Faculty of Electronics and Computer Technology and Engineering

DEVELOPMENT FOR ATOM AND DOPING PROCESS USING AUGMENTED REALITY IN MICROELECTRONICS

MUHAMMAD SHAZNI FIKRI BIN SUHAIMI

Bachelor of Electronics Engineering Technology with Honours

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2025

DEVELOPMENT FOR ATOM AND DOPING PROCESS USING AUGUMENTED REALITY IN MICROELECTRONICS

MUHAMMAD SHAZNI FIKRI BIN SUHAIMI

This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

Faculty of Electronics and Computer Technology and Engineering
Universiti Teknikal Malaysia Melaka

2025

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRONIK DAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Development For Atom And Doping Process Using Augumented Reality Inmicroelectronics

Sesi Pengajian : 2023/2024

Saya MUHAMMAD SHAZNI FIKRI BIN SUHAIMI mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

☐	**SULIT***	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD***	(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.
☑	**TIDAK TERHAD**	

Disahkan oleh:

Alamat Tetap: ....
....
....

DAYANASARI BINTI ABDUL HADI
Jurutera Pengajar
Fakulti Teknologi Dan Kejuruteraan Elektronik Dan Komputer (FTKEK)
Universiti Teknikal Malaysia Melaka (UTeM)

Tarikh : 24 Januari 2025

Tarikh : 24 Januari 2025

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this project report entitled "Development For Atom And Doping process Using Augumented Reality Inmicroelectronics" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Student Name : MUHAMMAD SHAZNI FIKRI BIN SUHAIMI

Date : 24 Januari 2025

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology with Honours

Signature :

Supervisor Name : DAYANASARI BINTI ABDUL HADI

Date : 28/01/2025

Signature :

Co-Supervisor Name (if any) : DR. HASLINAH BINTI MOHD NASIR

Date : 28/01/2025

DEDICATION

Thank you to my family and friends who have always supported me and pushed me to accomplish my final project. In the meanwhile, I would like to express my gratitude to my mentor and co-mentor, Mrs Dayanasari Binti Abdul Hadi and Dr Haslinah Binti Mohd Nasir, for their direction and support in completing my final year project. I sincerely appreciate everything you've done for me. Their dedication, effort, and thoughtfulness were essential to our achievement. I am really appreciative of their constant help, encouragement, and faith in my ability to accomplish.

ABSTRACT

Microelectronics education faces significant challenges in effectively teaching abstract and complex concepts, including atomic structures, semiconductor physics, and doping processes. Traditional methods often fail to engage students or provide sufficient visualization, limiting comprehension and retention of key topics. To address this, an Augmented Reality (AR) system was developed to enhance learning through immersive and interactive experiences. The primary objectives of this project were to explore the potential of AR technology in microelectronics education, develop an interactive AR-based learning tool with detailed visualizations of atom structures and doping processes, and validate its effectiveness through user feedback. The system was designed using Rhino 3D for 3D modelling and Unity for AR environment integration, resulting in a mobile application with features including interactive atomic models, dynamic periodic table exploration, and animated doping process demonstrations. Survey results from 21 users indicated significant improvements in learning outcomes, with 93% reporting enhanced comprehension compared to traditional approaches. Students found the system engaging, citing clear visual representations of complex processes as a major benefit. However, challenges such as device accessibility, implementation costs, and limited technical skills were identified. Future improvements include incorporating advanced simulations like energy band diagrams and conductivity models, adding real-time annotations, and expanding the content to cover more semiconductor-related topics. The AR system has strong commercialization potential, particularly for higher education institutions and corporate training in semiconductor manufacturing. Offering scalable, cost-effective versions and forming partnerships with educational technology firms could further broaden its impact. This project demonstrates the

transformative potential of AR in technical education, providing a foundation for continued innovation in immersive learning tools.

ABSTRAK

Pendidikan mikroelektronik menghadapi cabaran besar dalam mengajar konsep abstrak dan kompleks dengan berkesan, termasuk struktur atom, fizik semikonduktor, dan proses doping. Kaedah tradisional sering gagal melibatkan pelajar atau menyediakan visualisasi yang mencukupi, sekali gus mengehadkan pemahaman dan pengekalan topik utama. Bagi menangani isu ini, satu sistem Realiti Terimbuh (AR) telah dibangunkan untuk meningkatkan pengalaman pembelajaran melalui pendekatan yang imersif dan interaktif.

Objektif utama projek ini adalah untuk meneroka potensi teknologi AR dalam pendidikan mikroelektronik, membangunkan alat pembelajaran berasaskan AR yang interaktif dengan visualisasi terperinci struktur atom dan proses doping, serta mengesahkan keberkesanannya melalui maklum balas pengguna. Sistem ini direka bentuk menggunakan **Rhino 3D** untuk pemodelan 3D dan **Unity** untuk integrasi persekitaran AR, menghasilkan aplikasi mudah alih yang menampilkan model atom interaktif, penerokaan jadual berkala yang dinamik, serta animasi proses doping. Hasil kajian daripada 21 pengguna menunjukkan peningkatan ketara dalam hasil pembelajaran, dengan 93% melaporkan pemahaman yang lebih baik berbanding pendekatan tradisional. Pelajar mendapati sistem ini menarik, dengan visualisasi yang jelas bagi proses yang kompleks dianggap sebagai kelebihan utama. Namun, cabaran seperti kebolehcapaian peranti, kos pelaksanaan, dan kemahiran teknikal yang terhad turut dikenal pasti. Penambahbaikan masa depan termasuk integrasi simulasi lanjutan seperti rajah jalur tenaga dan model konduktiviti, penambahan anotasi masa nyata, serta pengembangan kandungan kepada lebih banyak topik berkaitan semikonduktor. Sistem AR ini mempunyai potensi komersial yang kuat, khususnya untuk institusi pendidikan tinggi dan latihan korporat dalam bidang pembuatan semikonduktor. Menawarkan versi yang berskala dan kos

efektif serta membentuk kerjasama dengan syarikat teknologi pendidikan boleh memperluaskan impaknya. Projek ini membuktikan potensi transformatif AR dalam pendidikan teknikal, menyediakan asas untuk inovasi berterusan dalam alat pembelajaran yang imersif.

ACKNOWLEDGEMENTS

First and foremost, I extend my gratitude to the Almighty for granting me the strength, well-being, and empathy to fulfil my tasks. To my beloved family, your unwavering love, patience, and sacrifices have enabled me to pursue my dreams. I am deeply thankful for your endless support and belief in me.

To my friends, your support and guidance have been invaluable. Thank you for always being there to listen and help; I feel incredibly fortunate to have such wonderful people in my life.

Special thanks to my mentors, Mrs. Dayanasari Binti Abdul Hadi and Dr. Haslinah Binti Mohd Nasir, for their invaluable advice and knowledge. Your guidance has greatly contributed to my growth as a student, and I am forever grateful for your encouragement and support.

This project would not have been possible without each of you, and I am profoundly grateful for your love and support. Thank you for everything.

TABLE OF CONTENTS

PAGE

DECLARATION

APPROVAL

DEDICATIONS

DEVELOPMENT FOR ATOM AND DOPING PROCESS USING AUGMENTED REALITY IN MICROELECTRONICS **i**

DEVELOPMENT FOR ATOM AND DOPING PROCESS USING AUGUMENTED REALITY IN MICROELECTRONICS **i**

ABSTRACT **i**

ABSTRAK **iii**

ACKNOWLEDGEMENTS **v**

TABLE OF CONTENTS **vi**

LIST OF TABLES **viii**

LIST OF FIGURES **ix**

CHAPTER 1 INTRODUCTION **1**

1.1 Background 1

1.2 Addressing Societal Issues Through Development for Atom and Doping Process Using Augmented Reality in Microelectronics 2

1.3 Problem Statement 3

1.4 Project Objective 4

1.5 Scope of Project 5

CHAPTER 2 LITERATURE REVIEW **6**

2.1 Introduction 6

2.2 History of Evolution Augmented Reality (AR) 6

2.3 Type of AR 9

2.3.1 Marker-Based AR 9

2.3.2 Maker-less AR 10

2.4 Application of Augmented Reality in Education 12

2.4.1 Summary 14

2.5 Table Comparison of Previous Studies 15

2.6 Summary 20

CHAPTER 3 METHODOLOGY **21**

3.1 Introduction 21

3.2 Project Overview 21

3.2.1 Project Flowchart 22
3.2.2 Project Development Flowchart 24
3.2.3 Table Main Menu 28
3.3 Module Development 30
3.4 Software Requirement 31
3.5 Project Development 34
3.5.1 Designing Phase 34
3.5.2 Integration Phase 36
3.5.2.1 Main Menu 37
3.5.2.2 Atom Structure 39
3.5.2.3 Periodic Table 41
3.5.2.4 Doping Process 43
3.5.2.5 Quiz 45
3.5.3 Application Development 48
3.5.4 User feedback and improvement 49
3.6 Sustainable Development Goals (SDG) 49
3.7 Summary 50

CHAPTER 4 RESULTS AND DISCUSSIONS 51
4.1 Introduction 51
4.2 Result 51
4.3 Analysis (Betulkn graf tambah label) 56
4.3.1 Interactive Augmented Reality (AR) Interface 56
4.3.1.1 Atomic Structures and AR Technology 57
4.3.1.2 Groups 3, 4, and 5 of the Periodic Table 59
4.3.1.3 Doping Process 62
4.3.1.4 General Feedback 65
4.4 Summary 67

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS 69
5.1 Conclusion 69
5.2 Future Improvement 70
5.3 Commercialization Potential 70

REFERENCES 72

APPENDICES 75

LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1	Comparison of previous studies regarding conventional education aids	15
Table 2.2	Comparison of previous studies regarding interactive education aids	16
Table 3.1	Table of Main Menu	28
Table 3.2	Module Development of AR system	30
Table 3.3	Software description	31

LIST OF FIGURES

FIGURE **TITLE**
PAGE

Figure 2.1 Illustrates the Virtual Continuum visual 7

Figure 2.2 Illustration hologram drift in markerless Visual-Inertial Simultaneous Localization and Mapping (VI-SLAM)-based Augmented Reality (AR) [23] 11

Figure 3.1 Project Flowchart 23

Figure 3.2 Drsigning Flowchart 24

Figure 3.3 Integration Flowchart 26

Figure 3.4 Atom Structures 34

Figure 3.5 Periodic Table 35

Figure 3.6 Elements group 3, 4, and 5 in Periodic Table 35

Figure 3.7 Part of Silicon(Si) and Aluminium(Al) Doping Process 36

Figure 3.8 Interface Main Menu AR 37

Figure 3.9 Script for Main Menu 38

Figure 3.10 Interface Atom Structure 39

Figure 3.11 Script Atom structure 40

Figure 3.12 Interface Periodic Table 41

Figure 3.13 Script for Enlarge Elements 42

Figure 3.14 Doping Process Interface 43

Figure 3.15 Script for Doping Process 44

Figure 3.16 Quiz Interface 45

Figure 3.17 Script for Quiz Interface 46

Figure 3.18 APK file device configuration and scene structure 48

Figure 3.19 APK file API setting 48

Figure 3.20 Survey Interface 49

Figure 4.1 Interface of Start 52

Figure 4.2 Animation of Atom Structure 52

Figure 4.3 Interface of Periodic Table 53

Figure 4.4 Animation of Doping Process 54

Figure 4.5 Interface of Quiz 55

Figure 4.6 Interface of Scores and Exit 55

Figure 4.7 Histogram About AR can Visualizing Atomic Structures to Enchance Understanding 57

Figure 4.8 Pie Chart showing User Understanding of Basic Atomic Concepts 58

Figure 4.9 Histogram demonstrating how users can find elements in the periodic table. 59

Figure 4.10 The histogram shows how beneficial the information supplied to the user proved to be for semiconductor elements in groups 3, 4, and 5 60

Figure 4.11 The histogram illustrates the AR features that assist the user understand components in groups 3, 4, and 5 61

Figure 4.12 Histogram demonstrating the difficulties of understanding doping processes in semiconductors such as silicon and aluminium doping. 62

Figure 4.13 The histogram shows if this AR simulations of the doping process help user knowledge. 63

Figure 4.14 Histogram showing which components of the doping process should be included in this AR system. 64

Figure 4.15 The pie chart presents the proposal question of whether incorporating AR technology into higher education, such as microelectronics classes, may be advantageous 65

Figure 4.16 Histogram of possible obstacles that users experience while utilizing AR for teaching microelectronics courses. 66

Figure 4.17 Pie chart showing user interest in future testing or assessment of this AR technology. 67

CHAPTER 1

INTRODUCTION

1.1 Background

Microelectronics education is essential for students who want to excel in the fast-changing electronics sector. The program includes a variety of topics, including integrated circuit design, semiconductor physics, and microfabrication processes. However, microelectronics may be difficult to learn since it is abstract and sophisticated, forcing students to imagine intricate tiny processes and procedures. Conventional education frequently falls short in teaching complicated microelectronics concepts such as atom processes and semiconductor doping. Interactive education, such as Augmented Reality (AR), may greatly improve student learning by delivering engaging, hands-on experiences that make complex subjects more accessible and interesting.

Augmented Reality(AR) allowing interaction between virtual and real-world elements in real-time, offers a more engaging and participatory learning experience. AR can enhance student motivation and attention, making learning more effective and attractive. It also enables collaborative applications in various fields, including education. Many students struggle with understanding molecular structures due to the lack of visualization in traditional teaching methods [1].

Augmented reality (AR) can solve these issues by giving interactive 3D simulations of small components and circuits, therefore improving learning outcomes and encouraging spatial comprehension [2]. AR also promotes cooperation and collaborative learning, making theoretical knowledge relatable to real-world devices and systems [3]. By bridging the gap between imagination and reality, AR assists students in comprehending intricate microscopic processes and activities, making abstract concepts more approachable and tangible [4].

Exploring the potential benefits of an AR system for microelectronic fabrication education, this project also addresses the technical challenges of developing such a system. Additionally, it considers the potential impact such technology could have on the microelectronics industry.

1.2 Addressing Societal Issues Through Development for Atom and Doping Process Using Augmented Reality in Microelectronics

Augmented reality (AR) technology is rapidly being applied to improve learning outcomes in a variety of sectors, including chemistry and microelectronics. AR may be used in microelectronics to overcome the difficulties of teaching abstract notions by presenting interactive 3D models of microscopic parts and circuits. This technology can bridge the gap between imagination and reality, allowing students to better understand complex microscopic processes and activities. By properly addressing the obstacles of teaching abstract concepts, incorporating AR into microelectronics education has huge promise for improving student comprehension and performance in the subject. The use of AR in microelectronics education can help improve collaboration and collaborative learning by allowing students to work together on virtual projects, share ideas, and solve problems as a group. This encourages greater understanding through peer learning and discussion. Furthermore, AR applies theoretical material to the real world, boosting students' relevance and engagement with abstract concepts. To summarize, the development of augmented reality models for teaching atom and molecule processes in microelectronics can dramatically improve learning results by delivering interactive and immersive experiences.

This technology can bridge the gap between imagination and reality, allowing students to better understand complicated microscopic processes and activities.

1.3 Problem Statement

Microelectronics is crucial for modern industry, demanding students to comprehend its intricate physics and chemistry. It is rapidly evolving and vital for the e-economy and e-society. However, it involves complex concepts in semiconductor physics, circuit design, and fabrication processes, posing challenges for learners. Continuous training is essential, but the field is multidisciplinary nature and need for expensive equipment pose challenges for individual research institutes, labs, or companies to keep up [5]. Traditional physics labs, despite promoting interaction and inquiry, may not always ensure effective learning outcomes.

These issues raise the question of how to better teach students about microelectronic subject while using modern technologies like augmented reality (AR). Augmented reality can provide fascinating visualizations of intricate microelectronic components and processes, making abstract concepts more tangible and easier to understand. Students can interact with virtual circuits and devices in real-time, gaining a deeper understanding of complex principles. Augmented reality (AR) techniques offer a solution by enabling interactive visualization of complex 3D structures, enhancing understanding of inorganic chemistry properties [6]. The development of this project allows students to learn about the microelectronic process in an interactive and engaging way, allowing student to better comprehend the complicated stages involved and enhance their skills.

1.4 Project Objective

The primary objective of developing an Augmented Reality (AR) system for microelectronic is to enhance students learning by providing an interactive and immersive method for understanding the atom and molecule process. The specific aims of the AR system are:

a) To investigate AR technology to implement in education especially in microeletronic subject

b) To develop an interactive interface for the AR system, overlaying visual images and animations onto the real-world environment.

c) To verify the AR performance in practical applications using user feedback or surveys.

1.5 Scope of Project

The scope of this project are focus on developing a markerless AR system that involves creating software for an interactive learning tool that enables students to explore microelectronics and fabrication concepts. It encompasses building, integrating, and testing the AR system for usability and effectiveness.

Secondly, creation of virtual images and animations focus on generating visuals that overlay real-world views of microelectronic fabrication processes. These images must appropriately portray complicated processes mentioned in the module atom, molecule, and doping process. Developing marker less AR involves techniques like object recognition, depth sensing, and SLAM methods.

Lastly, integration with microelectronic fabrication that Collaboration with higher education is essential to ensure the AR system aligns with real-world processes. This involves extensive coordination to validate the accuracy and success of the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the crucial facts and details discovered by various studies and research from prior studies. As a result, the chapter opens with an explanation about background of Augmented Reality and its types. Additionally, this chapter also covers the part application of Augmented Reality in various fields such as education, healthcare, and industry. Furthermore, this research highlights the importance of Augmented Reality in education as our main goal in this project while to conduct study on these principles because they are the chosen way to complete this project. This is used as a comparison and reference for the system that is developed in this project.

