert_evaluations,expert_avr))
print("Yuxiao_Liu-user_corr:\n",pearson(user_evaluations,user_avr))
```

In the Pearson programming software, the code was run using the Pearson correlation coefficient function as shown in Figure 4.3.

```
import numpy as np

def pearson(x, y):
    """
    计算Pearson相关系数
    """
    x_mean = np.mean(x)
    y_mean = np.mean(y)
    numerator = np.sum((x - x_mean) * (y - y_mean))
    denominator = np.sqrt(np.sum((x - x_mean) ** 2) * np.sum((y - y_mean) ** 2))
    return numerator / denominator
```

Figure 4.3. Pearson's Correlation Coefficient Function
(Picture Credit: Author's Self-Drawn)

Then according to Table 4.5 and Table 4.6 for the expectations of expert assessment and user assessment, in Pearson programming software, sequentially to write in the data box, run the above code, as shown in Figure 4.4, to calculate the correlation coefficient of the results, if the correlation value of the value obtained is between -1 and 1, close to 1 indicates a negative association, approaching -1 indicates an inverse relationship, nearing 0 indicates no association.

```
if __name__ == '__main__':
    expert_evaluations = np.array([4.4, 4.8, 4, 4.2, 4.8, 4.2, 4.8, 3.6])
    expert_avr = np.array([4.3, 4.9, 3.9, 4.3, 4.9, 4.2, 4.8, 3.5])
    user_evaluations = np.array([1.6, 1.83, 1.78, 1.7, 1.83, 1.9, 1.8, 1.78])
    user_avr = np.array([1.6, 1.75, 1.8, 1.6, 1.8, 2.0, 1.7, 1.8])


    print(" Yuxiao_Liu-expert_corr:\n",pearson(expert_evaluations,expert_avr))
    print("Yuxiao_Liu-user_corr:\n",pearson(user_evaluations,user_avr))
```

Figure 4.4. Calculated Correlation Coefficient
(Picture Credit: Author's Self-Drawn)

Finally, Figure 4.5 shows the result of the calculated correlation metric. The result of the correlation coefficient for the expert assessment is 0.9897712960341843 and the result of the correlation coefficient for the user assessment is 0.852617743654659.

```
D:\Anaconda3\python.exe C:/Users/10155/PycharmProjects/paper_data_analyse/main.py
 Yuxiao_Liu-expert_corr:
 0.9897712960341843
Yuxiao_Liu-user_corr:
 0.852617743654659

Process finished with exit code 0
```


Figure 4.5. Correlation Coefficient Results
(Picture Credit: Author's Self-Drawn)

Based on the results, it was judged that the obtained correlation coefficients were significant and in the same direction as the hypotheses, so it can be judged that integrating usability principles into the design of augmented reality instructional models for DMA will significantly increase learner engagement, comprehension, and creativity, resulting in a more effective and immersive educational experience. In other words, the hypotheses presented in Chapter 1 are valid.

4.7 Experimental Results and Analysis

This experiment aims to explore the differences in readers' acceptance and comprehension of the picture book design of the AR program in digital media arts courses compared to printed picture books through the differences in single and combined retelling scores between the treatment and control groups. The Mann Whitney U (Mann Whitney U Test, 2024) test is a nonparametric statistical method that can effectively analyze whether there is a substantial variance in the distribution of data between both cohorts when the sample size is small or does not obey a normal distribution. The test does not depend on the pre-conditions of the data distribution.

The Mann-Whitney U test procedure consisted of the following.

