



AUGMENTED REALTY (AR) IN EDUCATION: ASSESSMENT AND RANKING FRAMEWORK BASED ON FUZZY DELPHI AND HYBRID OF AHP ENTROPY AND VIKOR METHODS



GHAILAN ABBOOD KHUDHAIR AL-SHAFEE

SULTAN IDRIS EDUCATION UNIVERSITY

2021









AUGMENTED REALTY (AR) IN EDUCATION: ASSESSMENT AND RANKING FRAMEWORK BASED ON FUZZY DELPHI AND HYBRID OF AHP ENTROPY AND VIKOR METHODS

GHAILAN ABBOOD KHUDHAIR AL-SHAFEE



O 5-4506832 gustaka.upsi.edu.my



THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FORTHE DEGREE OF DOCTOR OF PHILOSOPHY

FACULTY OF ART, COMPUTING & CREATIVE INDUSTRY SULTAN IDRIS EDUCATION UNIVERSITY

2021







Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shal

UPSI/IPS-3/BO 32
Pind : 00 m/s: 1/1



Please tick (√)
Project Paper
Masters by Research
Master by Mixed Mode
PhD

INSTITUTE OF GRADUATE

STUDIES DECLARATION OF

ORIGINAL WORK

i. Student's Declaration:

I, Ghailan Abbood Khudhair Shafeey, P20161001053 , FSKIK (PLEASE

INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled Augmented Realty (AR) in Education: Assessment and Ranking

Framework based on Fuzzy Delphi and Hybrid of AHP Entropy and Vikor Methods $_{
m is}$

original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me

by another person. pustaka upsi.edu.my

Perpustakaan Tuanku Bainun Kampus Sultan Abdul, Jalil Shah

my

Signature of the student

ii. Supervisor's Declaration:

I Associate Prof. Ts. Dr. Muhammad Modi Lakulu (SUPERVISOR'S NAME) hereby certifies that the work entitled Augmented Realty (AR) in Education: Assessment and Ranking Framework based on Fuzzy Delphi and Hybrid of AHP Entropy and Vikor Methods

(TITLE) was prepared by the above named student, and was

submitted to the Institute of Graduate Studies as a * partial/full fulfillment for the conferment

of_____ Doctor of Philosophy

THE DEGREE), and the aforementioned work, to the best of my knowledge, is the said student's work.

PROF. MADYA DR. MUHAMMAD MODI BIN LAKULU Timbelan Detan (Panyelidikan dan Inovasi) Pskutil Seni, Komputaran dan Industri Kreatil Universiti Pendidikan Sultan kiris 35806 Tanjong Malian, Perak

24 day... of ...May... 2021

Date

Signature of the Supervisor



(PLEASE INDICATE



INSTITUT PENGAJIAN SISWAZAH / INSTITUTE OF GRADUATE STUDIES

BORANG PENGESAHAN PENYERAHAN TESIS/DISERTASI/LAPORAN KERTAS PROJEK DECLARATION OF THESIS/DISSERTATION/PROJECT PAPER FORM

Augmented Realty (AR) in Education: Assessment and Ranking

Tajuk / Title:

Framework based on Fuzzy Delphi and Hybrid of AHP Entropy and Vikor Methods

No. Matrik /Matric's No.:

Saya / I:

P20161001053

Ghailan Abbood Khudhair Shafeey

(Nama pelajar / Student's Name)

mengaku membenarkan Tesis/Disertasi/Laporan Kertas Projek (Kedoktoran/Sarjana)* ini disimpan di Universiti Pendidikan Sultan Idris (Perpustakaan Tuanku Bainun) dengan syarat-syarat kegunaan seperti berikut:-

acknowledged that Universiti Pendidikan Sultan Idris (Tuanku Bainun Library) reserves the right as follows:-

- 1. Tesis/Disertasi/Laporan Kertas Projek ini adalah hak milik UPSI. The thesis is the property of Universiti Pendidikan Sultan Idris
- 2. Perpustakaan Tuanku Bainun dibenarkan membuat salinan untuk tujuan rujukan dan penvelidikan. Tuanku Bainun Library has the right to make copies for the purpose of reference and research.
- 3. Perpustakaan dibenarkan membuat salinan Tesis/Disertasi ini sebagai bahan pertukaran antara Institusi Pengajian Tinggi. The Library has the right to make copies of the thesis for academic exchange.
- 4. Sila tandakan ($\sqrt{}$) bagi pilihan kategori di bawah / Please tick ($\sqrt{}$) for category below:-

SULIT/CONFIDENTIAL	Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub dalam Akta Rahsia Rasmi 1972. / Contains confidential information under the Official Secret Act 1972
	Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan ini dijalankan. / Contains restircted information as specified by the organization where research was done.
TIDAK TERHAD / OPEN ACCES	SS
Mailan	Land.
	- FROF, MADYA DR. MUHAMMAD MODI BIN LAKULU Timbelan Deten (Penyelidikan dan hoyasi) Petutif Seni, Komputeran dan industri Kreatil Universiti Pendidikan Suitan Kris 35500 Tenjong Malim, Perak
(Tandatangan Pelajar/ Signature)	(Tandatangan Penyelia / Signature of Supervisor) & (Nama & Cop Rasmi / Name & Official Stamp)
Tarikh:	

Catatan: Jika Tesis/Disertasi ini SULIT @ TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan ini perlu dikelaskan sebagai SULIT dan TERHAD.



) 05-4506832 og pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah

ACKNOWLEDGMENT

"In the name of Allah, the Most Gracious and the Most Merciful"

Praise be to God, first and foremost, Praise be to God, Lord of the worlds, and the Messenger Muhammad, may God bless him and grant him peace, who God sent to be a great teacher of humanity. I would like to express my appreciation and respect to the Malaysian government and the kind Malaysian people who hosted us in our second home Malaysia, I would like to express my thanks to those who participated and provided a useful hand to ensure the success of this research. This research would not have paid off without all the help and support. I am very grateful to my supervisors, Dr. Muhammed Modi Bin Lakolo and Dr. Bilal Bahaa Zaidan, for guiding me during myresearch work. I would like to express my sincere thanks and gratitude to them for their constant guidance, support and patience. I would like to express my sincere thanks. I am also very grateful to my family, especially my brother Abd Al-Kazim Al-Shafiee, my sisters, Wahida, Leila and my dear wife Anhar, who collapsed for their support in blessings, patience, love and encouragement. I also express my thanks and appreciation to my dear friend Karim, and to my dear friend Khaled, Abdallah alamode and Mohamed chyad. Finally, I would like to thank all the friends who helped and encouraged me. Thank you. God bless you.