2.2 History of Evolution Augmented Reality (AR)

Technological development has a wide-ranging impact on daily life, including in the fields of healthcare, education, communication, transportation, and industry. While providing many benefits, technological development also poses new challenges, including issues of privacy, cyber security, and unemployment due to automation. Therefore, it is important for society to understand and manage the impacts of technological development wisely for sustainability and collective well-being. One of the technologies that has the most impact on enhancing a lot of different areas in our society is augmented reality (AR). Augmented Reality (AR) has evolved significantly since its inception, transforming from a concept in scientific research to a mainstream technology with applications in various fields such as education, healthcare, and entertainment.

The term "Augmented Reality" was first coined by Boeing researcher Thomas Caudell in 1992. Caudell and his colleague David Mizell developed an AR system to assist workers by superimposing assembly diagrams on physical components, marking one of the earliest industrial applications of AR [7]. This initial conceptualization of AR laid the groundwork for future advancements in the technology.

In 1994, Paul Milgram and Fumio Kishino introduced a framework known as the "Virtuality Continuum," which categorizes different types of reality media. Within this continuum, four distinct categories are identified: real environment (RE), augmented reality (AR), augmented virtuality (AV), and virtual environment (VE) as in Figure 2. These categories are arranged from left to right, with AR falling between the real environment and augmented virtuality. AR involves the integration of virtual and digital elements into the physical world, enriching the user's perception and interaction with their surroundings [8].

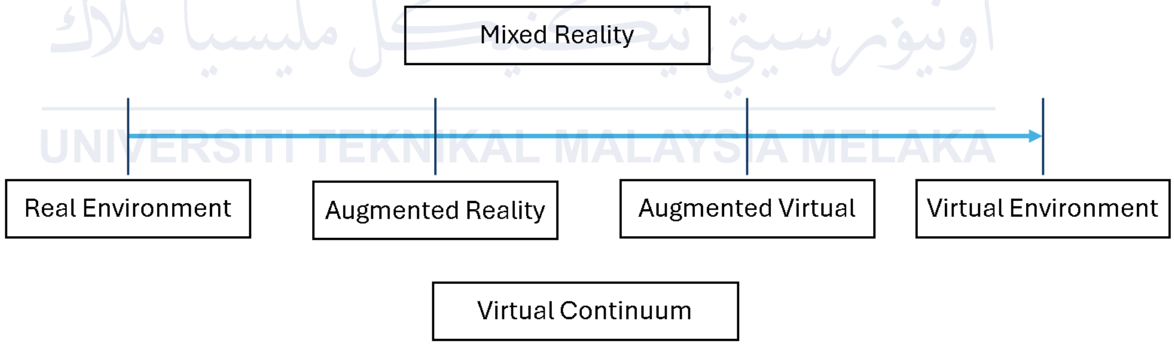

Figure 2.1 Illustrates the Virtual Continuum visual

The late 1990s and early 2000s saw significant advancements in AR technology. In 1999, the ARToolKit, an open-source software library for creating AR applications, was developed by Hirokazu Kato [9]. This toolkit allowed for marker-based tracking and significantly lowered the barrier to entry for AR development. In 2008, the launch of smartphones equipped with cameras and sensors paved the way for mobile AR applications, making the technology more accessible to the public.

Several researchers have made significant contributions to the development and popularization of AR. For instance, Steve Feiner's work at Columbia University in the early 1990s focused on developing AR systems for medical and maintenance applications [10]. Additionally, Ronald Azuma's 1997 survey on AR, "A Survey of Augmented Reality," provided a comprehensive overview of the state of AR research and identified key challenges and opportunities for future development [11].

Today, AR is widely used in various industries, including education, healthcare, retail, and entertainment. Companies like Google, Microsoft, and Apple have invested heavily in AR technology, leading to the development of products such as Google Glass [12], Microsoft HoloLens [13], and ARKit [14]. The future of AR looks promising, with ongoing research focusing on improving hardware, software, and user experiences to make AR more immersive and practical for everyday use.

The development of augmented reality has been characterized by ongoing innovation and contributions from forerunners in science and technology. AR has changed significantly since Thomas Caudell first conceptualized it and from then on to the creation of complex applications. Gaining an understanding of its past evolution might help one make important decisions about its future direction and potential.

2.3 Type of AR

Marker-based and markerless augmented reality (AR) technologies are two major subcategories of AR technology, each having unique methods for fusing virtual and real-world material. This study of the literature examines the evolution, features, and uses of marker-based and markerless augmented reality, emphasizing the advantages and disadvantages of each.

2.3.1 Marker-Based AR

Marker-based AR, also known as image recognition AR, relies on predefined visual markers to trigger the overlay of digital information [15]. These markers are typically black-and-white patterns (such as QR codes or fiducial markers) that the AR system can easily detect and interpret using a camera. When the system identifies a marker, it calculates the marker's position and orientation to superimpose the corresponding virtual content accurately.

With Hirokazu Kato's release of the ARToolKit in the late 1990s, marker-based augmented reality (AR) began to take shape. This toolkit greatly advanced the field by giving developers the resources they needed to construct AR apps using marker-based tracking [16]. Numerous applications, such as instructional materials, advertising campaigns, and maintenance manuals, make extensive use of marker-based augmented reality. In the field of education, for instance, it makes interactive textbooks possible, allowing students to examine 3D models and animations by scanning markers, thereby improving their learning process [17].

Marker-based AR's primary strength lies in its accuracy and reliability, as the markers provide a clear reference point for the system to track. However, it also has limitations, including dependency on the visibility and quality of the markers. If a marker is obscured, damaged, or poorly printed, the AR experience can be disrupted [18]. Additionally, the need for predefined markers can limit the flexibility and scalability of marker-based AR applications.

2.3.2 Maker-less AR

Markerless AR, also known as location-based or SLAM (Simultaneous Localization and Mapping) AR, does not require predefined markers. Instead, it uses the device's camera and sensors to analyze the environment and detect features such as surfaces, textures, and objects. This allows for the placement of virtual content in real-world spaces without needing specific markers [19].

Markerless AR has gained prominence with the advent of powerful mobile devices equipped with advanced sensors and cameras. Technologies such as Apple's ARKit and Google's ARCore have significantly contributed to the development and accessibility of markerless AR [20]. Applications of markerless augmented reality (AR) across a variety of industries, including gaming, navigation, retail, and healthcare, demonstrate how this technology may improve user experiences by fusing virtual aspects with physical environments [21]. For example, in figure 2.1, AR applications, such as IKEA Place.

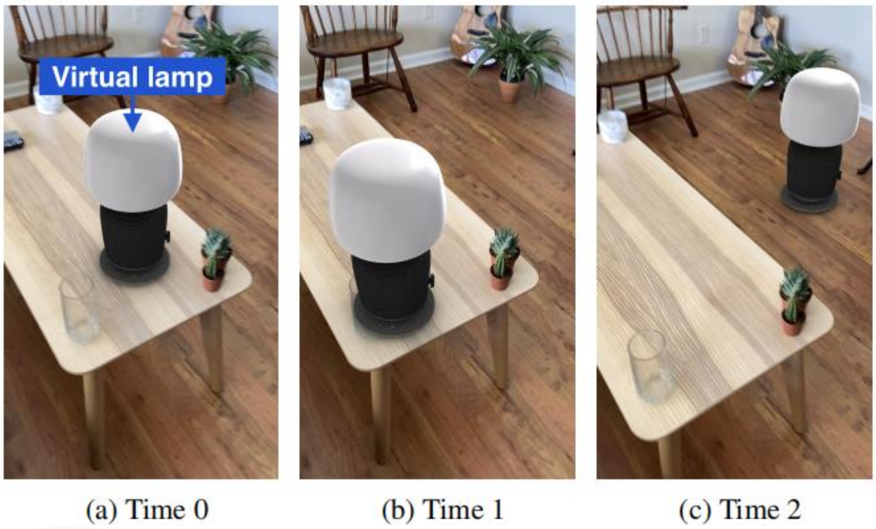

Figure 2.2 Illustration hologram drift in markerless Visual-Inertial Simultaneous Localization and Mapping (VI-SLAM)-based Augmented Reality (AR) [23]

In Figure 2.2, which took place in the IKEA Place app utilizing ARKit on an iPhone 11 running iOS 14.4, underscores the difficulties in sustaining precise positioning and tracking of virtual objects in markerless AR settings. The virtual lamp's drift away from its initial position as shown in Figure 2.2.(a), its collision with a real-world glass on the table that illustrates in Figure 2.2.(b), and its eventual displacement off the table entirely as in Figure 2.2.(c) exemplify the challenges encountered in maintaining the alignment of virtual content with the physical environment in such contexts [22].

The primary advantage of markerless AR is its flexibility and ease of use, as it does not require any physical markers. It enables more immersive and seamless AR experiences by integrating virtual content directly into the user's environment. However, markerless AR faces challenges related to accuracy and environmental conditions. Poor lighting, reflective surfaces, and complex backgrounds can affect the system's ability to detect and track features accurately [23].

Both marker-based and markerless augmented reality present different benefits and difficulties. Marker-based augmented reality is more dependable in controlled settings where markers are readily maintained, which makes it appropriate for high precision applications. Markerless AR, on the other hand, is more adaptable and user-friendly, which makes it perfect for a variety of dynamic settings [24]. With distinct uses and purposes, marker-based and markerless augmented reality have both made substantial contributions to the development of augmented reality technology. It is essential to comprehend their advantages and disadvantages in order to choose the best AR type for a given set of use cases. Future advancements in AR technology might expand on the potential uses and functionalities of marker-based and markerless AR.

2.4 Application of Augmented Reality in Education

Technology has had a significant influence on many parts of our lives in recent years, and education is no exception. Augmented Reality (AR) is one of the most fascinating developments in educational technology. Augmented Reality (AR) creates interactive learning experiences that surpass conventional approaches by fusing digital material with the real environment. Teachers may boost student engagement, increase understanding, and give students previously unthinkable chances for hands-on learning by incorporating augmented reality (AR) into their classrooms. This introduction will look at the several ways augmented reality (AR) is being used in education and show how this cutting-edge technology is changing the way we teach and learn.

AR has changed traditional learning techniques by making instructional information more entertaining. Bacca J, Baldiris S (2014) found that applications of AR in textbooks and educational environments have boosted student engagement and motivation [25]. Akçayır

M, Akçayır G (2017) demonstrated that students can visualize difficult topics with AR-enabled textbooks, which improves understanding and recall [26]. Science education has benefited greatly from the application of augmented reality in virtual laboratories. Zhang et al (2022) showed that students may perform experiments in AR-based virtual laboratories in a cost-effective and safe manner, improving their comprehension of scientific ideas without the hazards involved with doing actual experiments [27]. Additionally, scalable, and repeatable solutions are provided by AR virtual laboratories to educational institutions with minimal resources.

Moreover, AR has been used to produce realistic historical simulations. Koutromanos et al (2015) highlighted that students may experience historical locations and events in three dimensions thanks to augmented reality (AR) applications in history classes, which help them comprehend historical settings and events more fully [28]. This immersive method fosters a more intimate connection between pupils and the historical material. However, Parmaxi et al (2020) state that AR has shown promising results by creating interactive environments that are more effective than traditional methods, engaging multiple senses, and promoting active learning. Despite slow adoption in language learning, many accessible tools, like Google Expeditions, are available [29].

On the other hand, Bölek et al (2021) reported that AR has been applied to improve anatomy teaching in medical education. Medical students may see organs and systems in detail thanks to augmented reality (AR)-based 3D representations of human anatomy, which enhances their spatial comprehension and helps them remember anatomical information. Interactive exploration and modification of anatomical structures are made possible by this practical method [30].

Lastly, Schutera et al (2021) discussed AR applications in mathematics teaching have improved the visualisation of complex concepts. "cleARmaths" is an augmented reality app that was created especially for educational use. With just a smartphone or tablet, the program seeks to assist students in seeing and studying geometric objects like planes, lines, and points inside a 3D coordinate system. Making sure the program had basic interaction was emphasized [31].

2.4.1 Summary

After years of development, AR has proven to have vast potential for changing teaching methods in several different sectors. Its adaptability and efficacy are demonstrated by its uses in virtual labs, historical simulations, language learning, and collaborative special needs education. But to effectively use augmented reality in education, issues including technological restrictions, high implementation costs, and the requirement for instructor education must be resolved.

2.5 Table Comparison of Previous Studies

Table 2.1 Comparison of previous studies regarding conventional education aids

Year [citation]	Paper Title	Type of Aids	Methodology	Hardware	Software	Future Works (if any)
2021[32]	**Microelectronics Design in Educational Apps for Technical Education Learning in Pandemic Eras**	**Educational Apps**	**Survey and content analysis, development of educational apps**	**Computers, tablets**	**Educational app development tools**	**Investigate the integration of microelectronics into online learning platforms**
2018[33]	**Textbook Effects and Efficacy**	**Textbook**	**Comparative study of test results using textbooks and e-books**	**None**	**None**	**Investigate long-term retention rates with digital textbooks.**
2005[34]	**Can electronic textbooks help children to learn?**	**Electronic Textbook**	**Comparative examination of learning results utilizing electronic textbooks against paper textbooks.**	**Laptops, desktops**	**Electronic textbooks**	**Explore long-term learning retention and engagement with electronic textbooks.**
2005[35]	**Enhancing Student Performance in Secondary Classrooms while Providing Access to the General Education Curriculum Using Lecture Formats**	**Lecture Formats / Notes**	**Examining lecture patterns in secondary classes and their effect on student performance**	**Projectors, whiteboards**	**Presentation software (e.g., PowerPoint)**	**Examine various lecture styles and their efficacy in different disciplines.**
2020[36]	**Formative assessment: A systematic review of critical teacher prerequisites for classroom practice**	**Formal Assessment**	**Systematic review of existing literature**	**Computers**	**Data analysis software**	**Develop teacher training programs focusing on formative assessment strategies**

Table 2.2 Comparison of previous studies regarding interactive education aids

Year [citation]	Paper Title	Type of Aids	Methodology	Hardware	Software	**Future Works** (if any)
2021[37]	Artificial intelligence (AI) in education: Using AI tools for teaching and learning process	Ai Tools	Review of AI tools and applications in education	Computers, tablets	AI software (various)	Investigate the long-term impact of AI tools on teaching efficacy and student outcomes
2022[38]	Entertainment Video Games for Academic Learning: A Systematic Review	Video Game	**A systematic review of existing studies on instructional video games.**	Gaming consoles, computers	Educational video games	**Examine the impact of various game genres on learning outcomes.**
2020[39]	An Application of Virtual Reality in Education: Can This Technology Enhance the Quality of	Virtual Reality	**Experimental research utilizing VR and conventional learning groups.**	VR headsets, computers	VR educational software	**Study the long-term impacts of VR learning on various disciplines.**

	Students' Learning Experience?					
2020[40]	Effects of Augmented Reality on Learning and Cognitive Load in University Physics Laboratory Courses	Augmented Reality	**Experiment with control and AR groups in physics lab classes.**	AR-capable devices (smartphones, tablets)	AR educational apps	**Investigate the long-term influence of Augmented Reality on learning outcomes in many fields.**
2022[41]	Bringing chemical structures to life with augmented reality, machine learning, and quantum chemistry	Augmented Reality	**Experimental study with AR and machine learning techniques**	AR devices, computers	AR and machine learning software	**Explore integration of AR with other educational domains**

Education systems are often divided into two categories: traditional education and interactive education. Both approaches attempt to teach students information and skills, but their methodology, levels of involvement, and outcomes differ dramatically. The term "conventional education," often referred to as "traditional education," describes the time-tested instructional strategies that have been in use for generations. It mostly depends on formal, organized teaching techniques and a set curriculum. The goal of interactive education, often referred to as active or participatory learning, is to get students actively involved in their education. It places a strong emphasis on using technology to create a more dynamic learning environment as well as teamwork and critical thinking.

Table 2.1 shows the 5 previous studies of conventional education that being researched and read related to the projects. The study focused on the educational tools and methods implemented. A recent research published in 2021 titled "Microelectronics Design in Educational Apps for Technical Education Learning in Pandemic Eras" focuses on educational applications. Researchers use PCs, tablets, and educational development tools together with survey and content analysis techniques to produce these applications [32]. Additionally, the 2018 research "Textbook Effects and Efficacy" compares the test results of traditional and e-book textbooks to determine which is more successful, without utilizing any particular technology or software [33]. Moreover, in the early research, the study "Can electronic textbooks help children learn?", 2005 compares the learning outcomes of electronic textbooks with paper textbooks making use of laptops, desktop computers, and electronic textbook software [34]. Another 2005 study, "Enhancing Student Performance in Secondary Classrooms while Providing Access to the General Education Curriculum Using Lecture Formats," looks at lecture formats and how they affect student performance, including the use of projectors and whiteboards, as well as presentation software such as PowerPoint [35]. Finally, a thorough evaluation of the literature on formal assessment is conducted in "Formative assessment: A systematic review of critical teacher prerequisites for classroom practice", 2020. The study synthesizes findings and suggests teacher preparation programs by using computers and data processing tools [36].

