USABILITY FRAMEWORK FOR MOBILE AUGMENTED REALITY LANGUAGE LEARNING

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ABSTRACT

After several decades since its introduction, the existing ISO9241-11 usability framework is still vastly used in Mobile Augmented Reality (MAR) language learning. The existing framework is generic and can be applied to diverse emerging technologies such as electronic and mobile learning. However, technologies like MAR have interaction properties that are significantly unique and require different usability processes. Hence, implementing the existing framework on MAR can lead to non-optimized, inefficient, and ineffective outcomes. Furthermore, state-of-the-art analysis models such as machine learning are not apparent in MAR usability studies, despite evidence of positive outcomes in other learning technologies. In recent MAR learning studies, machine learning benefits such as problem identification and prioritization were non-existent. These setbacks could slow down the advancement of MAR language learning, which mainly aims to improve language proficiency among MAR users, especially in English communication. Therefore, this research proposed the Usability Framework for MAR (UFMAR) that addressed the currently identified research problems and gaps in language learning. UFMAR introduced an improved data collection method called Individual Interaction Clustering-based Usability Measuring Instrument (IICUMI), followed by a machine learning-driven analysis model called Clustering-based Usability Prioritization Analysis (CUPA) and a prioritization quantifier called Usability Clustering Prioritization Model (UCPM). UFMAR showed empirical evidence of significantly improving usability in MAR, capitalizing on its unique interaction properties. UFMAR enhanced the existing framework with new abilities to systematically identify and prioritize MAR usability issues. Through the experimental results of UFMAR, it was found that the IICUMI method was 50% more effective, while CUPA and UCPM were 57% more effective than the existing framework. The outcome through UFMAR also produced 86% accuracy in analysis results and was 79% more efficient in framework implementation. UFMAR was validated through three cycles of the experimental processes, with triangulation through expert reviews, to be proven as a fitting framework for MAR language learning.

ABSTRAK

Selepas beberapa dekad diperkenalkan, rangka kerja kebolehgunaan ISO9241-11 sedia ada masih digunakan secara meluas dalam pembelajaran bahasa melalui teknologi Realiti Tambahan Mudah Alih (MAR). Rangka kerja sedia ada adalah generik dan boleh digunakan untuk pelbagai teknologi baharu seperti pembelajaran elektronik dan mudah alih. Walau bagaimanapun, teknologi seperti MAR mempunyai interaksi yang unik dan memerlukan proses kebolehgunaan yang berbeza. Oleh itu, penggunaan rangka kerja sedia ada pada MAR boleh membawa kepada hasil yang tidak dioptimumkan, tidak cekap, dan tidak berkesan. Tambahan pula, model analisis terkini seperti pembelajaran mesin tiada dalam kajian kebolehgunaan MAR, walaupun terdapat bukti hasil positif dalam teknologi pembelajaran lain. Dalam kajian pembelajaran MAR, faedah pembelajaran mesin seperti pengenalpastian masalah dan keutamaan tidak wujud. Kemunduran ini boleh melambatkan kemajuan pembelajaran bahasa melalui MAR, yang bertujuan untuk meningkatkan penguasaan bahasa dalam kalangan pengguna MAR, terutamanya dalam komunikasi bahasa Inggeris. Oleh itu, penyelidikan ini mencadangkan Rangka Kerja Kebolehgunaan untuk MAR (UFMAR) untuk menangani masalah penyelidikan dan jurang yang dikenal pasti pada masa ini dalam pembelajaran bahasa. UFMAR memperkenalkan kaedah pengumpulan data yang lebih baik dipanggil Instrumen Pengukuran Kebolehgunaan Berasaskan Pengelompokan Interaksi Individu (IICUMI), diikuti dengan model analisis berpacukan pembelajaran mesin yang dipanggil Analisis Pengutamaan Kebolehgunaan Berasaskan Pengelompokan (CUPA) dan pengukur pengutamaan yang dipanggil Model Pengutamaan Pengelompokan Kebolehgunaan (UCPM). UFMAR menunjukkan bukti empirikal untuk meningkatkan kebolehgunaan melalui MAR bermodalkan sifat interaksi uniknya. UFMAR mempertingkatkan rangka kerja sedia ada dengan kebolehan baharu untuk mengenal pasti dan mengutamakan isu kebolehgunaan MAR secara sistematik. Melalui keputusan eksperimen UFMAR, didapati kaedah IICUMI adalah 50% lebih berkesan, manakala CUPA dan UCPM adalah 57% lebih berkesan daripada rangka kerja sedia ada. Hasil melalui UFMAR juga menghasilkan ketepatan 86% dalam keputusan analisis dan 79% lebih cekap dalam pelaksanaan rangka kerja. UFMAR telah disahkan melalui tiga kitaran proses eksperimen, dengan pengesahan berdasarkan ulasan pakar, untuk dibuktikan sebagai rangka kerja yang sesuai untuk pembelajaran bahasa menggunakan MAR.