🕓 05-4506832 😵 pustaka.upsi.edu.my f Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah 💟 PustakaTBainun 👘 ptbupsi



ABSTRACT

This research aims to assist the educational institutions, teachers and students for the selection of augmented reality (AR) educational applications. Educational institutions face the challenge of evaluating and selecting educational AR applications particularly. Therefore, the main problem is the appropriate selection of instructional augmented reality applications. Framework was proposed to aid the educational institutions in selection and ranking the available AR educational applications to select the best one. Improper selection decisions may cause educational institutions to lose time, effort, and financial costs. The evaluation and benchmarking of AR educational applications are challenging because of the multiple conflicting evaluation criteria. This study constructed a decision matrix (DM) based on the crossover of the 'three evaluation perspectives (usability, immersing and user perspective) with 'six AR educational applications'. The matrix was evaluated using the criteria developed from the evaluation of 15 experts. The alternatives were evaluated by 13 users. Then asked to answer a questionnaire consisting of 90 questions for each application The AR educational applications were then selected and ranked using multi-criteria. decision-making techniques, including the Analytic Hierarchy Process (AHP), ENTROPY and 'VlseKriterijumska Optimizacija I Kompromisno Resenje' (VIKOR). AHP was applied to calculate the weights of the main evaluation criteria, ENTROPY to calculate the weights for evaluation sub-criteria and VIKOR to select and rank the AR educational applications. The results showed that (1) the integration of AHP, ENTROPY and VIKOR effectively solved the AR educational applications benchmarking\selection problems. (2) The rankings of the AR educational applications obtained from internal and external VIKOR group decision making were almost the same.

(3) The best AR educational application was more immersive and more usable. In the objective validation, significant differences were recognized between the groups' scores, thereby indicating that the ranking results of internal and external VIKOR group decision making were valid.



pustaka.upsi.edu.my

vi

REALITI TERIMBUH (AR) DALAM PENDIDIKAN: PENILAIAN DAN RANGKA KERJA PENARAFAN BERDASARKAN KAEDAH FUZZY DELPHI DAN KAEDAH HIBRID AHP-ENTROPI DAN VIKOR

ABSTRAK

Penyelidikan ini bertujuan untuk membantu institusi pendidikan, guru dan pelajar untuk pemilihan aplikasi pendidikan augmented reality (AR). Institusi pendidikan menghadapi cabaran untuk menilai dan memilih aplikasi AR pendidikan terutamanya. Oleh itu, masalah utama adalah pemilihan aplikasi realiti tambahan yang sesuai. Kerangka ini diusulkan untuk membantu institusi pendidikan dalam memilih dan menentukan aplikasi pendidikan AR yang tersedia untuk memilih yang terbaik. Keputusan pemilihan yang tidak betul boleh menyebabkan institusi pendidikan kehilangan masa, usaha, dan kos kewangan. Penilaian dan penanda aras aplikasi pendidikan AR sangat mencabar kerana terdapat pelbagai kriteria penilaian standard. Kajian ini membina matriks keputusan (DM) berdasarkan Menyeberang dari 'tiga perspektif penilaian (kebolehgunaan, perspektif mendalam dan pengguna) dengan' enam aplikasi pendidikan AR '. Matriks dinilai menggunakan kriteria yang dikembangkan dari penilaian 15 pakar. alternatif dinilai oleh 13 pengguna. Kemudian diminta untuk menjawab soal selidik yang terdiri daripada 90 soalan untuk setiap aplikasi. Aplikasi pendidikan AR kemudian dipilih dan diberi peringkat menggunakan teknik membuat keputusan multi kriteria, termasuk Proses Analisis Hierarki (AHP), ENTROPY dan Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR).). AHP digunakan untuk mengira berat kriteria penilaian utama, ENTROPY untuk mengira berat untuk subkriteria penilaian dan VIKOR untuk memilih dan menilai aplikasi pendidikan AR. Hasil kajian menunjukkan bahawa (1) integrasi AHP, ENTROPY dan VIKOR berkesan menyelesaikan masalah penanda aras \ pemilihan aplikasi AR. (2) Peringkat aplikasi pendidikan AR yang diperoleh dari pengambilan keputusan kumpulan VIKOR dalaman dan luaran hampir sama. (3) aplikasi pendidikan AR terbaik lebih mendalam dan lebih berguna. Dalam pengesahan objektif, perbezaan yang signifikan diakui antara skor kumpulan, sehingga menunjukkan bahawa keputusan pemeringkatan keputusan keputusan kumpulan VIKOR dalaman dan luaran adalah sah.





vii

TABLE OF CONTENTS

		Page
	DECLARATION OF ORIGINAL WORK	ii
	DECLARATION OF THESIS	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xiv
	LIST OF FIGURES	xvi
	LIST OF ABBREVIATIONS	xviii
) 0	5 LIST OF APPENDICES.my f Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah	Xxptbupsi
	CHAPTER 1 INTRODUCTION	
	1.1 Introduction	1
	1.2 Background of the Study	2
	1.3 Research Problem	5
	1.4 Research Questions	8
	1.5 Research Objectives	9
	1.6 Relationship Between Research Objectives, Research Questions and Research Problem	9
	1.7 Scope of the Study	10
	1.8 Motivation	12
	1.9 Significance of the Study	15
	1.9.1 Practical Significance of the Study	15