In comparing to Table 2.2 illustrates the 5 prior studies of interactive education that have been review and evaluated in relation to the projects. These study focuses on the educational tools and methodologies employed. Firstly, the study "Artificial intelligence (AI) in education: Using AI tools for teaching and learning process", 2021 [37] examines the use of computers, tablets, and a range of AI software in educational settings. Secondly, the paper "Entertainment Video Games for Academic Learning: A Systematic Review", 2022 [38] does a comprehensive evaluation of existing research on instructional video games that use gaming consoles and PCs to run educational video game software. Meanwhile, a comparison between VR and traditional learning groups is made in "An Application of Virtual Reality in Education: Can This Technology Enhance the Quality of Students' Learning Experience?", 2020 [39] through experimental study that makes use of VR headgear, PCs, and VR educational software. Besides that, the study "Effects of Augmented Reality on Learning and Cognitive Load in University Physics Laboratory Courses", 2020 [40] analyzes the influence of augmented reality employing AR-capable devices such as smartphones and tablets, as well as AR educational applications. The following research, "Bringing chemical structures to life with augmented reality, machine learning, and quantum chemistry", 2022 [41], finishes with an investigation of the application of augmented reality (AR) and machine learning approaches in education. In this experiment, AR devices and PCs with particular AR and machine learning software are employed.

To conclude, while conventional education gives structure and a standardized method, interactive education creates a more engaging and individualized learning environment. Each approach has advantages over the other and can work well together. A more comprehensive and successful educational experience may be produced by incorporating interactive education components into a traditional framework to improve learning results and student engagement. To create a more dynamic and captivating learning environment, interactive exercises, technology, and group projects can all be included into a regular classroom.

2.6 Summary

This chapter presents a detailed overview of the development and implementation of augmented reality (AR) in a variety of sectors, with a special emphasis on education. The chapter opens with a history of augmented reality, focusing on how it evolved from an idea proposed by Thomas Caudell in 1992. The chapter then goes into the two primary forms of AR: marker-based and markerless AR.The analysis also looks at the many applications of AR in education. AR can help bridge the gap between abstract concepts and practical knowledge in microelectronics education by providing interactive 3D simulations that improve student comprehension and cooperation. The chapter ends with a table that summarizes numerous studies on educational aids. This comparison focuses on the changing environment of educational technology and the potential for digital formats to greatly enhance learning outcomes.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, we discuss how we developed an augmented reality (AR) tool to assist students in learning microelectronic fabrication. We will cover the steps we took, including creating flowcharts and block diagrams, defining parameters, and testing our methods. Our goal is to give you a clear understanding of how we integrated AR into microelectronic fabrication courses to help students learn more effectively.

3.2 Project Overview

This project applies to a mixed-method project design, integrating both qualitative and quantitative research methods to gain a comprehensive understanding of the effectiveness, user experiences, and potential benefits of augmented reality (AR) study aids. The primary aim is to develop microelectronic courses as study aids using AR technology. In this project, marker-less AR is utilized, eliminating the need for physical markers. Marker-less AR relies on advanced computer vision algorithms to interpret the user's environment without predefined markers. This necessitates sophisticated tracking, feature recognition, and scene comprehension capabilities.

3.2.1 Project Flowchart

The initial step involves creating virtual objects based on the microelectronic subject. Next, the AR system is constructed using Unity, a platform renowned for creating 3D animations. Unity facilitates the development of immersive and interactive AR experiences. Following construction, the system undergoes rigorous testing to assess its functionality and performance. Through this testing phase, any issues or areas for improvement are identified and addressed before the AR system is deployed for educational purposes.

During the testing phase, the application is executed on mobile phones operating on the Android platform. In the event of an error, the system undergoes re-rendering to identify and rectify the issue. The functionality of the system is thoroughly assessed to ensure seamless operation. Upon successful operation and performance, the project is deemed successful and ready for summary and documentation.

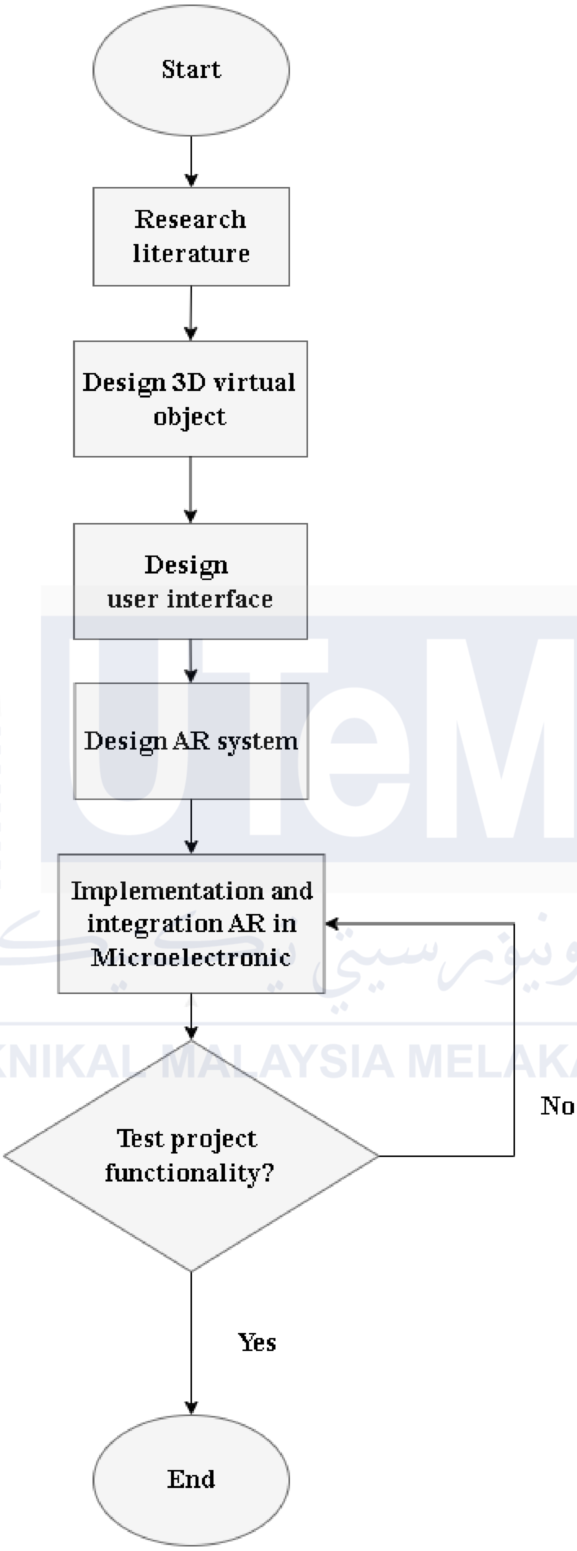

Figure 3.1 Project Flowchart

3.2.2 Project Development Flowchart

The flowchart represents the project development steps for producing an Augmented Reality (AR) application. The process involves creating 3D objects and models with Rhino 3D software to precisely portray atomic structures and other scientific features. After the designs are finalized, the next stage is to create an interactive interface and incorporate animations using Unity. The combination of these technologies results in a dynamic and engaging AR experience that allows users to understand complicated subjects using immersive graphics and intuitive interactions.

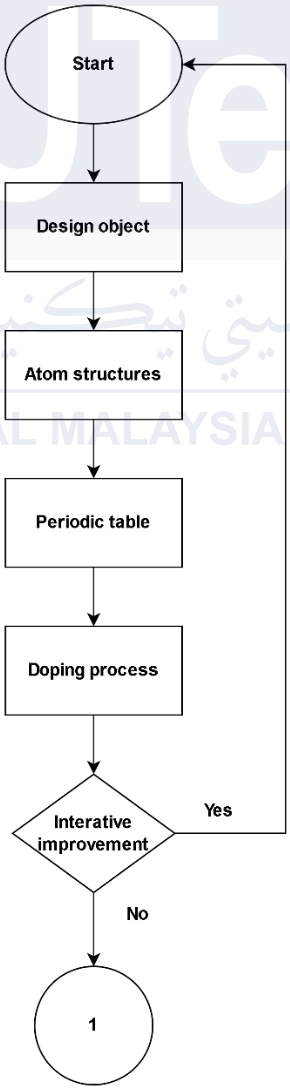

Figure 3.2 Drsigning Flowchart

The first flowchart shows the process of developing objects for an augmented reality (AR) interface. It begins with the Start step, which signals the start of the design process. The subsequent stage, Design Object, entails envisioning both 3D and 2D objects for visualization. Atomic structures in the AR environment are 3D, with elements such as protons, neutrons, and electrons represented spatially. The Atom Structures stage focuses on modelling atoms using recognized scientific representations, such as the Bohr model or quantum mechanical models, to demonstrate electron orbitals and bonding interactions in 3D space.

The Periodic Table stage focuses on creating a two-dimensional visualization of the periodic table that allows users to study chemical elements interactively. Only elements in groups 3, 4, and 5 are relevant to semiconductor or microelectronics courses. The Doping Process stage illustrates the doping process of silicon and aluminium, which is important for demonstrating concepts in semiconductor physics. In this stage, the AR interface simulates the dopant atoms within a lattice structure, providing users with an immersive understanding of material properties and behaviour.

Iterative Improvement enables continual design modification while incorporating input to increase visual correctness, usability, and performance. This loop is critical to improving both the AR graphics and the integration process. The last phase, indicated by 1, marks the shift to the next level, which is providing interaction and functionality within Unity. This organized design approach guarantees that the items are properly prepared for AR applications, allowing for smooth integration with Unity to provide an interactive, instructive, and engaging user experience.

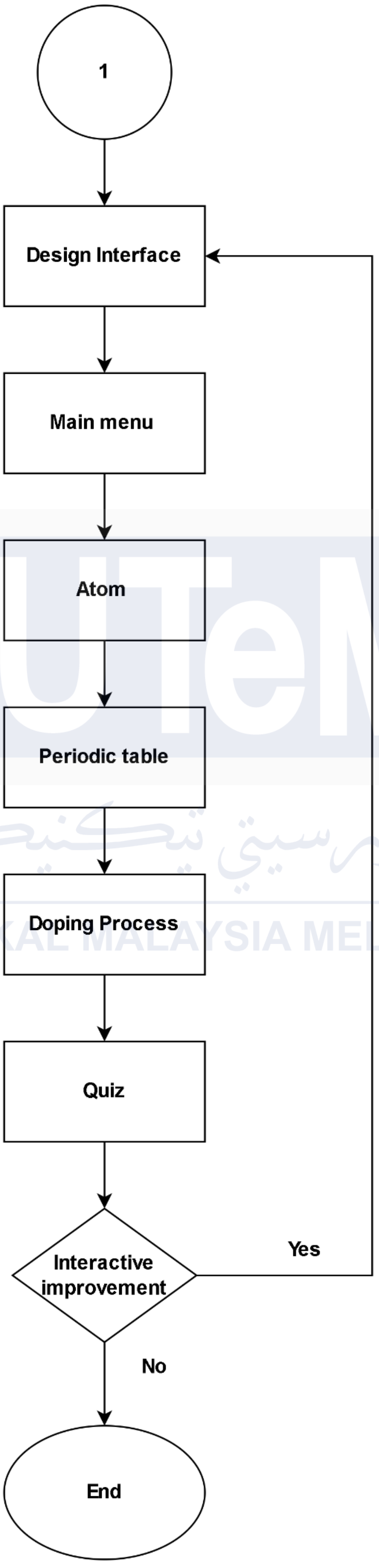

Figure 3.3 Integration Flowchart

The second phase of the project focuses on creating an interactive interface and animations in Unity, which builds on the 3D models and 2D visual components generated earlier in the design process with Rhino 3D. This step converts the assets into a functioning and user-friendly AR application. The process begins with the shift from design to development, which connects to the original phase when atomic structures, the periodic table, and the doping process were conceived. The next step is to design the application's user interface (UI), which includes layouts, buttons, and icons to ensure usability and an intuitive user experience. The main menu, which serves as the center hub, offers navigation choices to areas such as 3D atomic structures, the periodic table, doping simulations, and quizzes, with an emphasis on simplicity of use and visual attractiveness.

The 3D atomic models are animated and incorporated into the program, allowing users to see comprehensive views of protons, neutrons, and electron orbitals in an augmented reality environment, complete with animations of atomic bonding and electron movement. Similarly, the periodic table is turned into an interactive 2D display that allows users to choose elements and see their attributes while smoothly connecting to matching 3D models. The doping process simulation shows the assimilation of dopant atoms into materials such as silicon and aluminum, demonstrating changes in material characteristics within a lattice structure. A quiz function is also included, which uses multiple-choice questions and interactive exercises to measure users' grasp of subjects like as atoms, the periodic table, and semiconductor doping, using the immersive AR environment to increase engagement.

The development process includes iterative testing and refining based on user input, with an emphasis on enhancing animations, interface responsiveness, and general functionality to achieve a polished final result. The last stage marks the end of the development phase, leaving a fully integrated and working in AR application ready for deployment or further assessment. This step-by-step demonstration shows how Unity may be used to convert static models into an immersive, interactive instructional tool for understanding atomic structures and semiconductor physics principles.

3.2.3 Table Main Menu

This table describes the primary menu interfaces of the AR program, with a focus on instructional and interactive modules. Each part uses immersive animations and interactive tools to help users comprehend atomic structures, periodic table elements, the doping process, and other relevant concepts.

Table 3.1 Table of Main Menu

Interactive Elements	Description to visualized component for each interactive elements
Atom	The Atom interface aims to provide an interactive and visual representation of atomic structures. Users may investigate the fundamental components of an atom, including the nucleus, protons, neutrons, and electrons. It emphasizes the unique functions and qualities of each particle, such as protons' positive charge, neutrons' neutrality, and electrons' negative charge. Animations can show atom structure, nucleus structures that contain proton and neutron. This feature tries to clarify complicated atomic ideas for learners by using interactive 3D models and augmented reality experiences.
Periodic table	The periodic table interface focuses on elements in groups 3, 4, and 5 such as Boron, Aluminium, Gallium, Silicon, Germanium, Phosphorus, and Arsenic. Which are particularly significant to semiconductor physics. Users can study the characteristics and

	relevance of these elements in semiconductor applications by clicking on them individually and the audio will come out and explain the properties of these elements. For example, if user touch the Boron, the audio will explain the properties of Boron.
Doping process	This section is a thorough, graphic description of the doping process in materials such as silicon and aluminium. Using animations, the interface shows how dopant atoms are inserted into a host material's lattice structure, modifying its electrical characteristics. For example, it may demonstrate how adding a group 3 element (such as aluminium) produces p-type semiconductors by producing "holes." The interface also depicts the flow of electrons and holes inside the material, giving users a clear and compelling knowledge of how doping influences conductivity.
Quiz	The quiz function is intended to check and reinforce users' comprehension of the topics provided in the program. The questions are geared to the topics covered, such as atomic structure, semiconductor-related periodic table elements, and doping processes. Multiple-choice only options for the quiz. The quiz incorporates AR-based experiences, such as recognizing components in a 3D model or recreating a doping process, to provide a hands-on, engaging learning experience and guarantee that users understand important concepts.

3.3 Module Development

A thorough grasp of atomic structure and semiconductor processes is critical in the fast evolving domains of science and industry. This collection of module is intended to give a complete foundation for learners of all skill levels, from beginners to intermediate. Every module is carefully designed to expand on the one before it, guaranteeing a smooth and reasonable progression across the subjects.

Table 3.2 Module Development of AR system

No.	Module	Description
1.	Basic structure of atom	This module focuses on users fundamental understanding of the structure of an atom, which has a nucleus. The nucleus is the center of the atom, containing positively charged protons and neutral neutrons. The negatively charged particles known as electrons circle the nucleus in shells or energy levels.
2.	Periodic Table	This module provides an interactive visualization of the periodic table, emphasizing elements in groups 3, 4, and 5 that are significant in semiconductor applications. Group 3 includes elements like boron, aluminum, and gallium, which are commonly used as p-type dopants. Group 4, featuring silicon and germanium, represents the fundamental materials for intrinsic semiconductors. Group 5 elements, such as phosphorus and arsenic, act as n-type dopants, contributing extra electrons to enhance conductivity.
3.	Doping Process	This module describes how the doping process changes semiconductor conductivity by adding impurities. N-type doping

		adds donor atoms with extra electrons to enhance electron flow, while p-type doping introduces acceptor atoms, creating "holes" for electron movement. This combination is crucial for controlling current in electronic devices.

3.4 Software Requirement

The virtual object is crafted using both Rhinoceros 3D and Unity software platforms. Rhinoceros 3D provides an intuitive interface for creating basic 3D models, while Unity offers more advanced tools for developing interactive and immersive experiences. The phone application serves as a crucial interface for accessing and interacting with the system. This application will be developed using Unity to ensure compatibility and perfect integration with the AR system. The AR system itself is the central component of the project and will be constructed entirely within the Unity environment, leveraging its capabilities to create an engaging and interactive augmented reality experience.

Table 3.3 Software description

Software	Description
Unity	Unity is a powerful game engine and development platform widely used for creating interactive 3D and 2D experiences. Unity is utilized for designing and constructing the AR system that integrates virtual objects with real-world environments. Unity offers a wide range of tools and features for creating AR applications, including support for marker-based and markerless AR, real-time rendering, physics simulation, and animation. It provides a user-friendly interface and a robust scripting

	API, allowing developers to create immersive AR experiences tailored to specific project requirements.
Rhinoceros 3D	Rhinoceros 3D, sometimes known as Rhino, is a sophisticated 3D computer graphics and CAD program. The goal of this project is to use Rhino to create detailed and exact virtual items that will be integrated into an augmented reality (AR) system. Rhino has powerful tools for generating, modifying, analyzing, and documenting complicated 3D models with accuracy. It supports NURBS curves, surfaces, and solids, allowing for more versatility and precision in intricate design work. Benefits: Its considerable customization capabilities, such as scripting and plugins, make it appropriate for both basic and sophisticated modelling projects, resulting in high-quality virtual objects for the AR system.
Microsoft Visual Studio	Microsoft Visual Studio is an integrated development environment (IDE) commonly used for software development. In this project, Visual Studio is employed for developing the mobile application that serves as the interface for accessing and interacting with the AR system. Visual Studio provides a comprehensive set of tools and features for building cross-platform mobile applications, including code editing, debugging, and testing capabilities. It supports various programming languages such as C#, which is commonly used for developing mobile applications for the Android platform.
Mobile Application	The mobile application serves as the interface for accessing and interacting with the AR system on mobile devices. Developed using

	Microsoft Visual Studio, the mobile application provides users with a seamless and intuitive way to engage with the AR content. The application allows users to view virtual objects overlaid on their real-world surroundings through the device's camera, interact with the objects using touch gestures, and access additional features and information related to the AR experience. It serves as a key component of the project, enabling users to experience and benefit from the augmented reality content created using Rhinoceros 3D and Unity.