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LIST OF ABBREVIATIONS

AED	-	Average Euclidean Distance
ANOVA	-	Analysis of Variance
APE	-	Absolute pose error
AR	-	Augmented Reality
ARLE	-	Augmented Reality learning environment
ATT	-	Attractiveness
Ave	-	Average
Ave SS	-	Average Silhouette Score
BC	-	Book chapters
BLA	-	Qualitative Bipolar Laddering
CTB	-	Central Tendency Bias
CUPA	-	Clustering-based Usability Prioritization Analysis
CW	-	Cognitive walkthrough
EAL	-	English as Another Language
EF EPI	-	EF English Proficiency Index
EFL	-	English as a Foreign Language
EI	-	Enjoyment and Interest
e-learning	-	Electronic learning
ELT	-	English Language Teaching
ER	-	Expert review
ER	-	Error(s) registration
EREM	-	Evaluand-oriented Responsive Evaluation Model
ESL	-	English as a Second Language
ET	-	Engagement time
FE	-	Feature extraction
Fq.	-	Frequency
FS	-	Feature Selection
G	-	Gap
GLC	-	Government Linked Companies
H	-	Hypothesis

HA	-	Hierarchical Agglomerative Clustering
Hc	-	Heuristic
HE	-	Heuristic evaluation
HQ-I	-	Hedonic quality (Identification)
HQ-S	-	Stimulation
ICT	-	Information and Communication Technology
IICUMI	-	Individual Interaction Clustering-based Usability Measuring Instrument
IMI	-	Intrinsic Motivation Inventory
IMMS	-	Keller's Instructional Materials Motivation Survey
ISO-9241	-	International Organization for Standardization
IUCPS	-	Individual Usability Cluster Prioritization Score
Iw	-	Interview
Lik	-	Likert
LLS	-	Language Learning Strategies
MAD	-	Mean Absolute Deviation
MAR	-	Mobile Augmented Reality
MAR-I	-	Mobile Augmented Reality Interaction
ME	-	Malaysian English
MEF	-	Malaysia Employers Federation
Mini K-Means	-	Mini Batch K-Means
ML	-	Machine learning
M-learning	-	Mobile learning
MS	-	Mean Shift
MSE	-	Mean Squared Error
MSLQ	-	The Motivated Strategies for Learning Questionnaires
NI	-	Non-indexed Journals
NV	-	Navigation
Obs	-	Observation
OT	-	Object Tracking
P	-	Proceedings
PC	-	Perceived Competence
PCh	-	Perceived Choice