			1.9.2 Theoretical Importance the Study	15
	1.10	Main	Ferms	16
	1.11	Organ	ization of Research	17
CHAPTER 2	2 LITE	RATUR	RE REVIEW	
	2.1	Introdu	uction	20
	2.2	Educa	tional AR Applications	23
	2.3	System	natic Review Protocol	24
		2.3.1	Information Sources	24
		2.3.2	Selection of Study	25
		2.3.3	Search	25
		2.3.4	Eligibility Criteria	26
		2.3.5	Data Collection Process	28
4506832		2.3.6	Statistical Information and Articles Search Results Kampus Sultan Abdul Jalil Shah	28 ptbur
	2.4		omy of Literature Review on the Use of Augmented y Technology in Education	29
		2.4.1	AR in Education	32
		2.4.2	Development	33
		2.4.3	Resources	35
		2.4.4	Review and Survey	37
		2.4.5	Evaluation	39
		2.4.6	Others	42
		2.4.7	Methodological Aspects of Previous Research	44
	2.5	Discus	ssions	50
		2.5.1	Motivation	50

pustaka.up			ptbupsi
	2.5.2	Challenges	ix 60
	2.5.3	Recommendations	69
2.6	Usabil	ity Perspective	81
	2.6.1	Effectiveness	84
	2.6.2	Efficiency	84
	2.6.3	Learnability	85
	2.6.4	Errors Covering	85
	2.6.5	Usability Criteria	85
2.7	Immer	sion Perspective	87
	2.7.1	Types of Immersion	90
	2.7.2	Sensory and Psychological Conditions Associated with Immersion	91
	2.7.3	Immersion Levels	93
pustaka.up	2.7.4	Affecting Immersion Factors	95 ^{ptbupsi}
	2.7.5	Important Aspects Can Constitute and Promote an Immersive Experience	98
	2.7.6	Benefits and Advantages of Using Immersive Technology	101
	2.7.7	Types of Immersive Technology Environments	103
	2.7.8	The Relationship between the Immersions with Usability and User Perspective	104
	2.7.9	The Relationship between Immersion and Education	105
	2.7.10	Outcome of Using the Immersive Technology in Education	106
	2.7.11	The Theoretical Frameworks used in Immersive Technology	107

05-4506832	pustaka.up			
		2.7.12	Immersion Criteria in Literature	x 109
		2.7.13	Immersion Challenges	116
	2.8	User P	erspective	117
		2.8.1	Application User Review	120
		2.8.2	Types Application User Review	122
		2.8.3	User Perspective Criteria	127
	2.9	AR Ap	oplications (Alternative)	128
		2.9.1	Complete Anatomy Platform 2020	129
		2.9.2	Anatomy Insight Heart	131
		2.9.3	Anatomy AR	134
		2.9.4	Anatomy Luke AR	136
		2.9.5	Anatomy Brain AR App	138
05-4506832	pustaka.up	2.9.6	Human Anatomy 4D Bainun Kampus Sultan Abdul Jalil Shah	139 ptbups
	2.10	Critica	l Review and Analysis (Literature Survey)	141
	2.11	Fuzzy	Delphi Method (FDM)	143
	2.12	Multi- Import	Criteria Decision Making (MCDM): Definition and ance	144
	2.13	MCDN	/I Methods	146
		2.13.1	Analytic Hierarchy Process (AHP)	155
		2.13.2	ENTROPY Method	156
		2.13.3	VIKOR Method	156
	2.14	Chapte	er Summary	158
СНАР	FER 3 RESE	ARCH	METHODOLOGY	

3.1 Introduction 160

05-4506832	pustaka.up			o ptbups
	3.2	Investi	gation Phase	xi 163
	3.3		y Criteria for AR Application Phase Fuzzy Delphi d (FDM)	163
		3.3.1	Identify the Multi-Criteria Based on Literature Review	165
		3.3.2	Expert Selection	166
		3.3.3	Expert Questionnaire	166
		3.3.4	Data Collection	166
		3.3.5	Likert Scale Conversion to Fuzzy Scale	167
		3.3.6	Data Analysis	167
		3.3.7	Data Analysis and Interpretation of the Fuzzy Delphi Method	168
	3.4	Diction	n Matrices Construction Phase	168
05-4506832	pustaka.up	3.4.1 si.edu.my	Construct Decision Matrices Based On the Cross Over between the Evaluation Criteria and Education AR Applications	169 onal ptbups
		3.4.2	Criteria Set	170
		3.4.3	Alternative Set (AR Applications)	171
		3.4.4	Evaluation Instruments	172
		Evalua Perspe	te the AR Applications Based on the Three ctives	172
		3.5.1	User Selection for Assessment Educational AR Applications	173
	3.6	Develo	opment Phase	173
		3.6.1	Determine the Weight of the Evaluation Main Criteria Based On the AHP and the Sub-Criteria Based On the Entropy Method, and Then Rank the Educational AR Application Based On VIKOR	173
		3.6.2	Multi-Layer Analytic Hierarchy Process	176

	pustaka.up			O ptbups
		3.6.3	Entropy Process	xii 183
		3.6.4	Adaptive VIKOR Method for Ranking AR Applications	184
	3.7	Valida	tion Phase	188
	3.8	Chapte	er Summary	189
СНАР	TER 4 RESU	LTS A	ND DISCUSSION	
	4.1	Introd	uction	190
	4.2	Presen	tation of Data and Result (Fuzzy Delphi)	193
		4.2.1	Identify Evaluation Criteria from the Literature Review	193
		4.2.2	Selection of Experts	194
		4.2.3	Experts Questionnaire	195
		4.2.4	Expert's Questionnaire Data Collection	196
	pustaka.up	4.2.5	Likert Scale Conversion to Fuzzy Scale	197 ptbups
		4.2.6	Data Analysis (Triangular Fuzzy Number Threshold Value D)	198
		4.2.7	Data Analysis (Triangular Fuzzy Number) (Defuzzification Process) Fuzzy Score Value (A)	198
		4.2.8	Data Analysis and Interpretation	198
		4.2.9	Final Set Criteria Framework	200
	4.3	Experi	ment: Framework Test Results	201
		4.3.1	User Assessment on AR Applications	201
		4.3.2	User's Questionnaire	202
		4.3.3	Applications Assessment	203