3.5 Project Development

This project is being developed using a four-stage organized method with the goal of building an interactive Augmented Reality (AR) system for educational purposes. The project focuses on producing a complete and entertaining augmented reality application using Rhino 3D for design, Unity for system implementation, and Microsoft Visual Studio for coding and scripting. The four stages of development are described below:

3.5.1 Designing Phase

This stage requires creating accurate 3D models of atomic structures and a 2D periodic table, as well as modeling the doping process with Rhino 3D. The focus is on developing realistic, visually appealing, and interactive features to establish the framework for the AR application. These models feature atom components (protons, neutrons, and electrons), a 2D periodic table emphasizing semiconductor-related elements displaying the semiconductor doping process.

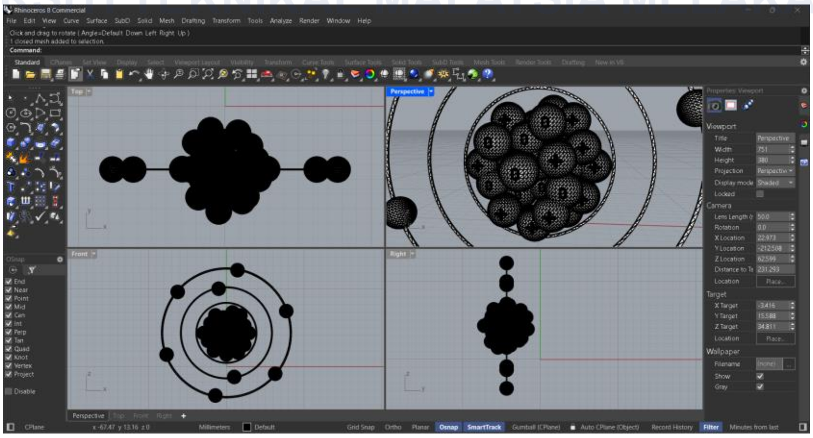

Figure 3.4 Atom Structures

Figure 3.4 shows an atom structure model that represents the entire atomic structure, including the nucleus and its surrounding electron orbits. It represents the atom's components, such as protons, neutrons, and electrons, in their proper locations. This design aims to create an accurate and thorough representation of an atom's physical and spatial arrangement, ideal for interactive exploration.

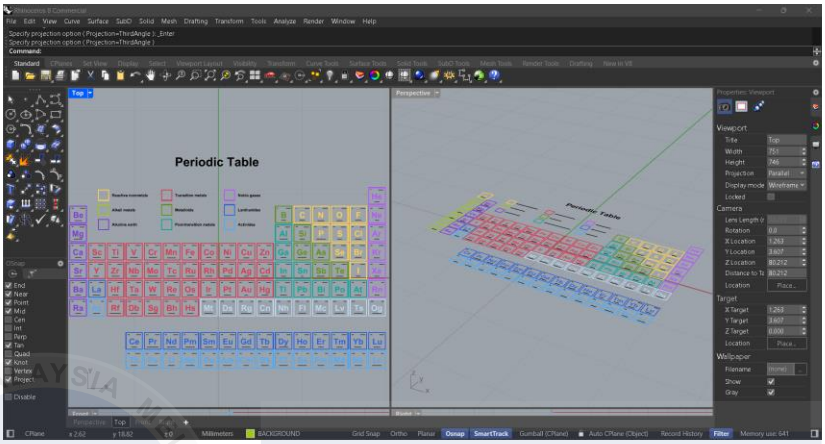

Figure 3.5 Periodic Table

Figure 3.5 illustrates how the periodic table design integrates a 2D depiction of the elements, with a focus on their organization according to atomic number and attributes. Groups 3, 4, and 5 (boron, aluminum, gallium; silicon, germanium; phosphorus, arsenic) get special attention due to their importance in semiconductors. This interactive model allows users to pick elements and investigate their chemical and physical properties.

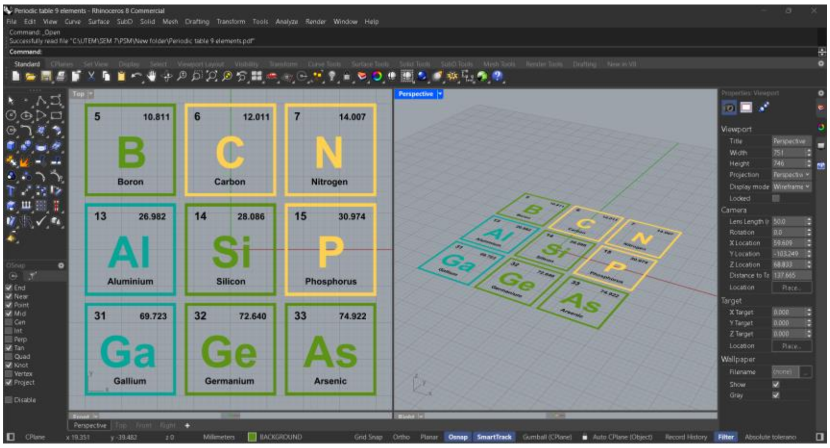

Figure 3.6 Elements group 3, 4, and 5 in Periodic Table

Figure 3.6 represents a thorough design of the project's nine elements: boron, aluminium, gallium, silicon, germanium, phosphorus, arsenic, and maybe others associated with doping and semiconductors. These elements are represented to emphasize their distinct characteristics and role in changing material conductivity.

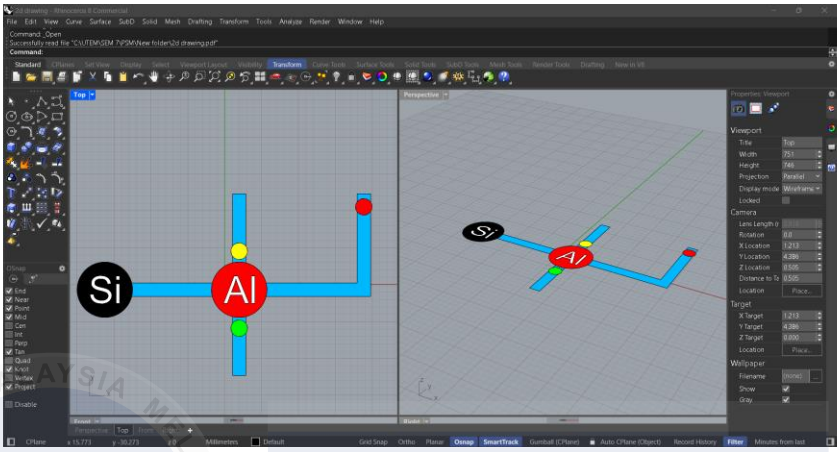

Figure 3.7 Part of Silicon(Si) and Aluminium(Al) Doping Process

Figure 3.7 depicted the doping process model that presents how dopant atoms (e.g., phosphorus for n-type or boron for p-type) integrate into a semiconductor lattice. It employs straightforward, step-by-step diagrams to demonstrate how doping changes the electrical characteristics of a material by adding free electrons or holes, hence increasing conductivity.

3.5.2 Integration Phase

The second stage involves combining 3D and 2D models into Unity to create an interactive augmented reality (AR) system that serves as a practical study aid for microelectronic fabrication courses. This process includes incorporating interactivity and animations into the designs to ensure they integrate seamlessly into an AR-compatible environment. The Unity platform is used to bring static designs to life, enabling users to interact with atomic structures, study the periodic table, and explore the doping process in an immersive environment. Additionally, the development of this AR application involves assembling the system, creating 3D animations for each process, and leveraging tools such as Unity and ARCore to integrate AR features like object detection, tracking, and interaction.

Through coding and implementing the AR framework, this stage transforms theoretical concepts into an engaging, hands-on educational tool. These are the components that are being developed for the AR system.

3.5.2.1 Main Menu

The Main Menu acts as the central navigation hub, allowing users to access various sections of the application, including interactive educational modules about atoms, the periodic table, doping processes, and quiz.

Figure 3.8 Interface Main Menu AR

Figure 3.8 shows the Main Menu provides a simple, user-friendly interface with buttons labeled as "Atom," "Periodic Table," "Doping Process," and "Knowledge Assessment." Navigation controls include "Play," "Try Again," and "Exit," allowing users to start or exit the application. The green background and clear button layout ensure easy interaction for users exploring scientific concepts.

```
            Time.timeScale = 1;
            page.SetActive(false);
            SceneManager.LoadScene("Atom");
            foreach (AudioSource audio in audios)
            {
                audio.Play(); ;
            }
        });
        table.onClick.AddListener(() =>
        {

            Time.timeScale = 1;
            page.SetActive(false);
            SceneManager.LoadScene("Table");
            foreach (AudioSource audio in audios)
            {
                audio.Play(); ;
            }
        });
        doping.onClick.AddListener(() =>
        {
            Time.timeScale = 1;
            page.SetActive(false);
            SceneManager.LoadScene("Doping");
            foreach (AudioSource audio in audios)
            {
                audio.Play(); ;
            }
        });
       answer.onClick.AddListener(() =>
        {
            Time.timeScale = 1;
            page.SetActive(false);
            SceneManager.LoadScene("Answer");
        });
    }
68 %    No issues found
```

Figure 3.9 Script for Main Menu

In figure 3.9, the Main Menu script defines interactions for each button. *onClick.AddListener()* assigns specific actions to button clicks, where *SceneManager.LoadScene("Atom")* and similar lines load corresponding scenes. *Time.timeScale = 1* resets gameplay speed to its default state, ensuring consistent behavior when scenes switch. Additionally, *audio.Play()* provides auditory feedback to enhance the user experience when buttons are clicked.

3.5.2.2 Atom Structure

This stage provides a 3D visualization of an atom, illustrating its protons, neutrons, and electrons. Users can explore its components for a better understanding of atomic structure.

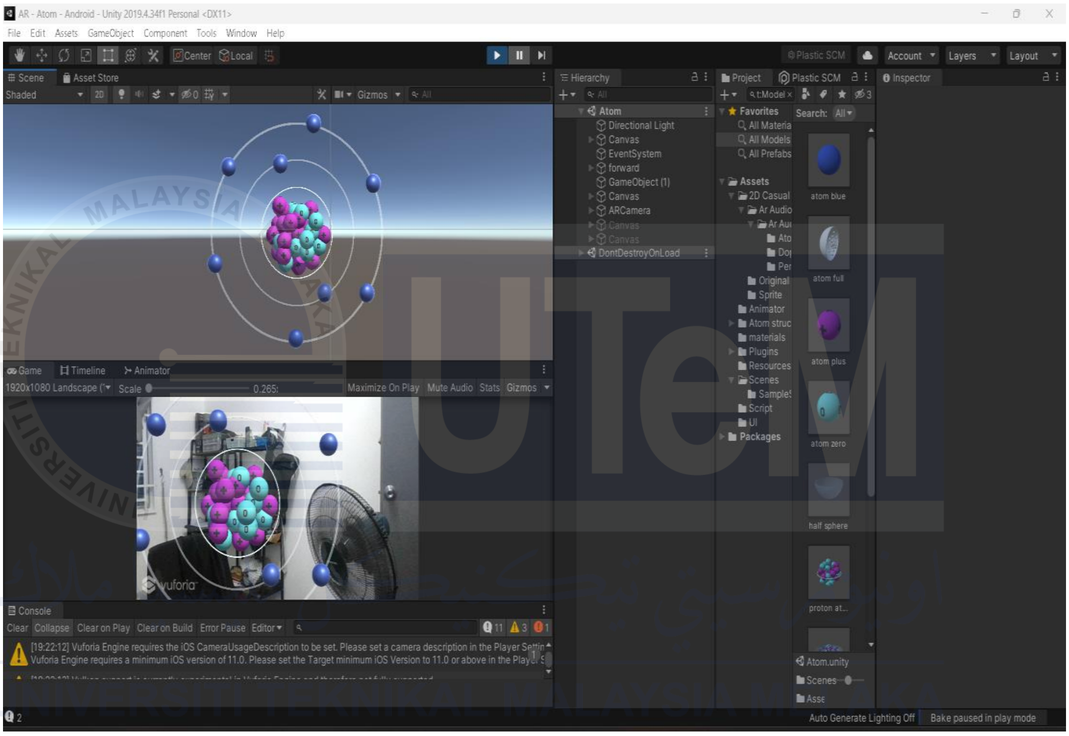

Figure 3.10 Interface Atom Structure

The Atom Structure interface displays a 3D model of an atom with interactive components representing protons, neutrons, and electrons, as shown in Figure 3.10. The Unity scene window allows users to explore this model, with a clear view of atomic structures to enhance learning through visual representation.

Figure 3.11 Script Atom structure

In Figure 3.11 show the Atom Structure script uses a *GameObject[]* atomParts array to store references to the various parts of the atom. The *Start()* method initializes the atom display, looping through the parts array and activating each one with part.*SetActive(true)*, as shown in Figure 3.11. This approach dynamically manages multiple atom components, ensuring they are visible when the scene loads.

3.5.2.3 Periodic Table

The Periodic Table stage allows users to explore chemical elements interactively, learning their properties by hovering over different elements. In this stage,

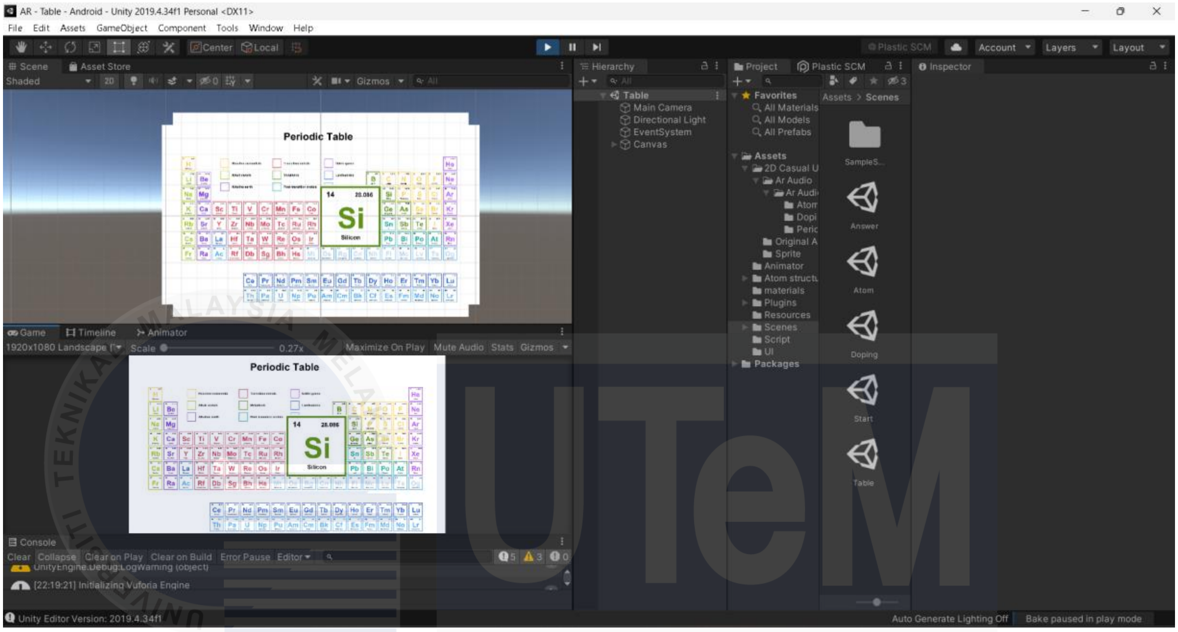

Figure 3.12 Interface Periodic Table

The Periodic Table interface provides a grid-like visual representation of chemical elements, as shown in Figure 3.12. Users can interact with individual elements by hovering the pointer over them to display additional information. This design allows users to explore the properties of elements in an intuitive and engaging manner.