POM	-	Profile of Mood States
PP&T	-	Perceived Pressure and Tension
PQ	-	Pragmatic quality
PSSUQ	-	Post-Study System Usability Questionnaire
Pub.	-	Publication
Qr	-	Quartile
Q	-	Questionnaire
QA	-	Quality Assessment
QOE	-	Quality of Experience
QUIM	-	Quality In Use Integrated Measurement
QUIS	-	Questionnaire for User Interface and Satisfaction
Refs.	-	Reference authors utilizing the instruments
RPE	-	Relative pose error
RQ	-	Research Question
SD	-	Significant Difference
SFQ	-	Short Feedback Questionnaire
SILL	-	Strategy Inventory for Language Learning
SL	-	Selection
SLR	-	Systematic Literature Review
SS	-	Silhouette Score
SUMI	-	Software Usability Measurement Inventory
SUS	-	System Usability Scale
TA	-	Think-aloud
TAM	-	Technology Acceptance Model
TLX	-	Task Load Index
ToT	-	Time-on-tasks
TTV	-	Threats to validity
UCPM	-	Usability Cluster Prioritization Model
UCPS	-	Usability Cluster Prioritization Score
UFMAR	-	Usability Framework for Mobile Augmented Reality
u-learning	-	Ubiquitous learning
UTAUT2	-	The Second Iteration of The Unified Theory Of Acceptance And Use Of Technology

UX	-	User Experience
Vs.	-	Versus
WTC	-	Willingness to Communicate

LIST OF SYMBOLS

df	-	Degrees of Freedom
P	-	probability value
t	-	t-test value
F	-	F-test value (Analysis of Variance)
F Crtitcal	-	F Critical Value in F-test
F Ratio	-	F Ration Value in F-test
α	-	Cronbach's Alpha
NewX	-	Normalization value
MSE	-	Mean Squared Error
MAD	-	Mean Absolute Deviation
$\overline{x}$	-	Mean
K-value	-	K value for K Means and Mini Batch K Means
X	-	Data points for the largest cluster
j – a	-	List of samples in largest cluster
i – n	-	Data dimensions in second cluster
Y	-	Data points for the second largest cluster
k – b	-	List of samples in second largest cluster
UCPS	-	Usability Cluster Prioritization Score
IUCPS	-	Individual Usability Cluster Prioritization Score

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Usability has been a vast and wide domain considering its nature of evolving across computational interfaces. From the "unconventional out of class" learning point of view, many newly introduced technologies such as Mobile Augmented Reality (MAR) language learning require a new usability framework considering the obsolete nature of currently available methodologies. Guidelines and taxonomy are one area of usability studies. However, post usability evaluation and analysis are just as crucial as the pre-usability guidelines. MAR learning in general is an emerging technology combining the benefits of Augmented Reality (AR) learning in natural spatial interaction with the mobility of Mobile learning. MAR learning introduces distinctively different nature of interaction options, making use of real environment affordances and spatial cues that renders more naturally tangible commands in a mobile environment. The introduction of MAR learning offers spatial navigation through a mobile application enabling unlimited boundaries within a mobile device's screen space, making it differs significantly from familiar interactions with desktop or mobile applications. Despite the obvious differences, many researchers in current MAR language learning research still relies heavily on existing usability framework for post usability evaluation. The widely used usability framework such as ISO9241-11 with related models such a Technology Acceptance Model (TAM) have proven to be implemented well across several decades to measure usability in electronic learning technologies. However, emerging technologies like MAR offers much newer dimensions to be measured. MAR interactions for instance have completely different properties as compared to older technologies such as desktop computers and mobile applications. Therefore, there is a need to revisit the much-used existing usability framework to discover more enhancement that can be optimized, suitable and tailored to the unique usability spectrum that MAR has to offer.