4.3.4 Analysis the Apps Evaluation Results 211



C

xiii

and Alternatives

	4.4	Weigh	t Measurement using AHP Main Criteria	212		
	4.5	0	Weight Measurement using Entropy Method for Sub-Criteria			
	4.6	VIKO	R Results of Decision Making	219		
		4.6.1	VIKOR Results of Individual Context for Difference Experts' Weight	ent 220		
		4.6.2	Group VIKOR with Internal and External Aggregation	223		
	4.7	Valida	tion Processes	225		
	4.8	Chapte	er Summary	228		
CHAP	FER 5 CONC	CLUSI	ON AND FUTURE WORK			
	5.1	Introd	action	231		
	5.2	How C	Our Objectives Are Achieved?	232		
	pustaka.ur 5.3	Resear	ch Contributions ¹ Abdul Jalil Shah	233		
	5.4	Resear	ch Limitation and Issues	235		
	5.5	Future	Work	236		
	5.6	Conclu	ision	236		

REFERENCES

LIST OF PUBLICATIONS

APPENDICES

239

259



xiv

LIST OF TABLES

	No. of	Tables	Page
	1.1	Link among Research Questions, Objectives and Problem	10
	2. 1.	The Main Points of Motivations	51
	2. 2.	The Main Points of Challenges	61
	2.3.	The Main Recommendations	69
	2.4.	Immersion Factors Affecting	110
	2.5.	Immersion Factors (Criteria) and Questions	111
	2. 6.	Criteria and Questionnaire Items for Measuring the Immersion	112
	2.7.	Lit Literature Survey In The Assessment The AR Application Quality.	143
	2. 8.	Multi-Criteria Problem Example	146
05-	2.9.32	Common MCDM Techniques5 pustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah	148 ₀₀₀
	2. 10.	Advantages And Disadvantages Of MCDM Methods	151
	3. 1.	Three Perspective Criteria	171
	3. 2.	The Alternative (AR Applications)	171
	3. 3.	The Nine Scales Of Pairwise Comparisons	178
	4. 1.	Expert's Background	194
	4. 2.	Data Collection	196
	4.3.	Five-Point Linguistic Variable Scale	197
	4.4.	Questionnaire Data Analysis	199
	4. 5.	User Information	202
	4. 6.	Completely Anatomy App Results	204
	4.7.	Anatomy Insight Heart App Results	205



O 5-4506832 gustaka.upsi.edu.my

Х	V

4. 8.	Anatomy Insight Heart App Results	206
4. 9.	Anatomy AR+ For Merge Cube App Results	208
4. 10.	Anatomy Luke AR App Results	209
4.11.	Human Anatomy 4D-Mixed Reality App Results	210
4. 12.	Final DM Result	212
4. 13.	Measuring AHP Weight Preference For Main Criteria (One Expert)	213
4. 14.	AHP Weights For Main Criteria (Five Experts)	214
4. 15.	The First Table Of Entropy Method (Convert Likert Scale To Numbers)	216
4. 16.	Normalisation And The Sum Values	217
4. 17.	Entropy Information (Ej)	218
4. 18.	Global Weight (Wj)	219
4. 19.	Ranking Results Based On The First Experts' Weights PustakaTBainun	220
4. 20.	VIKOR Results With Internal And External Group Decision Making	224
4. 21.	Validation Results Of Internal Group Decision Making Rank	226







xvi

LIST OF FIGURES

	No. o	of Figures	Page
	1.1.	Problem Statement Configuration	8
	1.2.	Research Scope	11
	1.3.	The Structure Of Study	19
	2.1.	Framework Of Literature Review	22
	2.2.	Selection Of Study, Search Query And Inclusion Criteria	27
	2.3.	Taxonomy Of Literature Review Augmented Realty In Education.	31
	2.4.	Number Of Included Articles In Different Categories	44
	2.5.	Distribution By Authors' Nationality	45
	2.6.	Distribution Of Studies According To The Sample Size Used	46
) 0	2.7.	Distribution Of Studies According To Analysis	47 _{ptbup}
	2.8.	Distribution Of Studies According To Methodology Test	48
	2.9.	Distribution Of Studies According To Subject	49
	2.10.	Number Of Included Articles By Year Of Publication	50
	2.11.	Usability Criteria	86
	2.12.	Immersion Types	90
	2.13.	Immersion Sensory And Psychological Conditions	91
	2.14.	Immersion Levels	94
	2.15.	Affecting Immersion Factors	96
	2.16.	Immersive Experience Aspects	99
	2.17.	The Immersive Technology Environments	103
	2.18.	Immersion Criteria	115



O 5-4506832 pustaka.upsi.edu.my

2.19.	Beneficiaries Of User Review	120
2.20.	Screenshots Of User Reviews For Complete Anatomy	122
2.21.	User Perspective Criteria	127
2.22.	Commonly Used MCDM Methods	147
2.23.	The Proposed Solution To Selection And Ranking Educational AR APP	154
3.1.	Research Methodology Phases	162
3.2.	Fuzzy Delphi Analysis Steps	164
3.3.	Flowchart Of Fuzzy Delphi Method Approach	165
3.4.	Structure Of Decision Matrix	170
3.5.	Methodology For Choosing And Ranking AR Application	175
3.6.	Main And Sub-Criteria Used	176
3.7.	Sample Evaluation Form f Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah	179 _{toupsi}
3.8.	The Design Of MLAHP Measurement Steps For The Weight Preferences	181
3.9.	Internal And External Aggregation	187
4.1.	Overview Of The Results For App Assessment	192
4.2.	Evaluation Criteria From Previous Study	193
4.3.	Final Set Criteria Framework	201
4.4.	Shows The Overall Final Ranking Of VIKOR For Five Experts	222
5.1.	Research Contributions	235





xviii

LIST OF ABBREVIATIONS

- 2D Two dimensions
- 3D Three dimensions
- AHP Analytic Hierarchy Process
- AR Augmented reality
- ARAs **AR** applications
- ARCS Augmented realty creative classroom
- **ARLEs** Augmented realty learning experiences
- ASD autism spectrum
- ASP.NET **Active Server Pages**
- 05-4506832CAIV pusta classroom learning is an interactive video

- **CLSAR** concepts learning scientific Augmented reality
- CMS concept map strategy
- cognitive theory of multimedia learning CTML
- DM **Diction matrices**
- GIM's Gradual Immersion Method
- GIQ Game Immersion Questionnaire
- HMD head-mounted display
- MAR mobile Augmented reality
- MCDM multi-criteria decision-making
- **MDAS** mobile digital armillary system
- **MPNS** mobile phone navigation system



xix

- MR Mixed reality
- OBL observation learning environment
- SDK Software Development Kit
- **STEM** science, technology, engineering and mathematics
- ToM Target Operating Model
- **TPCs** Tablets Personal computer
- UX user experience
- VE Virtual Environment
- VM video model
- VR Virtual reality