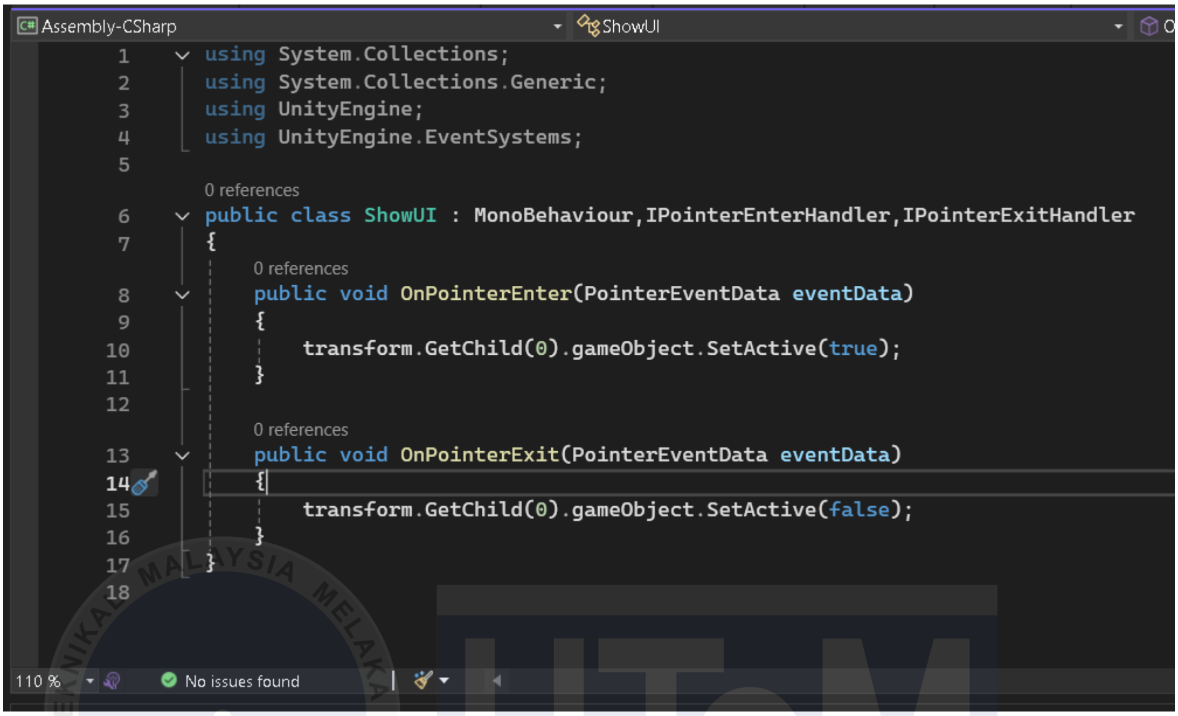

Figure 3.13 Script for Enlarge Elements

Figure 3.13 shows how the Periodic Table script uses the *IPointerEnterHandler* and *IPointerExitHandler* interfaces to handle mouse hover events. *OnPointerEnter()* enables the presentation of extra information via *transform.GetChild(0).gameObject.SetActive(true)*. *OnPointerExit()* uses *SetActive(false)* to conceal the information. These approaches provide dynamic interaction by showing or concealing data based on pointer movement.

3.5.2.4 Doping Process

This stage explains the concept of doping process in semiconductor to show how to add impurities that can alters the properties of semiconductor materials, demonstrated through a dynamic 3D model.

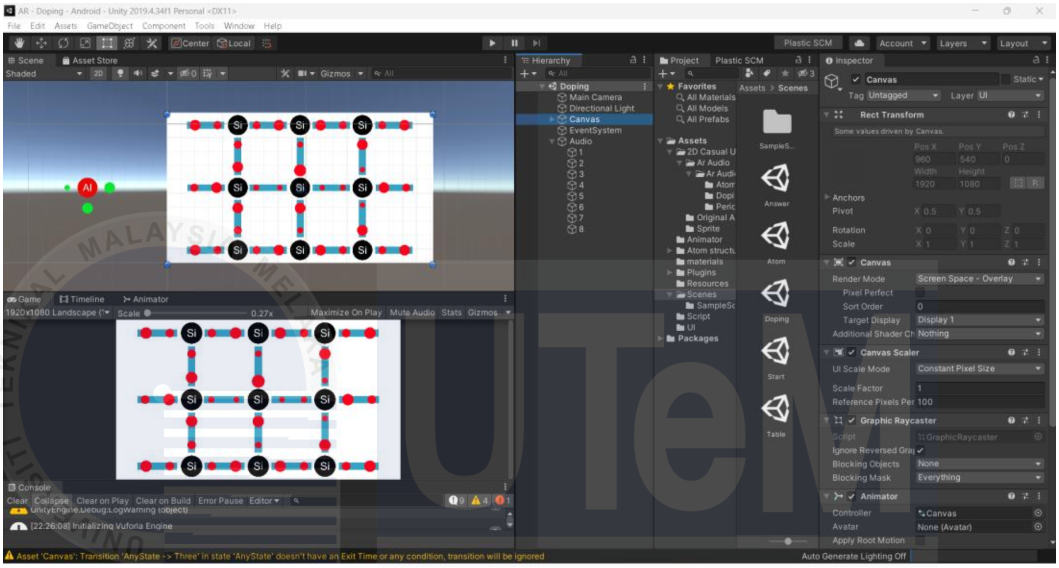

Figure 3.14 Doping Process Interface

The Doping Process interface illustrates the addition of impurities to a material's atomic structure, as shown in Figure 3.14. It uses a 3D model with connected nodes representing atoms, providing a step-by-step visualization of how doping affects material properties.

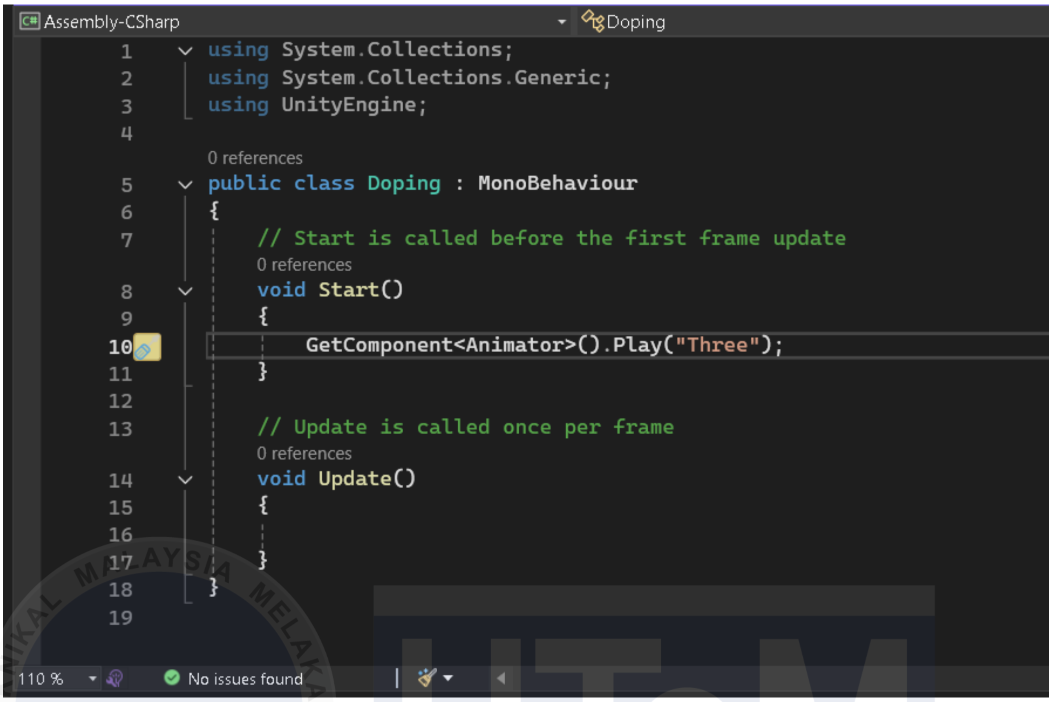

Figure 3.15 Script for Doping Process

Figure 3.15 demonstrates the Doping Process script use the Animator component to visualize atomic changes. The *Start()* function invokes *GetComponent().Play("Three")* begins an animated series titled *"Three"* to show doping effects. This script incorporates animation and interaction, making complicated scientific topics more understandable through visual storytelling.

3.5.2.5 Quiz

The final stage of this Unity project demonstrates a functional quiz system, allowing users to interact with a graphical interface to answer multiple-choice questions. This stage emphasizes integrating the user interface (UI) with C# scripting to manage dynamic behaviours, including updating scores, and transitioning between different UI elements. The quiz includes the following questions:

- What particles make up the nucleus of an atom?
- Which element from Group 4 is commonly used as the main material for creating semiconductors?
- When creating a p-type semiconductor, what type of element is added to silicon?
- What charge carriers are produced in a p-type semiconductor?
- Which element from Group 5 of the periodic table can be used for n-type doping in silicon?

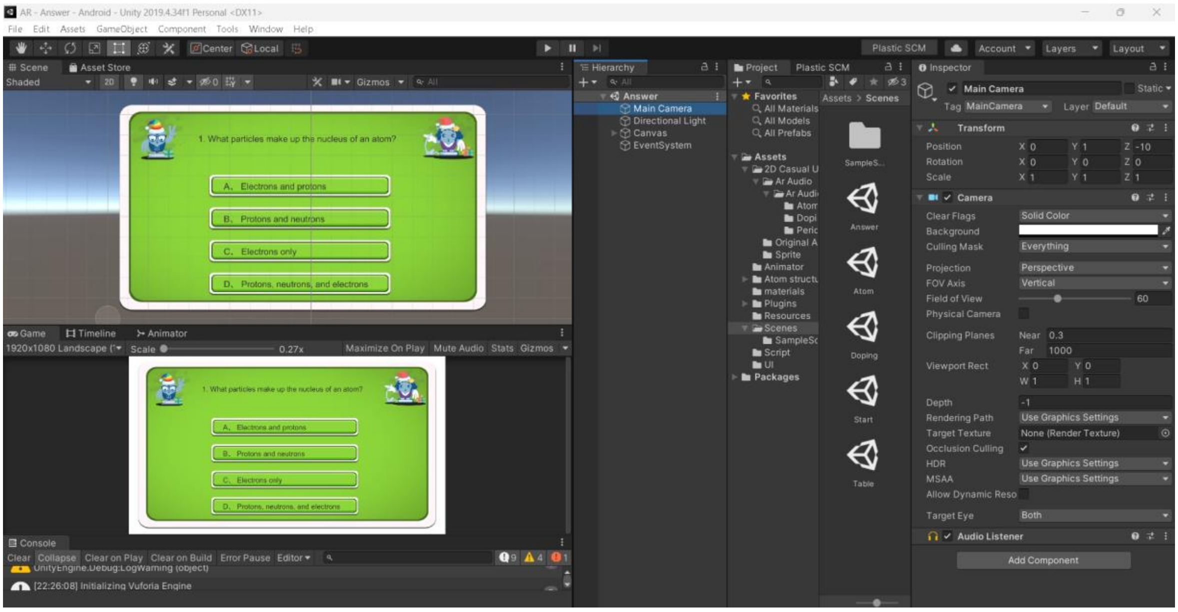

Figure 3.16 Quiz Interface

The final quiz interface is designed to display the current question along with multiple answer options as interactive buttons, as shown in Figure 3.16. It dynamically tracks and updates the user's score based on the correctness of their answers, providing marking scores. An exit button is included to allow users to terminate the application gracefully. The interface also manages transitions, such as moving to the next question after clicking the answer to ensuring a smooth user experience. Unity's Inspector shows that the button components are properly configured and linked to the relevant script functions, with canvas elements hierarchically organized for efficient UI management. Additionally, the interface includes references to objects like the Text component, which is used for tracking and displaying the score, along with other interactive elements critical to the quiz functionality.

```
    private static int count = 0;

    public Text source;

    public Button exit;
    // Start is called before the first frame update
    0 references
    void Start()
    {

        right.onClick.AddListener(Right);

        error.onClick.AddListener(Error);

        error_2.onClick.AddListener(Error);

        error_3.onClick.AddListener(Error);

        if(exit!=null)
        exit.onClick.AddListener(() => { Application.Quit(); });
    }

    1 reference
    public void Right()
    {
        count++;
        Cut();
    }

    3 references
    public void Error()
    {
        Cut();
    }

    2 references
    private void Cut()
    {
        print(index);
        if (index <= max)
        {
            gameObject.transform.parent.GetChild(index).gameObject.SetActive(false);
        }
        index++;
        if (index <= max)
        {
            gameObject.transform.parent.GetChild(index).gameObject.SetActive(true);
        }
        if (index == 5)
        {
            exit.gameObject.SetActive(true);
            source.text = (count*20).ToString();
        }

    }

}
42 %        No issues found
```

Figure 3.17 Script for Quiz Interface

Figure 3.17 displays the Quiz Interface script, which begins by creating variables such as a static integer count to monitor the score, a Text component for displaying the score, and a Button to quit the program. In the Start method, event listeners are linked to buttons for correct, wrong, and exit interactions. The Right method handles right answers by increasing the score and updating the display, whereas the Error method causes the Out method to handle erroneous answers. The Out function controls the quiz's dynamic behavior, allowing or disabling certain game items to transition between states, such as moving to a new question or resetting components.

3.5.3 Application Development

The final integration phase includes creating an APK file for mobile usage. Selecting the Android platform in the build settings generates an APK file, as seen in Figure 3.18. The APK file includes device settings and scene arrangement. To set the target API level to 24, compatible with Android version 7, additional option is required, as shown in Figure 3.19.

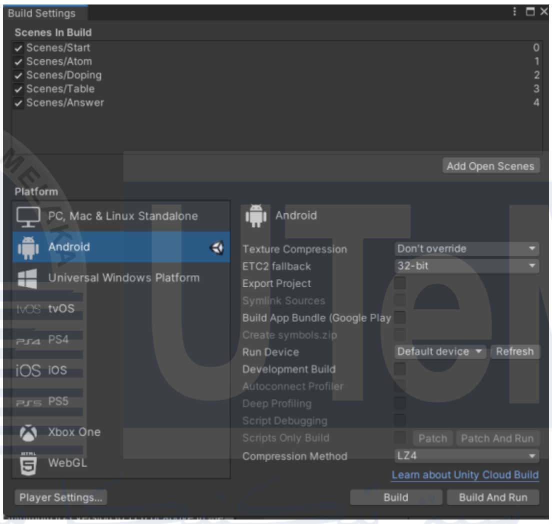

Figure 3.18 APK file device configuration and scene structure

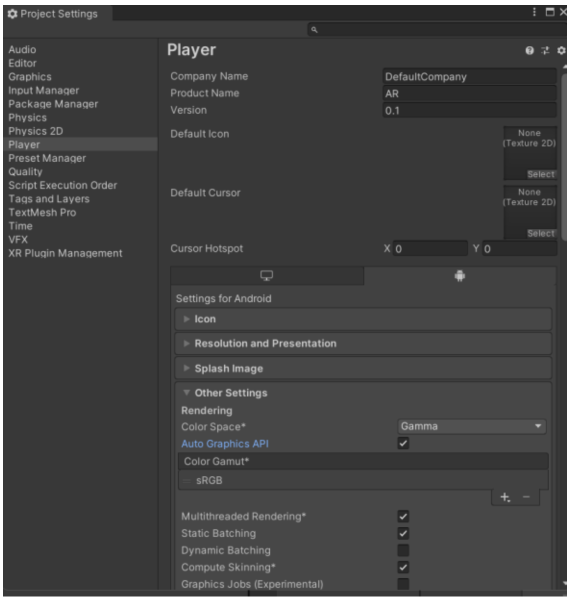

Figure 3.19 APK file API setting

3.5.4 User feedback and improvement

To finalize the project development, data collection through surveys is essential to gather user feedback and evaluate the system's effectiveness. The survey will provide insights into user experiences, usability, and overall satisfaction, forming the basis for a comprehensive analysis as shown in figure 3.20. This analysis will help identify areas for improvement and validate the system's impact as an interactive educational tool.

Figure 3.20 Survey Interface

3.6 Sustainable Development Goals (SDG)

Using Augmented Reality (AR) to educate atom and molecule processes in microelectronics coincides with Sustainable Development Goal 4 (SDG 4) by improving educational quality and accessibility. AR provides dynamic, 3D visuals that boost understanding and retention of complicated topics, appealing to a variety of learning styles and making education more accessible. It promotes lifetime learning by engaging students and encourages continued study. AR encourages critical thinking and innovation through real-time experimentation. Furthermore, it bridges the gap between theory and practice, preparing students for jobs in microelectronics. Overall, AR contributes to SDG 4 by offering high-quality, accessible, and inclusive learning experiences, encouraging continuous learning, and preparing students for future difficulties in the sector.

3.7 Summary

This project intends to create an Augmented Reality (AR) system to improve student learning in microelectronic production, with an emphasis on atom and molecule operations and doping. The process involves creating a complete project flowchart, block diagram, and system flowchart. The modules include the atomic structure, molecular interactions, and doping processes. Unity for AR creation, Rhino 3D for precise modeling, Microsoft Visual Studio for coding, and a mobile application (APK) for accessibility are all essential software needs. This augmented reality system aims to provide an interactive and immersive instructional tool, hence enhancing comprehension and participation in higher education.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and analysis achieved during this semester, focusing on the successful development of the Augmented Reality (AR) system. The results include the implementation of 3D modeling for Atomic Structures and the Doping Process, offering an interactive and visual approach to learning these complex scientific concepts. These outcomes highlight the effectiveness of integrating AR technology in education.

4.2 Result

This project object under the "Development For Atom And Doping Process Using Augumented Reality In Microelectronics" is created using Blender program. This project is based on markerless AR, hence powerful computer vision techniques are required for feature recognition. This enables the project to identify and track real-world elements without using markers.

I successfully developed an Augmented Reality (AR) system designed to enhance the understanding of scientific concepts such as Atomic Structures, Groups 3, 4, and 5 of the Periodic Table, and the Doping Process. The AR system provides an engaging and interactive learning experience through a user-friendly interface and visual animations. Below is a description of each interface:

Figure 4.1 Interface of Start

This is the initial interface users encounter when launching the AR system. It features a simple and clean design with a "Start" button at the center, providing an intuitive starting point for users to navigate the system, as shown in Figure 4.1.