Also in MAR research in general, much existing works used mostly self-reported data collection, which is prone to several social biases, according to many studies. The solution to this method would be the hybrid of performance and usability metrics which are surprisingly rarely used in the mentioned studies. Not to mentioned, modification for such usability data collection method can also be carried out to fit MAR language learning better. Besides issues identified in usability data collection methods, usability analysis in most current works in MAR leans towards conventional data analysis (descriptive especially) using established analytical tools rather than prediction models that can be carried out quantitatively compared to current reviewed methods. Machine learning clustering techniques, being one of the predictive models, have not been empirically applied in the usability analysis of MAR language learning, deriving curiosity if the implementation is possible and feasible. Moreover, with the applicability of machine learning, predictive models may encourage swift usability problem identification and prioritization, which previously can be taxing when analysed with existing statistical methods. The implementation of machine learning usability analysis has been proven to be positively feasible in many other areas related to desktop and mobile applications, but not in MAR language learning to the best knowledge of this research.

Relating to the research areas in MAR, studies done in English learning is still rare. Malaysian English (ME) is one of the unique localized and variety of English used according to Pillai (2008). In Malaysia, the term English as a second language (ESL) is applied. Although being one of the highest-ranked countries in English proficiency, results have shown that Malaysian graduates do not have English abilities up to the current industrial expectations (Aziz, 2018; “English proficiency still a big problem for many Malaysian grads | The Star,” 2020). Current researchers have shown evidence that the English literacy issues can be improved through MAR language learning (Bursali and Yilmaz, 2019; Hsu, 2017; Liu et al., 2016). Combining the advantages of both AR-learning and M-learning, MAR language learning has been shown by these researchers to enhance English learning. Despite these reported issues by mainstream media and positive evidences presented by in regards to ESL literacy in MAR, no research thus far has shown direction towards the improvement of spoken English closing the fissure between Standard English and ME in Malaysia using MAR.

On the other hand, research in MAR English language learning focuses more towards improving English proficiency, rather than tackling these technology interfaces' usability. User experience might reflect on fragile conclusions where the positive results might be contributed through content effectiveness but not necessarily the learning technology's effectiveness. Objective and subjective measures have also been a domain to be explored since most technology-based English Language Teaching (ELT) utilizes only qualitative self-reported metrics rather than quantifiable performance metrics in usability. Balancing the technical and pedagogical progress (FitzGerald et al., 2013), there might be a new area of study to achieve better usability results in future works of delivering academic knowledge, especially in ME and technology-based ELT. Therefore, potential research can be carried out looking into the improvements of usability framework for MAR in English language learning. The improvements of the framework can be approached from the perspective of unique MAR interactions, data collection method and machine learning-based usability analysis.

1.2 Problem Statement

Current publications and statistics have shown the needs to improve language communication among fresh graduates in developing countries through English Language Teaching (ELT). MAR language learning is an emerging area especially in ELT. While MAR technology has been suggested by many existing works to enhance language learning, the usability standards in MAR is still dependent on existing usability framework used for previous learning technologies. Despite the unique characteristics in MAR, which style of interactions are significantly different from conventional electronic related learning, MAR researchers still relies upon the commonly used ISO9241-11 framework when measuring user experience. However, the experience measured could not be identified nor prioritized by MAR interaction styles. This is because the unique interaction abilities in MAR are distinguished and significantly different than other technologies. These interactions serve as core elements that defines MAR as what it is in the first place, rendering them to be crucial factors in determining an MAR application to be usable with positive user

experience. However existing MAR research has yet to tweak, explore and propose a usability framework specifically for MAR language learning, where interaction's data serves as a major usability indicator. By not including this indicator, the existing usability framework adopted in MAR will not be optimized nor tailored, leading towards the possibility of less effective, less efficient and undiscovered improvements in the overall usability processes.

Additionally, usability analysis adopted by similar studies consist of common descriptive, inferential, and subjective statistics, despite myriad successes of emerging analysis techniques such as machine learning clustering models. Machine learning has shown significant positive outcomes when implemented in other technologies such as web and mobile application. With the advantages of machine learning being more efficient in identifying and prioritizing usability issues, its possibility and feasibility have yet to be discovered in MAR language learning applications. The identified problems are important in the field of education since many learning applications have adopted MAR more each day considering its benefits. With such rapid expansion of MAR especially in English language learning, the enhancement of existing usability framework to be tailored to MAR properties is imperative, since usability plays a major role in ensuring MAR's quality and good user experience. Therefore, this research will investigate further into the possibility of proposing a new usability framework for MAR language learning as a solution to the identified problems that have been highlighted.