1) The scores d1 and d2 of each element of the two groups of retellers are combined and sorted according to numerical magnitude, with ordinal values between 1 and $n_1 + n_2$ (33);

2) The ordinal rank is assigned to each reteller to obtain the ordinal values O1 and O2 for each of the two groups of retellers: $\{O_1(i,j),\ i=1,n_1; j = 1,6\}$, $\{O_2(i,j), i=1,n_2; j = 1,6\}$;

(3) Calculate the respective total ranked values of the two groups as in Eqs. (1) and (2) and use Eqs. (3) and (4) to calculate the U-statistic:

$$\left\{R_1(j) = \sum_{i=1}^{n_1} O_1(i,j), j = 1,6\right\} \quad (1)$$

$$\left\{R_2(j) = \sum_{i=1}^{n_2} O_2(i,j), j = 1,6\right\} \quad (2)$$

$$\left\{U_1(j) = R_1 j - \frac{n_1(n_1+1)}{2}, j = 1,6\right\} \quad (3)$$

$$\left\{U_2(j) = R_2 j - \frac{n_2(n_2+1)}{2}, j = 1,6\right\} \quad (4)$$

The smaller of U1 and U2 was chosen as the final U statistic.

The values of the U-statistics for each element in each group are shown in Table 4.7.

Table 4.7
Test Results of Mann-Whitney U and Eta-squared for retelling

		Background	Themes	Endings	Episodes	Sequence	Totals
Mann-Whitney U		114	82	84	112	96.5	72.5
Asymp.Sig.(2-tailed)		0.389	0.038	0.041	0.339	0.118	0.021
Eta-squared		.	0.116	0.115	.	0.073	0.136
Average Rank	Experiment Group	18.38	20.38	20.25	18.5	19.47	20.97
	Control Group	15.71	13.82	13.94	15.59	14.68	13.26

However, simply performing the Mann-Whitney U test does not directly give a conclusion on if there's a notable disparity in the distribution of data between the two groups. Therefore, in this study, with the help of (Eta Squared, 2024) statistical software SPSS, the Asymp. Sig. (2-tailed) value was obtained based on the sample size and the corresponding U-statistic, which can be employed to ascertain if a significant divergence exists between the two data sets. The Asymp. Sig. (2-tailed) value for the composite score in this study was 0.021, which is less than the conventional significance level of 0.05 (FISHER R A, 1966), thus indicating that there is a notable distinction between AR illustrated books and traditional printed illustrated books in children's retelling scores.

This study also attempted to quantify the extent to which the picture book design of the Digital Media Arts AR program affects children's reading comprehension by introducing a measure of effect size, Etasquared (η^2), which is calculated as in equation (5) (Eta Squared, 2024):

$$\eta^2 = \frac{SS_{effect}}{SS_{total}} \qquad (5)$$

The SS_{effect} refers to the sum of squares of the variances of each test element caused by the independent variable (AR Picture Book Program reading), while SS_{effect} represents the aggregate of squared differences of the variances of each test element for the two groups of children.

The SPSS software platform calculated that the Eta-squared values for story theme, plot, sequence, and composite scores were 0.116, 0.115, 0.073, and 0.136, respectively. According to the common assessment criteria for effect size, i.e., small small impact (0.01), moderate impact (0.06), and substantial impact (0.14)(COHEN J,1988), suggesting that AR picture books exhibit moderate to nearly large effects in improving children's story theme grasping, plot retelling, plot sequence perception, and overall reading comprehension. This implies that AR picture books have some positive effects in promoting children's reading comprehension.

Through analysis of Table 4.8, the mean rank and median story-retelling scores of the children who used the digital media arts AR project picture books exceeded the control group's significantly children who used the traditional printed picture books. This difference highlights the actual utility of AR picture books and corroborates with the previous Mann-Whitney U-test results in Table 4.8, further validating the effectiveness of AR picture books in improving children's story-retelling skills.

Table 4.8
Mean Rank and Median for Retelling

	Groups	Numbers （N）	Mean rank	Median
Retell stories.	Experiment Group	16	20.97	6.1
	Control Group	17	13.26	5.5

4.8 Conclusion

The experimental results showed that the Asymp.Sig. (2-tailed)) values of the Mann-Whitney U test for story theme, plot, and composite scores were less than the conventional significance level of 0.05, indicating noticeable variations among the two cohorts. The analysis of the Eta-squared values further indicated that the digital media arts AR program picture books had moderate to nearly large effects. Additionally, the comparison of mean rank and median supported this result, suggesting that the use of the Digital Media Arts AR Program picture book design can somewhat improve children's reading comprehension levels.