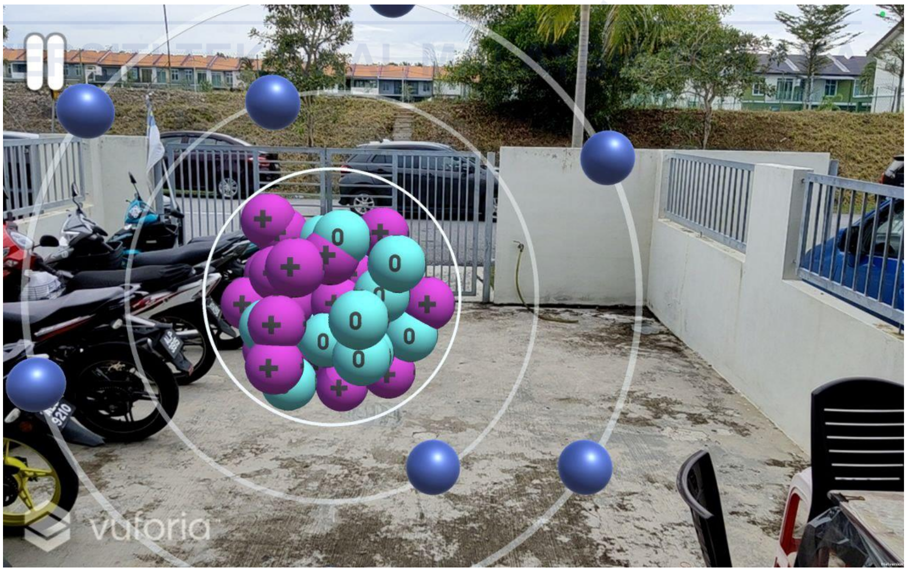

Figure 4.2 Animation of Atom Structure

Figure 4.2 displays a dynamic, interactive animation of atomic structures. It enables users to see and investigate the arrangement of subatomic particles, which improves their grasp of the subject. This interactive feature provides a hands-on approach to learning, making abstract concepts more tangible and easier to understand. By visualizing protons, neutrons, and electrons in their respective positions, students can develop a deeper understanding of atomic structures. Such animations are particularly useful in educational settings, where they can enhance engagement and foster a more immersive learning experience.

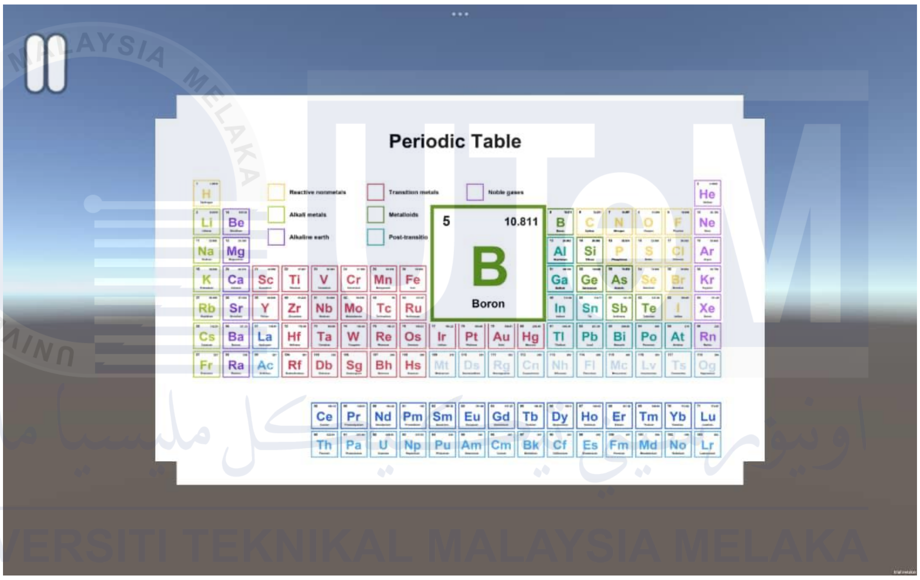

Figure 4.3 Interface of Periodic Table

As seen in Figure 4.3, this interface presents an interactive periodic table in which users may explore elements from Groups 3, 4, and 5. Boron, a Group 3 element, is a trivalent dopant with three valence electrons. When introduced into a silicon semiconductor, it creates a deficiency of electrons, known as 'holes,' forming a p-type semiconductor. This process allows electrical current to flow through the movement of these holes. The design allows users to touch certain element such as Boron, Aluminium, Gallium, Silicon, Germanium, Phosphorus, Arsenic, and the audio will play the most important information while keeping them engaged.

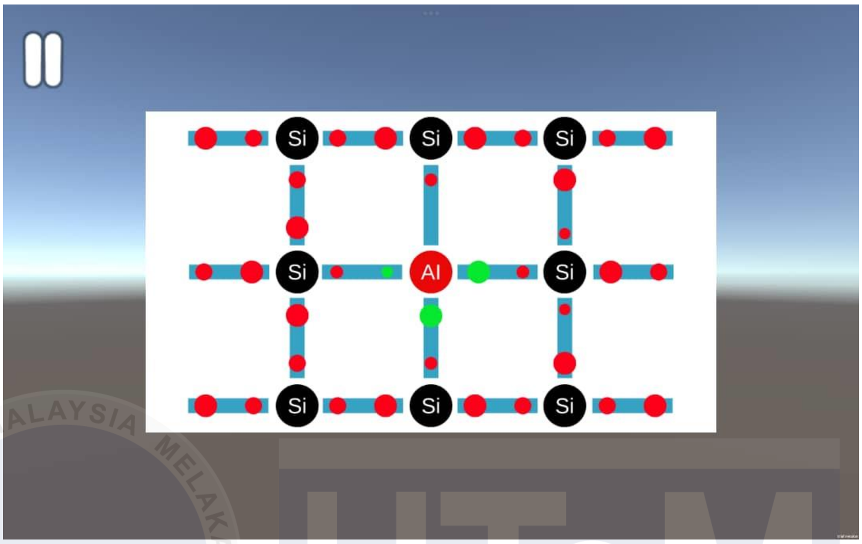

Figure 4.4 Animation of Doping Process

In Figure 4.4, the animation demonstrates the doping process in semiconductors, visually illustrating how impurities are introduced to modify the electrical characteristics of a material, simplifying the concept. The figure shows a pure silicon crystal structure, where each silicon atom is covalently bonded to four other silicon atoms, forming a stable lattice. The red circles represent electrons that facilitate these covalent bonds between atoms. To create a p-type semiconductor, an aluminum atom, which has three valence electrons, is introduced into the silicon lattice. The aluminum atom replaces a silicon atom, but since aluminum can only form three covalent bonds with its neighbors, it creates a vacancy or "hole." This hole behaves as a positive charge and can move freely within the lattice. As an electron from a neighboring bond fills this hole, the hole shifts to a new position. This movement of holes is the mechanism behind electrical conduction in a p-type semiconductor, where holes act as the majority charge carriers.

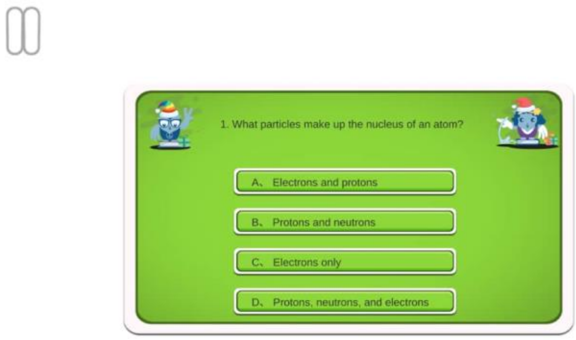

Figure 4.5 Interface of Quiz

As seen in Figure 4.5, this interface includes a quiz to assess users' comprehension of the AR system's content. It offers an interactive evaluation tool to help reinforce learning outcomes. The quiz interface allows users to actively engage with the content, testing their understanding and promoting critical thinking. This interactive approach not only enhances knowledge retention but also encourages self-paced learning, making it a valuable tool for both students and educators.

Figure 4.6 Interface of Scores and Exit

Figure 4.6 displays the final interface, which displays the quiz scores and provides an option to quit the system. It ensures a seamless end to the user's learning experience by summarizing their performance.

4.3 Analysis (Betulkn graf tambah label)

A survey of 21 users from diverse occupations and educational backgrounds was conducted to understand their needs and attitudes toward augmented reality (AR) technology. The results show that 85.7% of users are between the ages of 22 and 25, while 14.3% are 26 years old and above. Most respondents are students (81%), with the remaining comprising educators (9.5%) and industry professionals (9.5%). Most participants are pursuing engineering or related fields, displaying strong academic orientations but limited exposure to AR technology. Specifically, 33.3% of users are not familiar with AR, 57.1% are somewhat familiar, and 9.5% have never used it.

Despite their limited experience with AR, users demonstrate a high level of familiarity with scientific topics such as atomic structures, periodic table groups, and doping processes in semiconductors. This indicates that while AR technology is relatively new to many, their solid foundational knowledge positions them well for AR-based learning. To maximize engagement, AR modules should be designed to be intuitive for beginners while leveraging users' expertise in scientific subjects.

4.3.1 Interactive Augmented Reality (AR) Interface

This survey was conducted to gather insights into user requirements, attitudes, and familiarity with using Augmented Reality (AR) in scientific education. The survey focuses on four key areas: Interactive AR Interface for Atomic Structures and AR Technology, Groups 3, 4, and 5 of the Periodic Table, the Doping Process in Semiconductors, and general feedback. By understanding user preferences and knowledge in these areas, the study aims to design AR modules that enhance learning experiences and engagement with complex scientific topics.

4.3.1.1 Atomic Structures and AR Technology

This section focuses on the use of augmented reality technologies to view and better comprehend atomic structures. Users may learn more about subatomic particles and their characteristics by using animations and interactive elements. The response emphasizes Augmented Reality (AR) usefulness in bridging conceptual learning gaps and improving user comprehension.

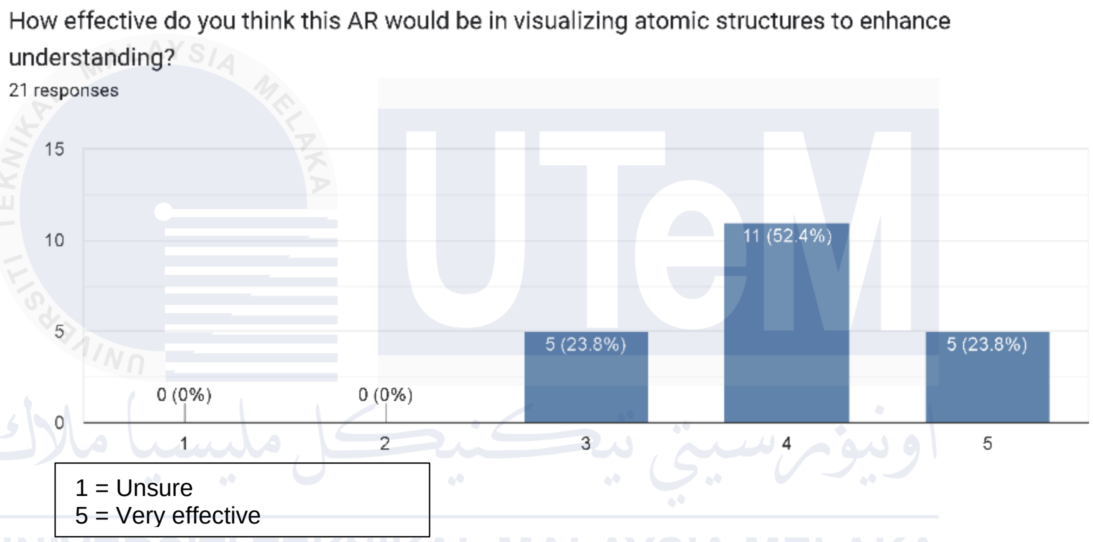

Figure 4.7 Histogram About AR can Visualizing Atomic Structures to Enchance Understanding

Figure 4.7 shows the histogram represents how users rate the effectiveness of AR technology in enhancing their understanding of atomic structures. The x-axis shows a scale from 1 (Unsure) to 5 (Very effective), while the y-axis represents the number of respondents. The majority of users rated the AR interface highly, with most selecting 4 or 5. This indicates that a significant percentage of respondents find AR helpful for visualizing and learning about complex atomic structures. Specifically, 85.7% of users rated AR between 3 and 5, showing strong approval of its educational benefits.

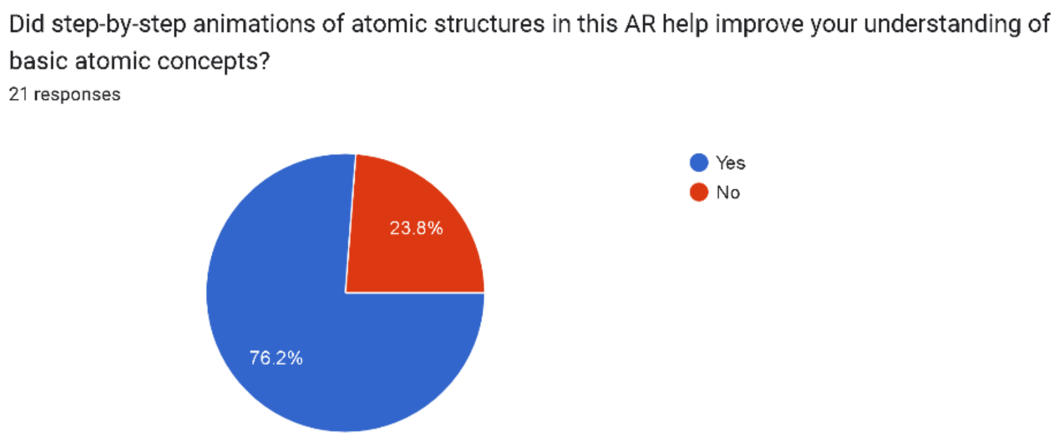

Figure 4.8 Pie Chart showing User Understanding of Basic Atomic Concepts

Figure 4.8 shows the pie chart illustrates the level of user understanding of basic atomic concepts. It categorizes responses into familiar, somewhat familiar, and unfamiliar. A majority (57.1%) of users reported being somewhat familiar, while 33.3% indicated familiarity, and 9.5% had no prior exposure. This distribution highlights a gap in foundational knowledge that AR modules can help bridge, making interactive learning tools valuable for these users.

From the survey and based on the users response, we may assume that they want to include in Atom structures:

- Include links to more videos with greater information.
- Real-time annotations to show atomic component attributes (e.g., mass, charge, chemical bonding roles), with voiceovers or pop-up comments to provide context.
- Include 3D graphics for greater observation and interactive manipulation of subatomic particles.
- Provide more comprehensive views, video explanations, and augmented reality hands-on experiences for constructing atomic structures.
- Expand the module to cover additional periodic table categories and make it easier to grasp

4.3.1.2 Groups 3, 4, and 5 of the Periodic Table

This section investigates the use of augmented reality (AR) to interactively educate elements from Groups 3, 4, and 5 of the periodic table, with a focus on their functions in semiconductors. Users found the AR interface useful for exploring items, understanding their features, and relating theoretical knowledge to practical applications.

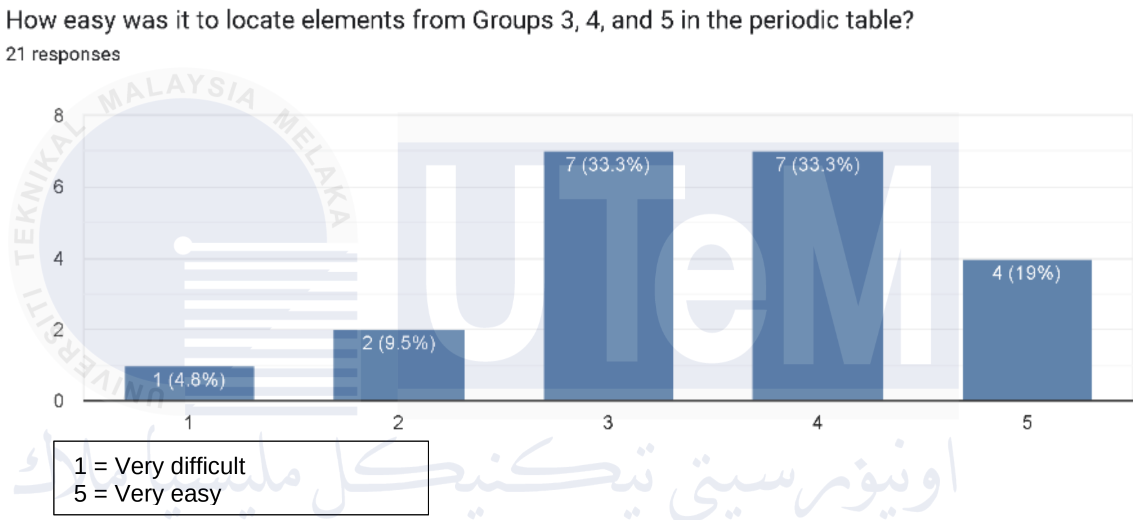

Figure 4.9 Histogram demonstrating how users can find elements in the periodic table.

The histogram in Figure 4.9 illustrates the distribution of responses from 21 participants on the ease of locating elements from Groups 3, 4, and 5 in the periodic table using augmented reality (AR). Participants rated their experience on a scale from 1 (Very difficult) to 5 (Very easy). The results show that only 1 participant (4.8%) found the task very difficult, while 2 participants (9.5%) found it somewhat difficult. A significant portion of the respondents, 7 participants (33.3%), rated the task as moderately easy, with an additional 7 participants (33.3%) finding it fairly easy. Moreover, 4 participants (19%) reported that locating the elements was very easy. Overall, 85.6% of the participants rated their experience as moderately easy to very easy (Scores 3, 4, and 5), highlighting the effectiveness of the AR system. These results suggest that the user-friendly interface of the AR tool significantly contributes to simplifying the visualization and identification of elements in the periodic table, demonstrating its potential as a valuable aid in chemistry education.