1.3 Research Questions

The problem statement in section 1.2 has generated several research questions. Table 1. 1 below shows 14 identified research questions based on possible research areas to be included in this dissertation. Research Question (RQ) listed seek to find answers for three generic areas: usability in MAR learning, machine learning clustering techniques, and the ELT domain of study. Answering the research question below will help design and formulate a framework to meet the research objectives of this dissertation.

Table 1. 1 Research questions

RQ1	What are the common domains, research types, and contributions for combined MAR learning applications and usability studies?
RQ2	What are the common primary domain, usability metrics, methods, techniques, instruments, analysis tools and sample size used in MAR learning studies?
RQ3	What are the correlations in between these identified usability metrics, research types, contributions, methods, and techniques in MAR learning?
RQ4	What are the commonly used machine learning-based clustering techniques and how are they applied in usability studies?
RQ5	How can the usability metrics be combined to be used to prioritize MAR learning usability issues?
RQ6	How can current usability metrics be designed to be compatible with machine learning clustering-based analysis as compared to statistical analysis?
RQ7	Is machine learning clustering-based analysis empirically feasible for MAR learning usability and which clustering technique is the most suitable to be performed on usability data?
RQ8	Can clustering-based analysis of MAR learning usability prioritization based on user-interaction improve individual usability issues and does it outperform current practices?

1.4 Research Aims and Objectives

Referring to the research problem statement and questions, a research aim has been formulated for this research. This research aims to propose a framework that improves usability data collection and analysis processes in MAR language learning utilizing interaction segregation and machine learning clustering techniques. To achieve the aim of this research and to answer the research questions, the following three objectives are established:

(a) To study the current domain, usability evaluation practices and analysis techniques applied in MAR language learning application research.
(b) To propose a usability framework that uses interaction and machine learning-based usability prioritization approaches for MAR language learning.
(c) To improve the efficiency of current usability evaluation, identification, and analysis processes in MAR language learning.

1.5 Scope of Research

In general, the extent of this research is within the boundaries of the Mobile Augmented Reality (MAR) learning usability studies. Therefore, the scope of this research is to be articulated as follows:

(a) This study is targeted on usability framework in MAR language learning. This research is specifically bounded only within English Language Teaching (ELT), which is a sub-domain of language learning and MAR education in general. The main outcomes of this research shall contribute to the body of knowledge in Human Computer Interaction (HCI), focusing on the area of usability and user experience conclusively. Despite limiting the implementation only in ELT for this research, contributions of this research is anticipated to be robust for utilization in other language learning and education-based areas.

(b) In English Language Teaching, the MAR application will focus solely on the subtopic of English communication. This is because current published evidence have shown the need for improvements in English communication skills among tertiary education graduates.

(c) This research focused clearly on implementation in three sub-research areas namely, refinement of usability framework for MAR language learning, enhancement of usability methods, models plus metrics, and adoption of machine learning clustering-based usability analysis.

(d) Within the first sub research area, this research will focus only on the adaptation and refinement of usability framework used to evaluate MAR language learning application

(e) Within the second sub research area, this research will focus only on the experimental adoption, combination and enhancement of usability processes for MAR language learning application. The usability processes adopted will be based on existing usability methods and metrics applied in current MAR domain.

(f) Within the third sub research area, this research will focus only on adoption and implementation of machine learning clustering-based models in MAR English language learning.

(g) The experimental targets of this research will focus solely on usability improvements in MAR language learning, which includes proposing new approaches to evaluate, analyse, prioritize, and improve usability issues.