05-4506832 🚱 pustaka.upsi.edu.my 🚹 Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah







LIST OF APPENDICES

- Expert form of Augmented Reality Evaluation А
- В User form of augmented reality evaluation
- С Pairwise comparisons
- Weights Measurement Using entropy method for sub-criteria D
- Ε VIKOR RESULT
- F Experts answers





05-4506832 🚱 pustaka.upsi.edu.my 🖪 Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah 💟 PustakaTBainun 👘 ptbupsi











INTRODUCTION



Augmented reality in education is surging in popularity in schools worldwide. Through augmented reality (AR), educators are able to improve learning outcomes through increased engagement and interactivity. And that's just for starters. AR even has some surprising advantages over virtual reality (VR). Here are a few ways AR benefits education... and then a few examples of how it has already worked. Augmented Reality (AR) in education features aspects that enhance learning of abilities like problem-solving, collaboration, and creation to better prepare students for the future. It is also good for traditional pedagogy focused on technical knowledge and proficiencies. While AR is still somewhat in its infancy, especially in comparison to virtual reality (VR), it does offer more







cost-friendly options to school districts with tighter budgets – while still providing many of the same features and benefits.

This chapter presents a brief background on the research, the statement of the research problem, the motivation of this research, and the research objectives. Section 1.2 presents a brief background of the research components. Section. 1.3 provides the research problem while in Sections 1.4 and 1.5, the research questions and research objectives are elaborated, respectively. Section 1.6 elaborates on the relationship between research objectives, research questions and research problem. The scope of the research is presented in Section 1.7. The motivation of the research and the significance of the study are outlined in Sections 1.8 and 1.9, respectively. Finally, the outline of the main structure of the thesis is reported briefly in Section 1.10, while Section 1.11 provides the organization of the research.

1.2 **Background of the Study**

Augmented Reality (AR) can be defined as the upgraded version of reality that extends into virtual reality (VR). The main difference between AR and VR is that in AR, one feels as though one is still in the real world, while VR separates an individual directly from the real world. In AR, one is kept in the real and virtual world at the same time through the use of a smooth interface and tools and applications designed for this purpose, such as a headset, interactive glasses, tablets and 3D objects. The SR has three main aspects, namely,





(1) the integration of real and virtual objects, (2) the interaction of these things at the same time and (3) the participation of real and virtual things for the same task (Giasiranis & Sofos, 2017; Zhang, Sung, Hou, & Chang, 2014). Previous studies have provided many different definitions, but the consensus is that AR technology combines VR with reality same time (Azuma, 1997; Cai, Chiang, Sun, Lin, & Lee, 2017; Cai, Wang, & Chiang, 2014; Giasiranis & Sofos, 2017; M. B. Ibáñez, Di Serio, Villarán, & Kloos, 2014) Some studies have defined AR as computer-generated images that users see in the real world and provide a composite vision for objects (Dalim, Kolivand, Kadhim, Sunar, & Billinghurst, 2017; Tarng, Lin, Lin, & Ou, 2016). Some definitions have focused on devices that allowed virtual objects to be visualized in a real environment (T.-C. Huang, Chen, & Chou, 2016)(AlShifay, Udofia, Zuhair, & Hassan). Another definition of AR is that it is a direct or indirect presentation of a real environment complemented by virtual elements created by a computer (Gan et al., 2018). Since its advent, AR technology has been used in various fields, including medical, military, industry, tourism, entertainment, advertising, psychology, marketing, engineering and arts. AR technology has also had an effective influence, especially in education. The use of AR technology for education has gained considerable interest because it has stimulated students to be more engaged in learning, enabling them to participate more actively, have a higher concentration and better understanding of the subjects being taught (Giasiranis & Sofos, 2017). Educational researchers have recognized the great potential and significant influence of AR technology on cognitive and emotional learning outcomes (M. B. Ibáñez et al., 2014). Researchers have recognized that AR technology aids students in connecting what they observe in the real world with their previous knowledge and deal with the goals and tasks of the real world



(S.-C. Chang & Hwang, 2018; Hwang, Wu, Chen, & Tu, 2016) because it provides effective learning environments and new opportunities to enhance the learning process (T.-C. Huang et al., 2016). It also combines the digital environment with the real sensory life, allowing the coexistence of the real and virtual, which in turn leads to better interactions for users not only to provide knowledge but also guidance on how to process acquired information (T. H.-C. Chiang, S. J. Yang, & G.-J. Hwang, 2014; Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017; Toledo-Morales & Sanchez-Garcia, 2018). AR technology is also an easy and natural way of teaching because it creates large areas of exploration (Giasiranis & Sofos, 2017). It is also a mature area of psychophysical studies (Azuma, 1997). One of the advantages of introducing AR technology in educational reliability is that it increases students' experiences in real-world environments and their awareness of the environmental context by interfacing digital environments with real environments (Wu, Hwang, Yang, & Chen, 2018). It also enhances reality with additional virtual information (S. K. Kim, Kang, Choi, Choi, & Hong, 2017) and increases the sensory perception of users (M.-B. Ibáñez & Delgado-Kloos, 2018). The learning experience provided by AR technology makes it a good interface for the next generation because it can provide different ways of handling information by designing better learning experiences (Santos et al., 2014). It can also achieve great progress in fostering an educational environment through electronic activities and scientific training activities (C.p. Chen & Wang, 2015). The results also indicated the significant benefits of using AR technology in education, especially in primary and secondary schools (pre-university education). Previous research has shown that this technology can improve students' education (Radu, 2014). However, this technology has major determinants that must be





🕟 05-4506832 🛞 pustaka.upsi.edu.my 🚹 Perpustakaan Tuanku Bainun 💟 PustakaTBainun 👘 ptbupsi

5

considered to be acceptable in the learning field, which gives rise to the necessity of finding appropriate methods for educational institutions to achieve the maximum benefit possible while providing low-cost devices and applications based on AR technology (M.-

B. Ibáñez & Delgado-Kloos, 2018). One of the ways to enhance the educational process is by improving the quality of the educational system based on AR technologies, such as usability for applications, immersion and enjoyment for the learner (Pribeanu, Balog, & Iordache, 2017). Hence, identifying the most efficient methods to help educational institutions make the right decision and choose the best AR applications for a given circumstance. Therefore, it is necessary to conduct an assessment and measurement to identify and build a multi-category model that will help these institutions to make the most of this technology in education.