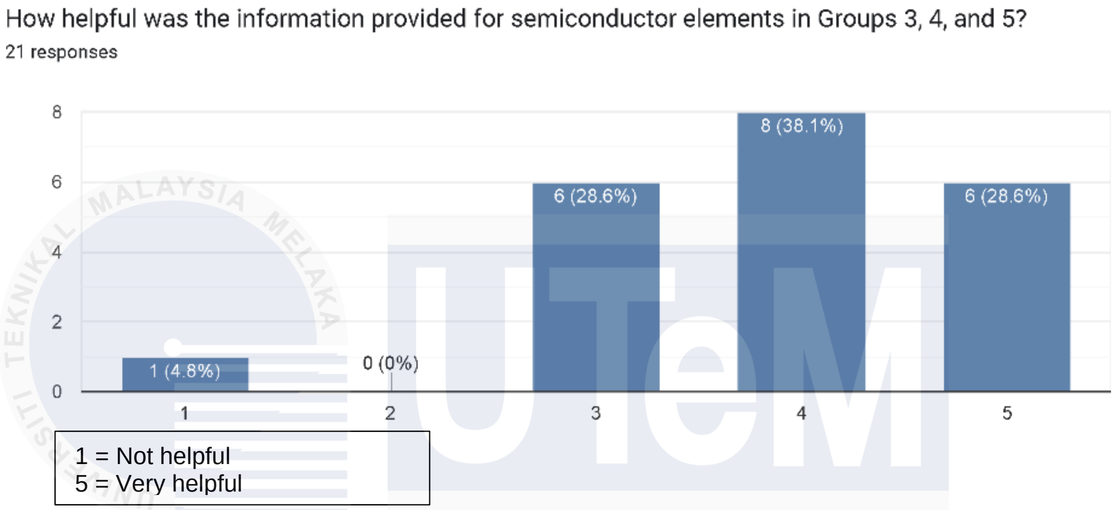

Figure 4.10 The histogram shows how beneficial the information supplied to the user proved to be for semiconductor elements in groups 3, 4, and 5

The histogram in Figure 4.10 represents user responses on how helpful they found the information provided for semiconductor elements in Groups 3, 4, and 5, using augmented reality (AR). The scale ranges from 1 (Not helpful) to 5 (Very helpful). The results indicate that only one respondent (4.8%) rated the information as not helpful, while none selected a rating of 2. A significant number of participants, 6 respondents (28.6%), rated the experience as moderately helpful (3), and the same proportion rated it as very helpful (5). The largest group, 8 respondents (38.1%), rated the information as helpful (4). Overall, approximately 80% of respondents gave high ratings (4 or 5), reflecting the effectiveness of the AR tool in delivering educational and useful information about semiconductor elements. This underscores the relevance of AR as a tool for conveying complex concepts in an accessible and engaging manner.

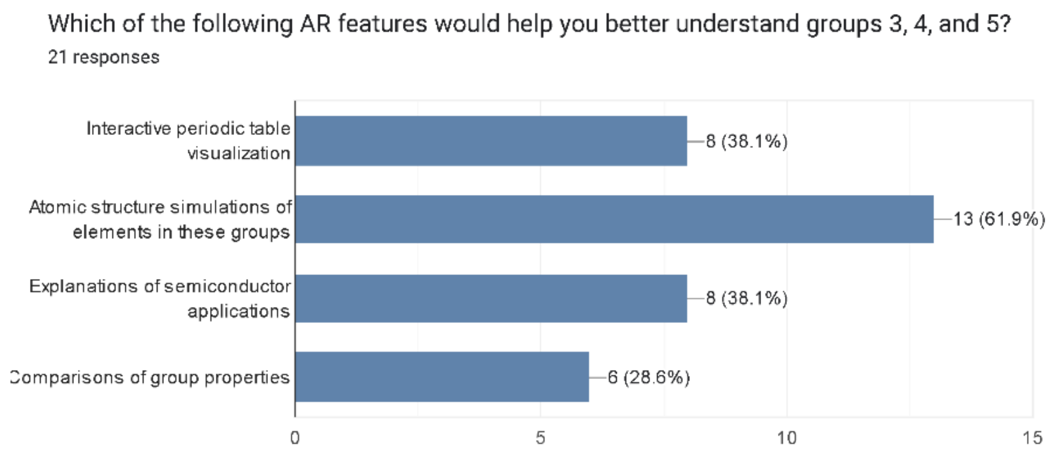

Figure 4.11 The histogram illustrates the AR features that assist the user understand components in groups 3, 4, and 5

Figure 4.11 shows the histogram presents user preferences for various augmented reality (AR) features that could enhance their comprehension of periodic table groups 3, 4, and 5. Among the responses, atomic structure simulations of elements in these groups emerged as the most preferred feature, with 13 users (61.9%) selecting it. This reflects a strong interest in dynamic, visual representations to better understand atomic structures. The next most popular features are interactive periodic table visualization and explanations of semiconductor applications, each chosen by 8 respondents (38.1%). These responses indicate a substantial need for engaging and explanatory tools to clarify chemical group behaviors and real-world applications.

Finally, the feature with the least interest is comparisons of group properties, selected by only 6 users (28.6%). This suggests that while comparisons may be useful, they are viewed as less critical than other interactive and simulation-based approaches for learning. In summary, this data highlights a strong user preference for visual simulations and interactive elements to enhance scientific understanding, particularly in complex chemical and semiconductor topics. Future AR tools should prioritize these features to maximize educational impact.

4.3.1.3 Doping Process

This section explains how augmented reality may simplify complicated topics such as semiconductor doping. Key concepts including energy band structures, conductivity changes, and temperature impacts are shown through interactive simulations and animations. The response suggests that consumers found the AR system useful for viewing these complex processes.

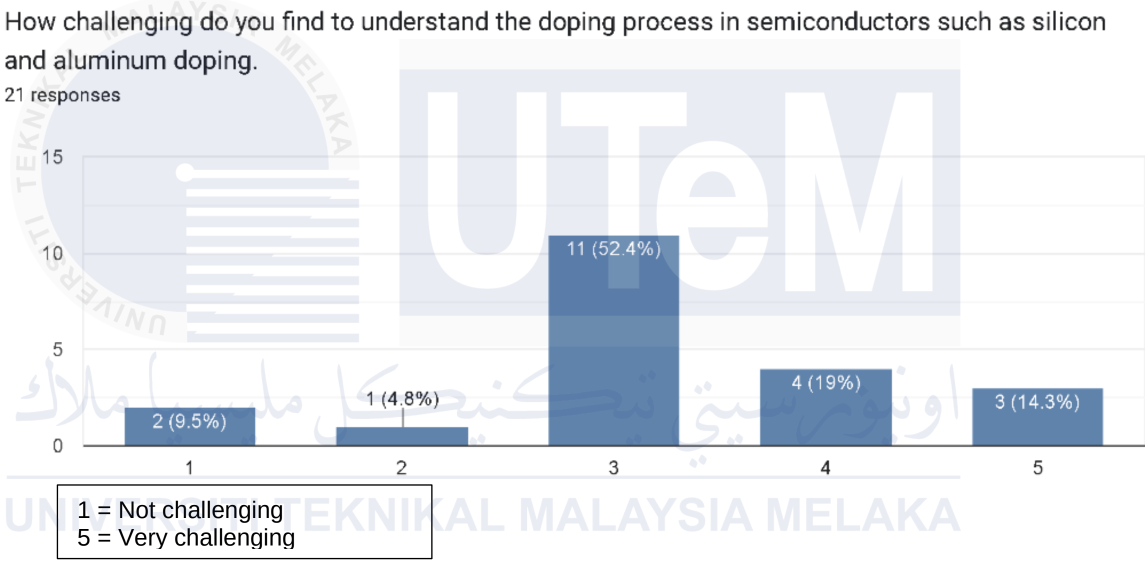

Figure 4.12 Histogram demonstrating the difficulties of understanding doping processes in semiconductors such as silicon and aluminium doping.

The histogram in Figure 4.12 illustrates how participants rated the difficulty of understanding doping processes in semiconductors, such as silicon and aluminium doping. The responses, collected from 21 individuals, reveal a range of perceived difficulty. The majority of participants (52.4%) rated their experience as moderately challenging (3 on the scale), indicating that most found the topic somewhat difficult but not overly complex. A smaller number found it less challenging (9.5% rated 1, and 4.8% rated 2), while others experienced greater difficulty, with 19% rating it as 4 and 14.3% as very challenging (5). This distribution highlights the potential for augmented reality (AR) or other interactive methods to bridge understanding gaps and simplify complex semiconductor concepts through engaging simulations.

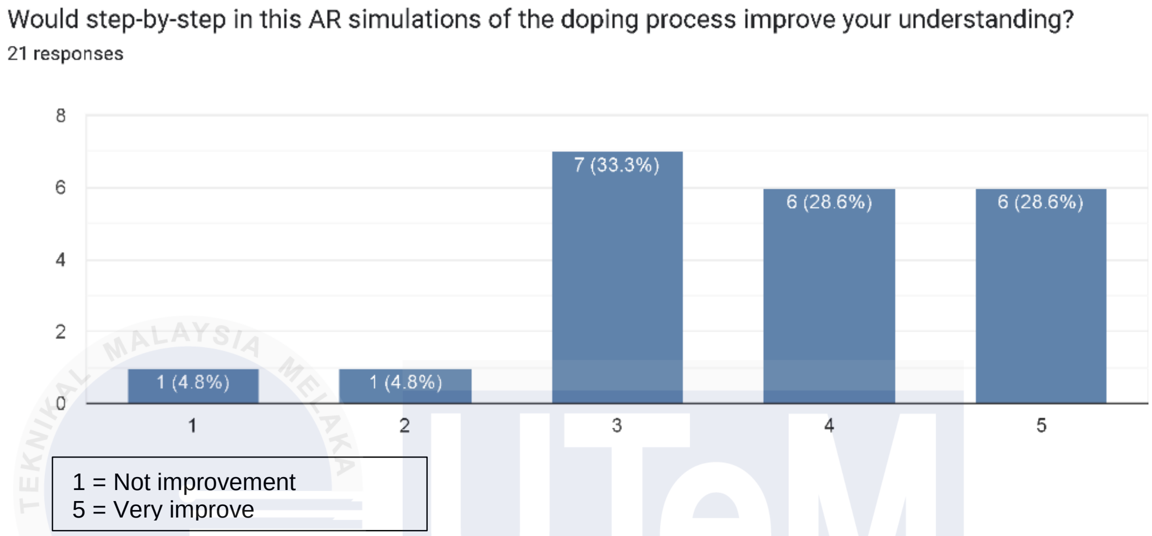

Figure 4.13 The histogram shows if this AR simulations of the doping process help user knowledge.

The histogram in Figure 4.13 demonstrates participants perceptions of the effectiveness of step-by-step augmented reality (AR) simulations in improving their understanding of doping processes in semiconductors. Out of 21 responses, the majority expressed a positive outlook. A significant portion of participants rated the feature as highly beneficial, with 28.6% assigning a rating of 4 and another 28.6% giving it the highest rating of 5. Additionally, 33.3% rated it as moderately useful (3 on the scale), while only a small minority found it less helpful, with 4.8% rating it 2 and 4.8% rating it 1. These results suggest that AR simulations are perceived as an effective tool to enhance comprehension of complex scientific concepts.

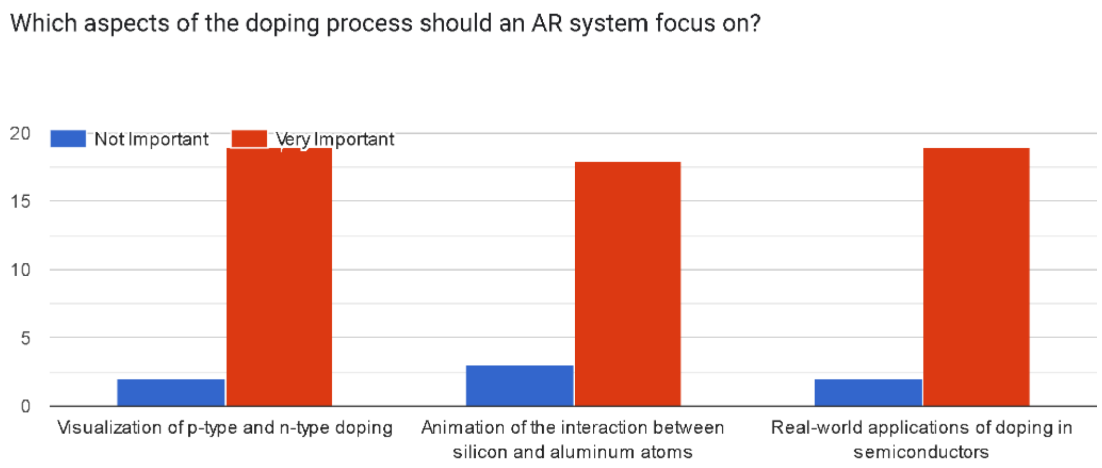

Figure 4.14 Histogram showing which components of the doping process should be included in this AR system.

The histogram in Figure 4.14 show the user preferences for specific components of the doping process to be emphasized in an augmented reality (AR) system. Three key aspects were evaluated: the visualization of p-type and n-type doping, animation of the interaction between silicon and aluminum atoms, and real-world applications of doping in semiconductors. The results indicate a strong preference for all three components, as most participants rated them as "very important." This highlights the need to incorporate detailed visualizations, dynamic animations, and practical applications into the AR system. These features are expected to enhance user understanding by providing both theoretical and practical insights into the doping process.

From the survey and based on the users response, we may assume that they want to include in doping process:

- Add more options for interactivity.
- Simulate effects such as energy band diagrams, conductivity demonstrations, and temperature-dependent charge carrier activity.
- Include immersive experiences and toggling between different dopants.

- Provide additional videos and detailed explanations to enhance user understanding. between different dopant
- Immersive experience

4.3.1.4 General Feedback

This section collects overall user impressions of the AR system, emphasizing its benefits for boosting education, particularly in microelectronics. Users shared insights about possible roadblocks, such as technological issues, and showed a strong desire to continue investigating and trying AR technology. The feedback emphasizes AR potential to transform learning in scientific disciplines.

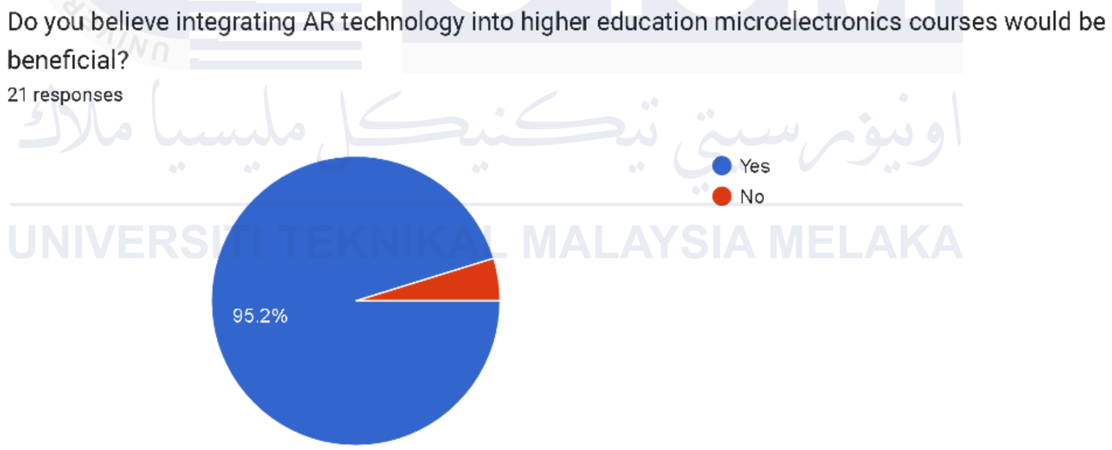

Figure 4.15 The pie chart presents the proposal question of whether incorporating AR technology into higher education, such as microelectronics classes, may be advantageous

Figure 4.15 presents a pie chart illustrating respondents' opinions on integrating augmented reality (AR) technology into higher education courses focused on microelectronics. The overwhelming majority (95.2%) expressed support for this innovation, recognizing the significant benefits AR could provide in enhancing learning experiences and understanding complex concepts. In contrast, only a small minority (4.8%) did not see the value of incorporating AR into such courses. These results demonstrate strong enthusiasm for AR as a tool to enrich microelectronics education and suggest its potential to improve student engagement and comprehension.

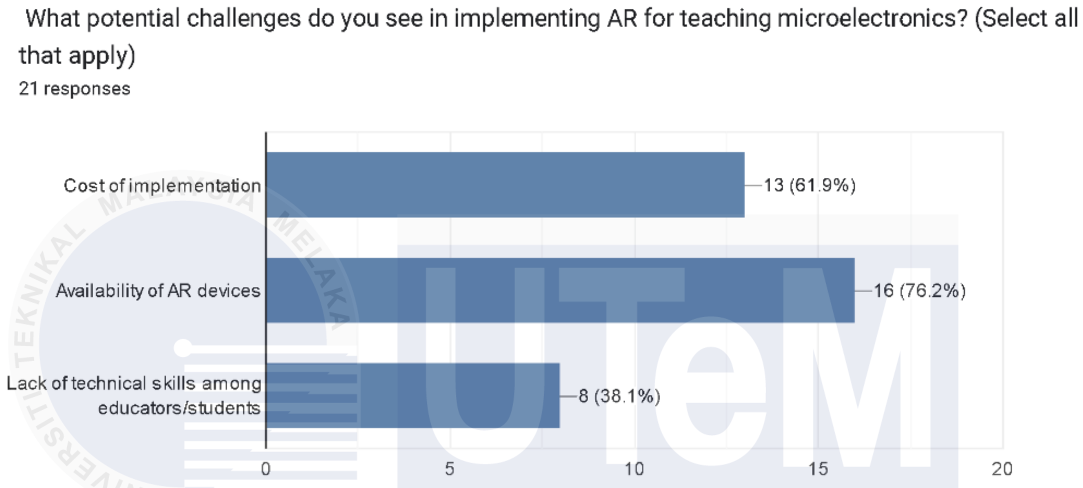

Figure 4.16 Histogram of possible obstacles that users experience while utilizing AR for teaching microelectronics courses.