1.6 Significance of the Study

This study's significance is to have a framework that shows the feasibility of technology-based ELT in Malaysia. Going along the nation's theme for globalization, the research provides significant proof for technology-based ELT to be implemented to improve Malaysian English overall limitations. Besides being a guideline to implement technology-based ELT in Malaysia, this research can pioneer more research to implement technology in Malaysian English Learning. Besides producing implementation structure, process, and measures in technology-based ELT, this research will also open paths to more research in usability measures within this domain, introducing more usability alternative models tailored to MAR learning. Since usability in technology-based ELT can be measured in a myriad of approaches, the outcome of this research is anticipated to pioneer interaction-based and machine learning-based usability processes. Besides being an improved usability model, the proposed framework is also targeted as a set of tailored usability solutions for MAR technologies.

1.7 Motivation

The motivation to conduct this research can be comprehended from three different perspectives. The first perspective resolves around the technical contribution towards human computer interaction and usability in general. The second perspective of the motivation is the need for improvements in Malaysian English. The third motivation resolves around how the outcome of this research can contribute to the nation.

The first aspect that motivates the proposal of this research is of course the opportunity in improving existing usability processes in MAR language learning. As mentioned before in problem background, initial studies found important gaps in between current usability practices and MAR user experience. The current ISO-9241-11 framework is undeniably the most used framework in the field of computer sciences and information technology. The ISO9241-11 framework has generated myriads of novel research outcomes in constant improvement of methods, proposal of new models and experience analysis. However, such intervention does not happen significantly in MAR, especially in language learning. Since the MAR technology possesses unique and distinguished interaction styles, this research believe that the applied ISO9241-11 framework can be further enhanced, maintaining the original core benefits, but also introducing new elements that are seamlessly tailored to the distinctive features of MAR technology. The enhancement can be seen possible in modifying the existing standards, usability models, methods, techniques, and metrics in the framework for a more efficient plus effective MAR usability processes.

Looking in a broader perspective, this research choses for improvements to be made around English language learning, especially in communication proficiency. The motivation arrives when this research learned about the declining of Malaysian English literacy among university graduates. The younger generation of the nation, who are supposed to lead brighter economy, political and societal well-being in Malaysia are perceived to be disadvantaged by their English communication abilities. Almost on a yearly basis, mainstream media have endless reporting on similar issue rendering the steady decline of language literacy among young Malaysians (Aziz, 2018; “English proficiency still a big problem for many Malaysian grads | The Star,” 2020; Reporters, 2019; Selan, 2021). Moreover, with reported success on how MAR technology manage to improve English proficiency in other non-native English-speaking countries, the research within this discipline is still infrequent to say the least. Therefore, with such current events, this research is motivated to conduct this research in the English learning education domain.

The third motivation is the possible contribution this research can give to the nation. This research is objectified to deliver several contributions to society and the nation. Firstly, the development of a MAR English language learning application

through this research can be commercialized to the public, hoping to improve communication abilities among young Malaysian graduates in general. With the development of the MAR application, an improved usability framework for MAR language learning will also be proposed. The proposed framework can hopefully open more opportunities for researchers, especially in Malaysia to improve MAR language learning from many different aspects. The contributions of this research are hopefully sound to also contribute to the advancement of computer sciences, learning technologies and education development in this country.

1.8 Thesis Organization

Chapter 1 highlights the essential background of the research and the information surrounding this research scope. This Chapter will explain problem statement formulation, which leads to inspiring this research through several research questions. The research aims and objectives share in detail the target of this research and the few important features to be met to achieve the aim. This Chapter will then highlight the research scope, the significance of the study, and its contribution to the nation.