The research also found that those children who were more familiar with AR technology performed particularly well in story retelling. Utilizing the interactivity and visual effects provided by AR technology, this group of children was better able to incorporate virtual scenes and characters into the storyline. Most of the children who used the digital media arts AR program for picture book design showed strong interest and active participation, believing that AR technology made the reading experience more interesting and vivid, which in turn enhanced the immersion and depth of understanding of the story content. This further confirms indicating that AR positively influences children's reading effects and points out that AR technology has great potential for application in improving children's reading experience. Therefore, augmented reality design grounded in the principle of usability guides instruction of digital media art within the design of AR project picture books feasibly.

Although the research shows positive results, its limitations need to be noted. The relatively limited participant number in this study and the fact that all third graders were from the same classroom could affect the applicability of the results. Future research should consider including a more extensive participant pool of students from various age groups, different schools, and different regions. The current phase of the study focused only on story-retelling scores as an assessment indicator and did not comprehensively cover all aspects of reading comprehension. Future studies should further consider the effects of digital media arts AR program picture book design on other cognitive abilities, such as vocabulary learning, thinking training, and creative expression, to fully explore the potential of augmented reality design-guided digital media arts instructional AR program technology based on usability principles in children's reading education.

4.9 Summary

The chapter focuses on the selection of the number of respondents in the experimental setup by statistically analyzing the data collected from the expert assessment and the user assessment, as well as the descriptive analysis, confirmatory factor analysis, and correlation analysis. The proposed hypotheses were finally validated and informed for practice and future research.

CHAPTER FIVE

FINDINGS AND CONCLUSIONS

5.1 Overview

In the previous chapter, the experts and users are surveyed, and the data of the questionnaire data are processed and analyzed. In this section, the findings and outcomes of the research will summarized and the degree to which the study's goals were met will be reviewed. The challenges and limitations in the research process are discussed, and solutions and improvement measures are proposed. The aim is to provide a comprehensive assessment and summary of an augmented reality instructional design model for DMA based on usability principles and to offer direction and insights for subsequent studies and instructional practice.

5.2 Recapitulation of the Study's Findings

This section collects relevant data by sending questionnaires to experts and users in Chapter 4, collates and analyzes the data, and draws three main findings, mainly in the following aspects:

Discovery 01: The application effect of usability principle in DMA augmented reality instructional design model.

The application of usability principles helps simplify the user interface and makes it easier for learners to understand and manipulate augmented reality content. Augmented reality models designed based on usability principles can provide personalized learning experiences that enhance learner engagement and engagement in the learning content. Effective usability design can improve learners' acceptance and learning effect of augmented reality technology.

Discovery 02: The impact of usability principles on learner engagement, comprehension, and creativity.

Through the application of the usability principle, it is easier for learners to participate in the DMA augmented reality teaching and improve the participation of learners. Usability design facilitates for students to understand learning content and improves learners' understanding of DMA concepts and techniques. Reasonable usability design can stimulate learners' creativity and imagination and promote their creative expression and practice in DMA.

Discovery 03: Relationship between usability principles and instructional design patterns for augmented reality in DMA.

The usability principles provide useful guidance for designing augmented reality teaching models for DMA, ensuring that the teaching model matches the needs and expectations of learners. Through the application of the usability principle, the DMA augmented reality teaching design model can more effectively cater to the educational requirements of learners and provide a better educational journey. The usability principle and the DMA augmented reality teaching design mode form a mutually promoting relationship, through continuous improvement and optimization of the teaching mode, to improve the utilization effect of augmented reality technology in art education.

Through the discussion of the above three main findings, we can have a deeper understanding of the application effect of the usability principle in the DMA augmented reality instructional design model, its impact on learners, and its relationship with the DMA instructional design model. This helps to further promote the advancement and implementation of AR education in DMA.