🕑 05-4506832 🥳 pustaka.upsi.edu.my 🖪 Perpustakaan Tuanku Bainun 💟 PustakaTBainun 👘 ptbupsi

1.3 **Research Problem**

Main Challenge

The development of AR technology in the past few years have resulted in the creation of millions of applications that offer assistance in the various aspects of practical and scientific life, including the educational aspect. Augmented reality technology has been used in educational institutions to some extent but studies that focus on the use of AR technology in education have obtained varying results.



) 05-4506832 🛞 pustaka.upsi.edu.my 🚹 Perpustakaan Tuanku Bainun 💟 PustakaTBainun 👘 ptbupsi



6

The AR technology has not been used correctly and widely in the education sector in proportion to its tremendous potential because of the challenges faced by educational institutions, which includes the inability to select the appropriate applications and the lack of experience in its use, the high cost of devices and applications. (T. H.-C. Chiang et al., 2014; Hwang et al., 2016), the lack of the use of appropriate educational applications in education (Joo-Nagata, Abad, Giner, & García-Peñalvo, 2017; Radu, 2014; Saidin, Halim, & Yahaya, 2015; Santos et al., 2014), the difficulty in linking observations of this technology to real-time content (J. L. Chiu, DeJaegher, & Chao, 2015), and the lack of appropriate instructions in the use of AR technology (Cai et al., 2017; Y.-M. Huang & Lin, 2017; Lee, Chen, Wang, & Chung, 2018). Despite the diversity of the existing methods for evaluating assessment, the evaluation criteria still need to be defined and a better method for evaluating AR technology is necessary to identify the best AR application among alternatives (T.-C. Huang et al., 2016).

Based on the above challenges that were found in previous studies, that there is a gap in the use of AR technology in educational institutions, and that the main problem is appropriate selection for educational AR applications. In order to bridge the gap between augmented reality technology and educational institutions and solve the problem, the appropriate choice of educational augmented reality applications, criteria for selecting educational augmented reality applications must be identify from previous studies, based on the identified criteria, It is possible to build a framework from which it can be educational institutions can selection the appropriate application from educational augmented reality applications..







Usability, immersion and user perspective are the primary quality standards that influence user acceptance of the AR because these standards determine the efficiency of application design (Lee et al., 2018).

Although the AR apps is available, choosing one is a difficult process. Consequently, the institution encountered difficulties in evaluating and comparing the AR applications to determine the best and an incorrect decision on the selection of the AR application may cause the institution loss in terms of effort, time and financial costs (R.-C. Chang, Chung, & Huang, 2016) and also affect professional development (Zhang et al., 2014), resulting in lesser motivation among students to learn (R.-C. Chang et al., 2016). To help the decision-maker, choose the best AR alternative, a multi-perspective evaluation to evaluate the AR application should be recognized. Thus, the problem of the evaluation process of AR is a complex multi-criteria problem. The main problem is identified from three phases. The first phase involves the process of evaluating multiple criteria. The second phase is the identification of the importance of each standard. The third phase pertains to the variability of data among the available alternatives identified by multiple criteria. According to the identified phases, AR evaluation requires assessing multiple criteria and identifying which ones have the most influence on the decision to choose AR applications (alternatives). The process of choosing alternatives can be considered problems with MCDM. An integrated approach to multi-perspective AR evaluation is needed. However, the method for choosing the best AR alternative has not been explored in previous studies, Hence, this thesis explores the issues of standardisation of criteria and importance of criteria.



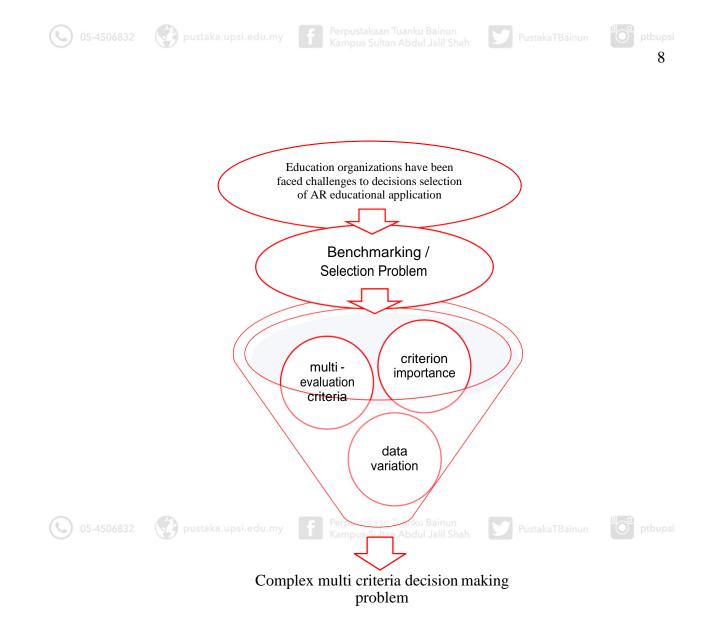


Figure 1.1. Problem Statement Configuration

Research Questions 1.4

The following research questions were drawn up to set the direction of this research:

- What is the current literature on the evaluation of educational AR applications? 1-
- 2- What are the suitable evaluation criteria for measuring the components (usability, immersion and user perspective) of AR educational applications?



- - 9
- 3- How is the evaluation decision matrix constructed based on the determined evaluation criteria?
- 4 What is the ranking framework based on construction decision matrix?
- 5- Is the proposed selection and ranking framework valid?

1.5 **Research Objectives.**

- 1- To investigate previous studies related to evaluation educational AR applications.
- 2- To identify the evaluation criteria for AR applications based on three components (usability, immersion and user perspective).
- 3- To construct an evaluation decision matrix based on identified evaluation criteria.
 - 4- To develop a ranking framework based on construction decision matrix.
 - 5- To validate the proposed selection and ranking framework.