Figure 4.16 presents a histogram depicting the potential challenges identified by respondents regarding the implementation of augmented reality (AR) in teaching microelectronics. The most frequently cited challenge, noted by 76.2% of respondents, was the availability of AR devices, highlighting concerns about access to the necessary hardware. The cost of implementation was also a significant concern, identified by 61.9% of participants, suggesting financial barriers could hinder widespread adoption. Additionally, 38.1% of respondents pointed out a lack of technical skills among educators and students, emphasizing the need for training to effectively utilize AR tools. These results underscore the importance of addressing these hurdles to ensure successful integration of AR into microelectronics education.

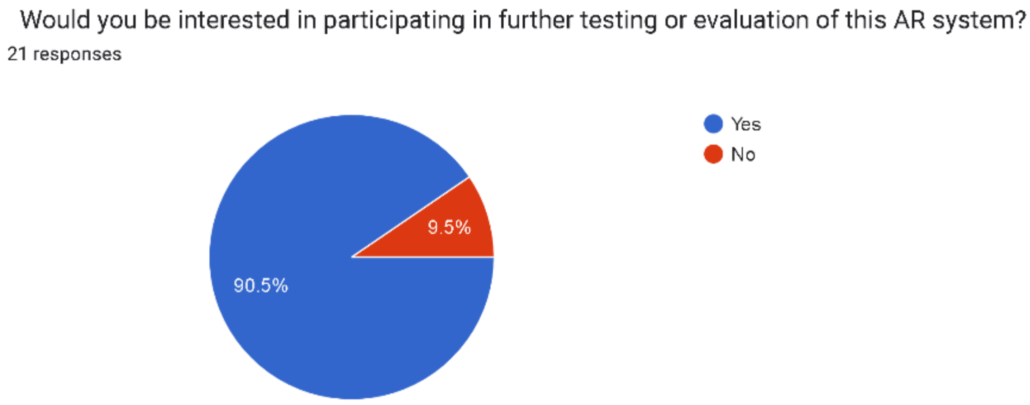

Figure 4.17 Pie chart showing user interest in future testing or assessment of this AR technology.

Figure 4.17 illustrates a pie chart reflecting respondents' interest in participating in future testing or evaluation of the augmented reality (AR) system. An overwhelming majority, 90.5%, expressed willingness to engage in further testing, indicating strong enthusiasm and support for the continued development of AR technology in education. Only a small minority, 9.5%, were not interested. These findings highlight the potential for active user involvement in refining and improving the AR system, which could contribute to its successful adoption and optimization for microelectronics education.

4.4 Summary

In summary, the general feedback aligns closely with the results of the survey, highlighting both the strong support for augmented reality (AR) in education and the areas for improvement identified by respondents. The survey results underscore the effectiveness of AR in enhancing understanding of complex microelectronics concepts, with a significant majority of participants rating it positively (Figures 4.7, 4.8, and 4.13). Similarly, general feedback emphasizes the potential of AR to improve student engagement and comprehension, as reflected in the overwhelming support for its integration into higher education courses (Figure 4.15).

At the same time, the survey results reveal specific challenges and areas for enhancement. Concerns such as the availability of AR devices (76.2%), cost of implementation (61.9%), and a lack of technical skills among educators and students (38.1%) (Figure 4.16) directly correlate with the feedback suggesting the need for accessible hardware, cost-effective solutions, and comprehensive training programs. Moreover, users expressed a desire for more interactivity and immersive experiences, including simulations of energy band diagrams, conductivity demonstrations, and 3D graphics for manipulating atomic structures (Figures 4.9, 4.11, and 4.14). This aligns with the feedback recommending features such as real-time annotations, detailed explanations, and hands-on augmented reality experiences to deepen understanding.

Finally, the high level of interest in participating in further testing (90.5%) (Figure 4.17) demonstrates user enthusiasm for refining the AR system and supports the general feedback advocating for continued development and user engagement.

In summary, the survey results validate the general feedback by highlighting user support for AR in microelectronics education, while also identifying specific enhancements and challenges that must be addressed to maximize its educational impact.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the project successfully demonstrated the application of augmented reality (AR) technology in education, particularly for microelectronics. By investigating AR's potential, the study highlighted its ability to enhance student engagement and understanding, offering an innovative alternative to traditional teaching methods. The development of an interactive AR interface, which overlays visual images and animations onto real-world scenarios, provided students with a detailed and engaging way to comprehend complex microelectronic fabrication processes. This interactive system offered step-by-step guidance, making abstract concepts tangible and easier to grasp.

Furthermore, to evaluate the system's performance, user feedback and surveys were conducted. The results showed a positive response from students, who appreciated the application for its accessibility and ability to promote self-directed learning. The AR application allowed students to explore and simulate fabrication processes independently, even from home, reducing the need for physical lab visits. Teachers also benefited from the ability to present complex concepts in a more engaging manner.

Lastly, the feedback validated the effectiveness of the AR system in improving learning outcomes and highlighted its potential to replace traditional methods. While challenges were noted, the application demonstrated how AR could address the limitations of conventional education, offering a scalable and motivational tool for learning. This project underscores AR value in education and its promising future in microelectronics and beyond.

5.2 Future Improvement

The survey results highlight several areas for future improvement of the AR system for microelectronics education. Users emphasized the need for enhanced interactivity, such as simulations of energy band diagrams, conductivity demonstrations, and temperature-dependent charge carrier activity. Immersive features, including real-time annotations with voiceovers or pop-ups and the ability to toggle between different dopants, were also suggested to boost engagement. Expanding the content scope is another key priority, with users expressing interest in covering additional topics like other periodic table groups, advanced semiconductor processes, and comprehensive views of atomic structures through 3D visualizations and augmented reality hands-on experiences. Accessibility improvements, such as addressing the availability and cost of AR devices, along with providing scalable and device-independent solutions, were noted as crucial to ensuring broader adoption. Additionally, resources to improve technical skills among educators and students, such as tutorials, workshops, and user-friendly guides, were identified as essential for successful integration.

5.3 Commercialization Potential

The commercialization potential of the AR system is substantial. With 95.2% of respondents supporting its integration into higher education (Figure 4.15), the product is well-suited for universities and technical institutions seeking innovative STEM tools. Furthermore, the system could cater to corporate training programs in industries like semiconductor manufacturing, where interactive simulations and real-world applications are highly valued. Offering cost-effective or device-independent versions could expand access to schools or regions with limited resources. A subscription-based model, providing regular updates, additional modules, and advanced features, could also appeal to both educational and industrial users.

Partnerships with EdTech companies could amplify the product's reach while leveraging their expertise in delivering technology-driven solutions. Additionally, customizing modules for niche industries, such as renewable energy or advanced materials, could open new market opportunities. By addressing the identified user needs and focusing on accessibility, interactivity, and content expansion, the AR system has the potential to revolutionize microelectronics education and training while achieving significant market success.

REFERENCES

[1] S. Singhal, S. Bagga, P. Goyal, and V. Saxena, “Augmented Chemistry: Interactive Education System,” 2012.

[2] P. H. Diao and N. J. Shih, “Trends and research issues of augmented reality studies in architectural and civil engineering education-A review of academic journal publications,” *Applied Sciences (Switzerland)*, vol. 9, no. 9, May 2019, doi: 10.3390/app9091840.

[3] M. B. Ibáñez and C. Delgado-Kloos, “Augmented reality for STEM learning: A systematic review,” *Comput Educ*, vol. 123, pp. 109–123, Aug. 2018, doi: 10.1016/j.compedu.2018.05.002.

[4] S. M. AlNajdi, “The effectiveness of using augmented reality (AR) to enhance student performance: using quick response (QR) codes in student textbooks in the Saudi education system,” *Educational Technology Research and Development*, vol. 70, no. 3, pp. 1105–1124, Jun. 2022, doi: 10.1007/s11423-022-10100-4.

[5] IEEE Education Society and Institute of Electrical and Electronics Engineers, *Proceedings of 2018 IEEE Global Engineering Education Conference (EDUCON) : date and venue: 17-20 April, 2018, Santa Cruz de Tenerife, Canary Islands, Spain.*

[6] J. R. Schmid, M. J. Ernst, and G. Thiele, “Structural Chemistry 2.0: Combining Augmented Reality and 3D Online Models,” *J Chem Educ*, vol. 97, no. 12, pp. 4515–4519, Dec. 2020, doi: 10.1021/acs.jchemed.0c00823.

[7] P. C. , & D. W. M. (1992, J. Thomas, “ Augmented reality: An application of heads-up display technology to manual manufacturing processes. ,” 1992.

[8] H. Altinpulluk, “Determining the trends of using augmented reality in education between 2006-2016,” *Educ Inf Technol (Dordr)*, vol. 24, no. 2, pp. 1089–1114, Mar. 2019, doi: 10.1007/s10639-018-9806-3.

[9] H. , & B. M. (1999, O. Kato, “Marker tracking and hmd calibration for a video-based augmented reality conferencing system.,” Oct. 1999.

[10] T. & F. Steven. (2004). Höllerer, “Mobile Augmented Reality. ,” 2004.

[11] R. T. Azuma, “A Survey of Augmented Reality,” 1997. [Online]. Available: http://www.cs.unc.edu/~azumaW:

[12] A. Q. M. Alhamad, I. Akour, M. Alshurideh, A. Q. Al-Hamad, B. Al Kurdi, and H. Alzoubi, “Predicting the intention to use google glass: A comparative approach using machine learning models and PLS-SEM,” *International Journal of Data and Network Science*, vol. 5, no. 3, pp. 311–320, Jun. 2021, doi: 10.5267/j.ijdns.2021.6.002.

[13] S. Park, S. Bokijonov, and Y. Choi, “Review of microsoft hololens applications over the past five years,” Aug. 02, 2021, *MDPI AG*. doi: 10.3390/app11167259.

[14] H. Le, M. Nguyen, W. Q. Yan, and H. Nguyen, “Augmented reality and machine learning incorporation using yolov3 and arkit,” *Applied Sciences (Switzerland)*, vol. 11, no. 13, Jul. 2021, doi: 10.3390/app11136006.

[15] Amity University and Institute of Electrical and Electronics Engineers, *Proceedings of the 9th International Conference On Cloud Computing, Data Science and Engineering : Confluence 2019 : 10-11 January 2019, Uttar Pradesh, India.*

[16] & S. D. Wagner, D, and Schmalstieg, “Artoolkit on the pocketpc platform. ,” Oct. 2003.

[17] M. Billinghurst and A. Dünser, “Augmented Reality in the Classroom,” 2012. [Online]. Available: www.youtube.com/

[18] F. Zhou, H. B. L. Duh, and M. Billinghurst, "Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR.," Sep. 2008.
[19] G. Klein and D. Murray, "Parallel tracking and mapping for small AR workspaces. In 2007 6th IEEE and ACM international symposium on mixed and augmented reality (pp. 225-234). IEEE.," vol. 11, 2007.
[20] P. Cipresso, I. A. C. Giglioli, M. A. Raya, and G. Riva, "The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature," *Front Psychol*, vol. 9, no. NOV, Nov. 2018, doi: 10.3389/fpsyg.2018.02086.
[21] A. P. Gee, M. Webb, J. Escamilla-Ambrosio, W. Mayol-Cuevas, and A. Calway, "A topometric system for wide area augmented reality," *Computers and Graphics (Pergamon)*, vol. 35, no. 4, pp. 854–868, 2011, doi: 10.1016/j.cag.2011.04.006.
[22] T. Scargill, J. Chen, and M. Gorlatova, "Here To Stay: Measuring Hologram Stability in Markerless Smartphone Augmented Reality," Sep. 2021, [Online]. Available: http://arxiv.org/abs/2109.14757
[23] R. Castle, G. Klein, and D. W. Murray, "Video-rate localization in multiple maps for wearable augmented reality.," Sep. 2008.
[24] M. Billinghurst, A. Clark, and G. Lee, "A survey of augmented reality," 2014, *Now Publishers Inc*. doi: 10.1561/1100000049.
[25] J. Bacca, S. Baldiris, R. Fabregat, and S. Graf, "Augmented Reality Trends in Education: A Systematic Review of Research and Applications," 2014.
[26] M. Akçayır and G. Akçayır, "Advantages and challenges associated with augmented reality for education: A systematic review of the literature," *Educ Res Rev*, vol. 20, pp. 1–11, Feb. 2017, doi: 10.1016/j.edurev.2016.11.002.
[27] J. Zhang, G. Li, Q. Huang, Q. Feng, and H. Luo, "Augmented Reality in K–12 Education: A Systematic Review and Meta-Analysis of the Literature from 2000 to 2020," Aug. 01, 2022, *MDPI*. doi: 10.3390/su14159725.
[28] G. Koutromanos, A. Sofos, and L. Avraamidou, "The use of augmented reality games in education: a review of the literature," *EMI Educ Media Int*, vol. 52, no. 4, pp. 253–271, Oct. 2015, doi: 10.1080/09523987.2015.1125988.
[29] A. Parmaxi and A. A. Demetriou, "Augmented reality in language learning: A state-of-the-art review of 2014–2019," Dec. 01, 2020, *Blackwell Publishing Ltd*. doi: 10.1111/jcal.12486.
[30] K. A. Bölek, G. De Jong, and D. Henssen, "The effectiveness of the use of augmented reality in anatomy education: a systematic review and meta-analysis," *Sci Rep*, vol. 11, no. 1, Dec. 2021, doi: 10.1038/s41598-021-94721-4.
[31] S. Schutera *et al.*, "On the potential of augmented reality for mathematics teaching with the application cleARmaths," *Educ Sci (Basel)*, vol. 11, no. 8, Aug. 2021, doi: 10.3390/educsci11080368.
[32] A. O. Ezeama, P. I. Obe, R. N. Ezeama, and V. Oguejiofor, "Microelectronics Design in Educational Apps for Technical Education Learning in Pandemic Eras," *Nigerian Journal of Technology*, vol. 40, no. 1, pp. 89–96, Mar. 2021, doi: 10.4314/njt.v40i1.13.
[33] Y. Behnke, "Textbook Effects and Efficacy," in *The Palgrave Handbook of Textbook Studies*, Palgrave Macmillan US, 2018, pp. 383–398. doi: 10.1057/978-1-137-53142-1_28.
[34] S. Maynard and E. Cheyne, "Can electronic textbooks help children to learn?," *Electronic Library*, vol. 23, no. 1, pp. 103–115, 2005, doi: 10.1108/02640470510582781.

[35] J. L. Stringfellow and S. P. Miller, “Enhancing Student Performance in Secondary Classrooms while Providing Access to the General Education Curriculum Using Lecture Formats,” 2005. [Online]. Available: http://escholarship.bc.edu/education/tecplus/vol1/iss6/1
[36] K. Schildkamp, F. M. van der Kleij, M. C. Heitink, W. B. Kippers, and B. P. Veldkamp, “Formative assessment: A systematic review of critical teacher prerequisites for classroom practice,” *Int J Educ Res*, vol. 103, Jan. 2020, doi: 10.1016/j.ijer.2020.101602.
[37] T. N. Fitria, “ Artificial intelligence (AI) in education: Using AI tools for teaching and learning process. I,” vol. 2021.
[38] L. Martinez, M. Gimenes, and E. Lambert, “Entertainment Video Games for Academic Learning: A Systematic Review,” *A Systematic Review. Journal of Educational Computing Research*, vol. 2022, no. 5, pp. 1083–1109, doi: 10.1177/07356331211053848ï.
[39] E. McGovern, G. Moreira, and C. Luna-Nevarez, “An application of virtual reality in education: Can this technology enhance the quality of students’ learning experience?,” *Journal of Education for Business*, vol. 95, no. 7, pp. 490–496, Oct. 2020, doi: 10.1080/08832323.2019.1703096.
[40] M. Thees, S. Kapp, M. P. Strzys, F. Beil, P. Lukowicz, and J. Kuhn, “Effects of augmented reality on learning and cognitive load in university physics laboratory courses,” *Comput Human Behav*, vol. 108, Jul. 2020, doi: 10.1016/j.chb.2020.106316.
[41] S. Sakshuwong, H. Weir, U. Raucci, and T. J. Martínez, “Bringing chemical structures to life with augmented reality, machine learning, and quantum chemistry,” *Journal of Chemical Physics*, vol. 156, no. 20, May 2022, doi: 10.1063/5.0090482.

APPENDICES

PSM 2 GANTT CHART 2024/2025 SEM I

TASKS	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7		WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14
Interface main menu : (Start)				Present on 6/11/2024											
Interface Atom structure				Present on 6/11/2024											
Repair methodology (report)					Discuss on 13/11/2024										
Periodic table						Present on 20/11/2024									
Doping process						Present on 27/11/2024									
5 quiz															
meet SV to present AR pogress for all pages							Discuss on 28/11/2024								
Survey							Discuss on 28/11/2024	MIDTERM BREAK							
Complete AR apps										Present on 18/12/2024					
distribute survey question to participant (target = 20 - 30 participant)															
Data analysis from survey												Present on 1/1/2024			
First draft report (without data analysis) SV													Submit to SV 9/1/2024		
Make report correction submit second draft with data analysis to SV															Submit to SV 21/1/2025
Submit final1 report to Panel															Submit to panel 23/1/2025
Panel Presentation														presentation with panel 15/1/2025	

Survey Link: https://docs.google.com/forms/d/e/1FAIpQLScs86hckqlk3tI-g-xXNUcY4wTi1Ouav28PM1IY076xOKrOHQ/viewform?usp=sf_link