5.3 Discussion

Based on the main findings of the study, the research questions raised in Chapter 1 are discussed as follows:

RQ 1: What are the elements of a hybrid augmented reality model based on instructional design and usability principles of digital media?

An intuitive, easy-to-understand, and operate user interface is designed so that students can easily navigate and use the augmented reality teaching mode. Provide multiple means of interaction, such as gesture, voice, or touch,to satisfy the requirements and preferences of various learners and encourage active participation in the teaching process. Provide rich, interesting, and relevant DMA teaching content to stimulate students' interest and active learning. According to the specific requirements and educational growth ability of learners, offer appropriate learning support, such as adaptive learning paths, personalized learning resources, etc. Considering the different abilities and special needs of students, accessibility features and accessibility design are provided to guarantee that each student possesses equal entry to and use of the augmented reality teaching mode. Optimize system performance and improve the stability and fluency of the augmented reality teaching mode to ensure that there are no delays or interruptions in the use of students.

The elements of designing the DMA augmented reality teaching model based on the usability principle are summarized as user interface design, interaction design, content design, feedback mechanism, personalized learning support, accessibility support, and performance optimization. Through comprehensive consideration of the above factors, a DMA augmented reality teaching model based on the principle of usability will be able to effectively enhance student education experience and learning outcomes.

RQ 2: How to construct a hybrid augmented reality model?

The construction of a mixed augmented reality (MAR) model based on digital media arts is a complex process involving several key steps. This is described in detail in Chapters 3 and 4. To summarize, firstly, the potential for educational applications of MAR needs to be understood and a detailed needs analysis needs to be conducted to identify the target audience and their learning needs. Next, clear educational goals should be set, and appropriate content and technology tools should be selected. In my study, I chose Zapworks as the technology tool to develop the program design of a digital media arts course on picture book reading for younger children. In the design, user experience, and interactivity were emphasized to enhance learner engagement. Upon finishing the model, responses were gathered and learning outcomes were evaluated through prototype testing, culminating in continuous improvement to ensure the model's currency and effectiveness. Through a systematic building process, the mixed augmented reality model based on digital media arts not only provides learners with a rich learning experience but also effectively promotes their engagement and deep learning.

RQ 3: How to validate a hybrid augmented reality model?

The research question is stated in detail in Chapter 5 of this study. In brief, the process of validating a mixed augmented reality model based on digital media arts can be divided into several key phases; firstly, a small-scale prototype test is conducted to collect learner feedback and data to assess the efficacy of the framework in facilitating learning engagement and outcomes. Next, optimization and adjustments are made by analyzing the feedback to ensure that the interaction design and content of the model meet the needs of the learners. Finally, quantitative and qualitative methods can be applied to comprehensively evaluate the practical applicability and educational value of the model to ensure its long-term usability and effectiveness. Through such a systematic validation process, the successful implementation and continuous improvement of the mixed augmented reality model in the educational environment can be effectively ensured.

5.4 Limitations of the Study

Although the hypothesis of this study is partially valid, it also has many shortcomings due to the limitation of its research level and the lack of time and energy:

Firstly, due to the limitations of research time and resources, data collection was completed at the same time, resulting in a limited sample size, which may not adequately represent the entire target group. In future studies, data collection could be conducted multiple times or over multiple academic years to obtain larger samples and more comprehensive data, as well as better generalization and generalization capabilities.

Secondly, the survey method of this study is relatively simple, only using questionnaires and interviews to collect data. In the process of investigation, respondents may not fully understand the contents of the questionnaire before answering the inquiries, and the survey outcomes are easily affected by subjectivity, resulting in bias in the collected data. In future research, a variety of data collection techniques, including observation, log recording, focus group discussion, etc., can be used to obtain data at different levels and angles, to improve the accuracy of survey results.

Finally, in the research of DMA augmented reality instructional design, the effect evaluation often relies on students' subjective evaluation. However, this research does not include students' subjective evaluation of the research object. In future studies, students can be included in the research objects, and objective indicators and assessment methods, such as learning performance, learning progress, and task completion time, can be combined to supplement subjective evaluation and improve the objectivity and scientific nature of effect evaluation.