1.6 **Relationship between Research Objectives, Research Questions and Research** Problem.

Research questions are outlined to provide the direction and focus of the research while the research objectives provide answers to the research questions. Table 1.1 presents the research questions and research objectives and determines what part of the research problem will be addressed when each research objective is achieved.







Table 1.1

Link among Research Questions, Objectives and Problem

Research Questions	Research Objectives	Research problem mappi Specific Gener Problem proble	ral
Q1) What is the current literature on the evaluation of educational AR applications?	1- To investigate previous studies related to evaluat educational AR applicati		
Q2) What are the suitable evaluation criteria for measuring the components (usability, immersion and user perspective) of AR educational applications?	 To identify the evaluatio criteria for AR applicatio based on three componen (usability, immersion and user perspective). 	uts nuts attion)	
Q3) How is the evaluation decision matrix constructed based on the determined evaluation criteria?	3- To construct an evaluation Kan decision matrix based on identified evaluation crit	Pustaka Evaluation ptbupsi	
Q4) What is the ranking framework based on construction decision matrix?Q5) Is the proposed selection	4 To develop a ranking framework based on construction decision ma	trix.	
and ranking framework valid?	5- To validate the propose selection and ranking framework.	ed	

Scope of the study 1.7

The scope of this research is defined by the following considerations:



1. This research focuses on the selection and benchmarking of the methodologies of educational AR applications based on multi-criteria decision making in the selection of educational AR applications.

2. A framework is developed according to multiple criteria analysis to select the most immersive educational AR application. Figure 1.2. Provides a general view of the research and presents the research method, type and field.

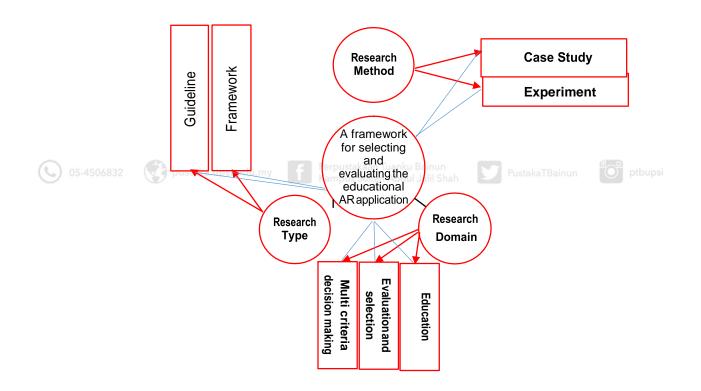


Figure 1.2. Research Scope

This study is multi-disciplinary research that involves the benchmarking of methodologies for the selection of the educational AR applications for primary, intermediate and high school (pre-university) levels to evaluate and choose the correct educational AR applications that would ensure that complete information can reach





students, reduce time and effort on the part of the teachers and enable educational institutions to keep pace with modern technology and reduce costs. This study is designed to address the evaluation/selection problem for educational AR applications.

In this study, educational AR applications (biology and human anatomy) are used in the user experience to generate the required data that will be used to demonstrate the concept of the proposed methodology. The test samples were from teachers and students.

Search results indicate the types of research outputs of this study. The first output is a methodology implemented through several steps to improve the process of assessing and selecting educational AR applications.

🕓 05-4506832 🔇 pustaka.upsi.edu.my 🕇 Perpustakaan Tuanku Bainun 💟 PustakaTBainun 👘 ptbupsi

The integrated MCDM method used for testing (evaluation and selection) was based on several criteria to improve the evaluation and selection decision for educational AR applications. Based on the above, this research belongs to the field of information technology and management.

1.8 Motivation

AR's relative seamlessness of digital objects within the "real world" encourages interactivity and engagement. It maximizes students' ability to spend their time learning curricular subjects while minimizing the time spent learning how to use the new tech. In





addition, as discussed in Stanford News on VR's applications within the classroom and "the effect of the body's actions on the mind," AR can also inspire empathy in an individual. It offers two-dimensional methods of presenting information versus the traditional one-dimension. This combination of interactivity and engagement with emotion, in turn, could enhance the ability of students to remember what they've learned- and lead to faster acquisition of information and skills. Therefore, AR provides students with opportunities to deepen their knowledge within several areas, including (Reading, Working with numbers, spatial concepts, and Content creation), this can include everything from field trips to exposure to training within different professions. When combined with assignments involving teamwork, AR similarly helps provide new opportunities for students to learn how to communicate and collaborate with one another.

Most studies have confirmed the effectiveness and effect of AR technology in the educational process and many benefits of using this technology in education have been observed especially in primary and secondary schools (pre-university) (Radu, 2014). The quality of the education system based on AR is an important factor for the success of the educational process. A successful system has the advantages of ease of use, enjoyment, immersion and scientific benefit (Pribeanu et al., 2017). When the application has these advantages, students become more enthusiastic and focused. One of the most difficult and important issues in the educational process is providing an appropriate strategy and ensuring effective teaching to encourage students to focus on what they need to know and observe (Hwang et al., 2016). Many applications of enhanced reality are available in the field of education and various disciplines, such as physics, chemistry, biology,

🕓 05-4506832 🔇 pustaka.upsi.edu.my 🕇 Perpustakaan Tuanku Bainun 💟 PustakaTBainun 👘 ptbupsi





mathematics, history, geography, languages, arts etc., making it difficult for teachers to choose because most teachers do not have experience in the use of AR technology and in choosing the appropriate application of the appropriate subject (Hung, Chen, & Huang, 2017; Wei, Weng, Liu, & Wang, 2015). Many teachers also face the fear of failure to use technology (Havlíčková et al., 2018) because of the absence of training or experience in its use (Toledo-Morales & Sanchez-Garcia, 2018). Some teachers also fear being too reliant on AR technology due to a lack of awareness (Tekedere & Göke, 2016; K. Tian, Endo, Urata, Mouri, & Yasuda, 2014). No guidelines are available for teachers to choose and use applications (Santos et al., 2014), making it difficult for them to choose the right educational AR application. As a result of these reasons, we note the limited use of AR technology in education. Hence, the main motivation of this study is to enable teachers to make the right decision in choosing the right application for the right topic. The choice of appropriate application in education will make the most of this technology in transferring information to students well, increasing the cognitive reasoning of students and their effective participation and shortening the time and effort for the teachers, thus making the technology acceptable and suitable as a useful teaching tool (Giasiranis & Sofos, 2017; Y.-M. Huang & Lin, 2017; Pribeanu et al., 2017). This study will be very useful for primary and secondary schools because it can serve as a guide in selecting the appropriate application in the teaching process. This study can motivate researchers to propose a mechanism for selecting educational AR applications that support teaching staff and educational institutions. Currently, no studies on the mechanism of selection of augmented reality applications and their associated assessment and measurement using MCDM can be found in the literature.