Chapter 2 first discusses a Systematic Literature Review (SLR) implemented to study MAR learning usability elements. The SLR collected 72 current reputable works and elaborated the findings based on domains, metrics, models, methods, techniques, contributions, instruments, tools, analysis, and the correlation of selected elements. This chapter will then conduct literature studies on machine learning clustering techniques and current usability studies. This chapter will next discuss an identified MAR learning application domain for implementation of experimentation and findings. Based on the three main research areas' overall findings, this chapter will be concluded with identified gaps that can be attended to for contributions and a visualization of a theoretical framework which parameters were derived from the chapter’s outcome.

Chapter 3 first highlight the possible recommended intervention to the identified gaps from chapter 2. The intervention was formulated theoretically based

on calculated knowledge obtained from literature summarized in a theoretical framework. Based on the theoretical intervention based on gaps, an improved usability framework called Usability Framework for Mobile Augmented Reality (UFMAR) is proposed for language learning. A seven phases operational framework was designed to implement the possible theories for solving the research gaps that can eventually answer some of the research questions and meet the dissertation's objectives. This chapter then discuss the development of a MAR English language learning prototype and the three other contributions. The contributions include a usability data collection method called Individual Interaction Clustering-based Usability Measuring Instrument (IICUMI), a usability analysis model called Clustering-based Usability Prioritization Analysis (CUPA) model and a prioritization model named Usability Clustering Prioritization Model (UCPM). The seven phases of the proposed operational framework will then be discussed in detail phase by phase before highlighting the hypotheses' list.

Chapter 4 presents the results and analysis of this research's first significant contribution, namely the Individual Interaction Clustering-based Usability Measuring Instrument (IICUMI). This chapter then discusses a pilot study carried out for two simultaneous purposes, which is to validate the prototype and to be used as input for the development of IICUMI. This chapter will then discuss the results pertaining the mapping of models, instruments, metrics, and measures before presenting a significant study validating and verifying the applicability of IICUMI.

Chapter 5 presents the results and analysis details of this research's second major contribution, namely the Clustering-based Usability Prioritization Analysis (CUPA) model, highlighting the application of machine learning clustering techniques as an analysis tool. This chapter measures both pre-and post-prototype improvement studies, scrutinizing clustering results based on the type of technique, feature selection options, data cleaning, clustering quality, clustering performances, and clustering consistencies. This chapter then presents the accuracy and inferential property of all four selected clustering techniques tested for the proposed framework. This chapter summarizes with the recommendation of clustering type suitability and hypotheses acceptance.

Chapter 6 presents the results and analysis details of this research's third major contribution, namely the Usability Clustering Prioritization Model (UCPM), consisting of Usability Clustering Prioritization Score (UCPS) and Individual Interaction Usability Clustering Prioritization Model (IUCPS). This model will be tested for feasibility and applicability on prioritizing MAR language learning application. This chapter will highlight pre and post-prototype improvements, verifying and validating both scores as a prioritization tool, complementing the output generated by CUPA, discussed in chapter 5. This chapter then discusses benchmarking of the major contributions with current reputable works before summarizing the chapter's outcome.

Chapter 7 is the last chapter presenting the summary of the work. A table is shown mapping the overall study in this dissertation, including the objectives, gaps, research questions, deliverables of contributions, and chapters involved. This chapter will then discuss the list of major and minor contributions before highlighting the challenges, followed by the anticipated future works.

1.9 Summary

This chapter has first discussed, in short, the problem background, which is a set of preliminary knowledge of research areas to be studied. Next, a problem statement is articulated based on several sub-micro problems identified throughout this research. Based on the formulated problem statement, eight research questions have been highlighted to navigate the research direction. This chapter then discusses the research aims and objectives, mainly focusing on studying the related research areas, developing a proposed usability framework for MAR language learning, and the evaluation plus refinement of the framework. The research scope was then discussed to rigidly keep the direction of this research focused on related body of knowledge. This chapter consequently highlights this research's motivation, followed by a summary of how this thesis was organized based on all seven chapters. This chapter is then concluded with the details of research planning and timeline.

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