Overall, to overcome these limitations, future research can employ multiple data collection methods, extended research time, and a combination of objective and subjective evaluation to more fully and accurately evaluate the effectiveness and applicability of the DMA augmented reality instructional design model based on usability principles. At the same time, it can cooperate with other researchers to conduct multi-center research and comprehensive analysis to improve the credibility of the research and the feasibility of popularization.

5.5 Conclusion

This study focuses on experts and teachers who teach DMA in universities in Sichuan Province. In this thesis, questionnaire star is used to survey experts and teachers, and the survey results are collected, as well as the gathered questionnaire data is analyzed to get the results. The study also analyzes the impact of integrating usability principles into the design of an augmented reality instructional design model for DMA on learner engagement, comprehension, and creativity. The research results address the study's inquiries and hypotheses presented in Chapter 1. Through the analysis, the conclusion is drawn: the DMA augmented reality teaching model based on the usability principle has a significant linear relationship with learners' participation, understanding, and creativity, and is positively correlated with it.

5.6 Recommendations

The following are some of the recommendations from the study, which we hope will enlighten and help practice and decision-making in related fields:

User experience evaluation methods: Future research can explore more comprehensive and accurate user experience evaluation methods to better understand students' feelings and needs in DMA augmented reality teaching. A variety of qualitative and quantitative methods such as user surveys, observations, and experiments can be used to obtain more reliable and objective data.

Technological improvement and innovation: As technology continues to evolve, future research can focus on how to adopt the latest augmented reality technology to improve instructional design models. For example, engagement with VR technology, mixed reality technology, etc., to enhance the experience and learning effect of students.

Operability and ease of use optimization: Further research can explore how to optimize the operability and ease of use of DMA augmented reality instructional design models. Research on improving user interface design, streamlining operational processes, and providing clear guidance and feedback can improve student learning experiences and outcomes.

Interdisciplinary cooperation and teaching integration: The interdisciplinary cooperation and teaching integration of DMA augmented reality teaching with other disciplines and fields can provide a richer and more comprehensive learning experience. For example, combining arts with science, engineering, culture, and other disciplines to develop more diverse and innovative teaching practices.

Educational practice case study: In future research, explore and document the application cases and practical experiences of DMA augmented reality teaching in actual educational scenarios. Through case studies, we can better understand the application effect and practical problems of the instructional design models and provide practical guidance and reference.

In general, future research can be deeply explored and improved in the aspects of user experience evaluation methods, technological improvement and innovation, operability and usability optimization, interdisciplinary cooperation and teaching integration, and educational practice case studies, to further enhance the effect and practical application of DMA augmented reality instructional design model.

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Appendix

Appendix A: Expert Evaluation Questionnaire

Dear participants, thank you for taking the time to complete this survey.

Your opinions are important to us and will help us optimize our products/services to meet your needs.

Name: Sex: Age: Title: Workplace:

(Personal information will only be used for thesis writing)

1. What is your assessment of the usability of the AR Instructional Design Model for DMA in your area of expertise?

   ☐ Excellent (5 points)

   ☐ Good (4 points)

   ☐ Fair (3 points)

   ☐ Inadequate (2 points)

   ☐ Very poor (1 point)

2. Please rate the effectiveness of the model in delivering rich AR media content.

   ☐ Very effective (5 points)

   ☐ Effective (4 points)

   ☐ Average (3 points)

   ☐ Limited effectiveness (2 points)

   ☐ Ineffective (1 point)

3. What room for improvement do you see in the design model's compliance with usability principles?

   ☐ Provide user training and support (5 points)

   ☐ User interface optimization (4 points)

   ☐ Simplification of operation (3 points)

   ☐ Feedback mechanism improvement (2 points)

   ☐ No need for improvement (1 point)

4. Please comment on whether the model provides sufficient guidance and support in

the teaching and learning process.