1.9 Significance of the study

1.9.1 Practical significance of the study

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah

In practical terms, through the proposed measurement methodology to select and ranking educational AR applications and technologies, educational institutions will be able to choose the appropriate applications for the appropriate subject matter and contribute to the success of the educational process, thereby increasing academic achievement and interest of students as well as enhancing their collective participation, enthusiasm, concentration and activity (Cai et al., 2017; Giasiranis & Sofos, 2017; Pribeanu et al., 2017). Through the proposed comparison methodology, the decisions of educational institutions on the selection and ranking of appropriate applications will be more accurate and based on a scientific method that will be developed and tested according to the proper scientific basis.

1.9.2 Theoretical importance the study

This study contributes to the literature by adopting the methodology for reviewing the methodological literature, providing an overview of the current information and evidence regarding the use of AR technology in education and the selection and ranking approach, and highlighting the trends in research on this topic. This study also contributes to the bridging of the lack of studies in this field and classifying the relevant literature. The classification can impose a type of organization on the collection of publications by







classifying different works into a purposeful, easy to manage and coherent design that will enable researchers to gain important insights on the subject area, identify potential trends in research in this field and reveal gaps in the literature and map studies related to the appropriate choice of AR educational applications in education. This study also provides a guide to the most important criteria that should be adopted in evaluating AR applications in the educational process.

1.10 Main terms

Main terms of the study:

Augmented reality refers to programs that combine virtual reality with reality at the same time through modern applications called augmented reality applications. These applications help to make virtual things closer to the truth, which could facilitate education and ensure that the full information reaches the recipient. In this study, it refers to those used in the medical field, specifically biology (Anatomy of the human body), and for an age group starting from four years old and above. These applications include Complete Anatomy Platform, Anatomy insight heart, Anatomy AR + for Merge Cube, Anatomy Luke AR, Anatomy the Brain AR App, Human Anatomy 4D- Mixed Reality.

Comparison process refers to the process of evaluating each application separately with a group of users through a specific set of criteria.







Multi-criteria decision-making is an umbrella term that describes a set of formal approaches that seeks to consider multiple criteria in helping individuals or groups to explore appropriate and correct decisions.

1.11 Organization of research

This study is composed of five chapters. Figure 1.3 illustrates the structure of the study. The background of research, research problem, research questions, research objective, the relationship between research questions and research objective, research scope, research motivation and significance of the study are outlined in Chapter One. The remainder of the study is organised as follows. Chapter Two provides the theoretical background (Literature review), Chapter Three contains the methodology research, Chapter Four provides the details of the results and Chapter Five lists the conclusion and suggestions for future work.

Chapter Two: Literature Review. In this chapter, previous studies that focused on the evaluation of AR technology in the educational process, particularly in the primary, intermediate and secondary schools (pre-university) are discussed. This chapter identifies and describes in detail the main criteria for assessment and measurement. The current assessment and measurement methods are also discussed with related problems and issues. This chapter also includes the theoretical background of the multi-criteria decision-making (MCDM) process, presents the common MCDM methods, and explains the main MCDM methods, which include Analytic Hierarchy Process (AHP), and ENTROPY and the





VIKOR methods. It also explains useful techniques that enable decision making on multistandard problems. The main purpose of this chapter is to identify the research gap and challenges and provide recommendations on possible solutions.

Chapter Three: Research Methodology. This chapter describes the requirements for developing the proposed framework for assessing and selecting the best educational AR applications and the following stages. The methodology is designed in five main phases, namely, the investigation, identification, decision matrices (DM), development and verification phases. This chapter will detail how the five research objectives will be achieved through these phases.

Chapter Four: Results and Discussion. This chapter presents the results and discussion of the selection and ranking methodology for educational AR applications framework. The chapter demonstrates how the results of the proposed methodology resolve the problems mentioned in the problem statements. It also presents the results of the validation process.

Chapter Five: Conclusion and Contributions. This chapter concludes and summarizes the research contributions made. The research limitations, future research proposals and conclusions are also reported.



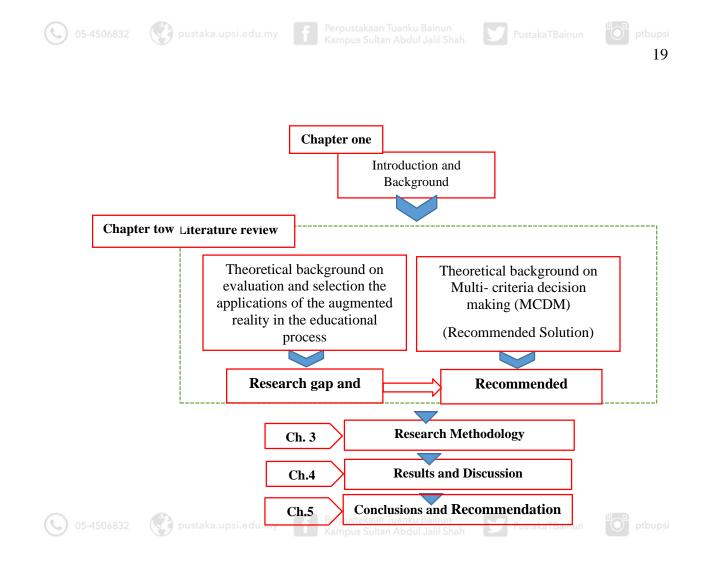


Figure 1.3. The Structure of Study