- ☐ Very adequate (5 points)
- ☐ Adequate (4 points)
- ☐ General (3 points)
- ☐ Limited (2 points)
- ☐ Inadequate (1 point)

5. Please give your comments and suggestions on the user interface design, operability and user experience of the model.

- ☐ Excellent (5 points)
- ☐ Good (4 points)
- ☐ Average (3 points)
- ☐ Inadequate (2 points)
- ☐ Very poor (1 point)

6. In your area of specialization, how effective do you think the model is in fostering students' creativity and innovation?

- ☐ Very effective (5 points)
- ☐ Effective (4 points)
- ☐ Average (3 marks)
- ☐ Limited effectiveness (2 points)
- ☐ Ineffective (1 point)

7. Please evaluate the effectiveness of the model in stimulating students' interest in learning and keeping them engaged.

- ☐ Very successful (5 points)
- ☐ Successful (4 points)
- ☐ Average (3 points)
- ☐ Limited success (2 points)
- ☐ Unsuccessful (1 point)

8. How flexible do you think the model is in catering for different learning styles and individual differences?

- ☐ Very flexible (5 points)

☐ Flexible (4 points)

☐ Average (3 points)

☐ Not flexible enough (2 points)

☐ Very inflexible (1 point)

9. Please provide what you consider to be the strengths and weaknesses of the model and give suggestions for improvement.

☐ Advantages (list) ____

☐ Weaknesses (list) ____

☐ Suggestions for improvement (list)________________________________

____

10. In what areas or scenarios do you think the model could be more widely used?

____

____

____

Appendix B: User Evaluation Questionnaire

Dear participants, thank you for taking the time to complete this survey.

Your opinions are important to us and will help us optimize our products/services to meet your needs.

Name: Sex: Age: Title: Workplace:

(Personal information will only be used for thesis writing)

1. How usable did you find the AR Instructional Design Model for DMA while you were using it for your studies?

☐ Very useful (5 points)

☐ Useful (4 points)

☐ Average (3 points)

☐ Not very useful (2 points)

☐ Useless (1 point)

2. Please rate the effectiveness of the model in helping you understand and learn art concepts and techniques.

☐ Very effective (5 points)

☐ Valid (4 points)

☐ Average (3 points)

☐ Limited effect (2 points)

☐ Invalid (1 point)

3. Do you think the model provides enough real-time feedback and guidance to help you with your learning tasks?

☐ Very good (5 points)

☐ Sufficient (4 points)

☐ Average (3 points)

☐ Not enough (2 points)

☐ Insufficient (1 point)

4. Please rate the user interface design, operation and interaction of the model.

☐ Excellent (5 points)

☐ Good (4 points)

☐ Average (3 points)

☐ Need improvement (2 points)

- ☐ Very poor (1 point)

5. How do you think the use of the model has affected your learning outcomes?
   - ☐ Very positive (5 points)
   - ☐ More positive (4 points)
   - ☐ Average (3 points)
   - ☐ Negative (2 points)
   - ☐ Very negative (1 point)
6. Did you find the learning process more interesting and interactive when using the model?
   - ☐ Strongly agree (5 points)
   - ☐ Agree (4 points)
   - ☐ Average (3 points)
   - ☐ Disagree (2 points)
   - ☐ Strongly disagree (1 point)
7. Please rate the effectiveness of the model in motivating and actively engaging you in learning.
   - ☐ Very effective (5 points)
   - ☐ More effective (4 points)
   - ☐ Average (3 points)
   - ☐ Limited effect (2 points)
   - ☐ Invalid (1 point)
8. Do you think the model meets your learning needs and personalized learning preferences?
   - ☐ Very consistent (5 points)
   - ☐ More consistent (4 points)
   - ☐ Average (3 points)
   - ☐ Not quite (2 points)
   - ☐ No (1 point)