FIRASS EL HOMSI

MULTI-CRITERIA DECISION MAKING OF MOBILE APPLICATION FOR

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NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF COMPUTER INFORMATION SYSTEM

MULTI-CRITERIA DECISION MAKING OF MOBILE APPLICATION FOR MATHEMATICS USING FUZZY TOPSIS TECHNIQUE

M.Sc. THESIS

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Approval

We certify that we have read the thesis submitted by Firas EL Homsi titled **" MULTI-CRITERIA DECISION MAKING OF MOBILE APPLICATION FOR MATHEMATICS USING FUZZY TOPSIS TECHNIQUE "** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

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Firass El Homsi

Abstract

Multı-Crıterıa Decısıon Makıng Of Mobıle Applıcatıon For Mathematıcs Usıng Fuzzy Topsıs Technıque

El Homsi, Firass

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The study is centered on the need to develop a web application for ranking mobile applications for mathematics. This was driven by observations made which depicted that quite a number of mobile learning applications for mathematics have high ratings which do not match their contributions towards improving learning. This was based on the assumption that high-quality and user enhancing mathematics mobile applications can be identified by their user ratings as well as the number of users using the applications. The Fuzzy TOPSIS was used to rank the most downloaded 6 mobile applications and this was done in conjunction with ISO/IEC 25010 standards which served as an evaluation framework. The mobile applications are yHomework, Cymath, Malmath, Math42, MathPapa and PhotoMath. These mobile applications were selected based on a user rating of at least 4.5 and a downloadable number of at least 100,000 users. The results of the study showed that PhotoMath was selected at the best application, The results also showed that yHomework Math Solver application got the lowest rank in terms of selected criteria according to fuzzy TOPSIS ranking procedure. It was further revealed that increasing the number of decision makers, alternatives as well as comparing and contrasting the efficiency of different MCDM methods applied to improve the precision of the selection process. Recommendations were thus made that it would be beneficial to create an application to automate MCDM in order to be used within a user-friendly environment to select the best application within a certain field.

Keywords: fuzzy topsis, iso/iec 25010, mathematics, mobile learning applications, multi-criteria decision making.

ÖZET

Fuzzy Topsis Tekniği kullanılarak Matematik Mobil Uygulamalarında Çok-Kriterli Karar Verme

El Homsi, Firass

Yüksek Lisans, Bilgisayar Bilişim Sistemleri Bölümü

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Bu çalışma, matematik mobil uygulamalarını sıralamak için bir web uygulaması geliştirme ihtiyacına odaklanmıştır. Matematik için mevcut olan yüksek değerlendirmeye sahip birçok mobil öğrenme uygulamasının öğrenmeyi geliştirmey yönelik olmadığı gözlemlenmiştir. Yüksek-kaliteli ve kullanıcı geliştirici matematik mobil uygulamalarının, uygulamaları kullanan kullanıcı sayısına ve kullanıc değerlendirmelerine bakılarak tanımlanabileceği varsayılmaktadır. En çok indirile mobil uygulamayı sıralamak için Fuzzy TOPSIS kullanılmış ve bu, bir değerlendirme çerçevesi görevi gören ISO/IEC 25010 standartlarıyla birlikte yapılmıştır. Bu mobil uygulamalar yHomework, Cymath, Malmath, Math42, MathPapa ve PhotoMath'dir. Bunlar, en az 4,5 kullanıcı puanına ve en az 100.000 kullanıcıdan oluşan indirme sayısına göre seçilmiştir. Çalışmanın sonuçları, PhotoMath'in en iyi, yHomework Math Solver uygulamasının ise, fuzzy TOPSIS sıralama prosedürüne göre seçilen kriterler açısından en düşük sırayı aldığını göstermektedir. Ayrıca, seçim sürecinin kesinliğini iyileştirmek için uygulanan farklı ÇKKV yöntemlerinin etkinliğinin karşılaştırılması ve kıyaslanmasının yanı sıra karar verici ve alternatif sayılarının arttırılmasının önemi de ortaya konmuştur. Bu nedenle, belirli bir alanda en iyi uygulamayı seçmek için kullanıcı dostu bir ortamda kullanılmak üzere ÇKKV'yi otomatikleştirecek bir uygulama oluşturmanın faydalı olacağı yönünde önerilerde bulunulmuştur.

Anahtar Kelimeler: fuzzy topsis, iso/iec 25010, matematik, mobil öğrenme uygulamaları, çok-kriterli karar verme.

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LIST OF ABBREVIATIONS

AHP:	Analytic Hierachy Process
MCDM:	Multiple Criteria Decision Making
MMLA:	Mathematics Mobile Learning Applications
MLA:	Mobile Learning Applications
NIS:	Negative Ideal Solutions
PIS:	Positive Ideal Solutions
WAP:	Wireless Access Protocols
WELCOME:	Wireless E-Learning and Communication Environment

CHAPTER I
INTRODUCTION

Background of the Study

There is a significant increase in the number of mobile applications that are being developed each year. Such an increase in the number of applications being developed is highly noticeable in the area of digital learning objects. These developments are justifiable by ideas given by Cresente and Lee (2011) which contends that new, better and effective learning platforms are needed to facilitate learning. İt is also apparent to note that developments in mobile learning applications are going hand in hand with educational developments. Hence, one can contend that the use of mobile learnings applications plays a vital role in education.

Researchers used some criteria to evaluate the performance of mobile applications. Some of these criteria consist of User satisfaction, which reflected how the application meet the user's expectations and fulfilled its tasks as expected (Lee & Lehto, 2013). Compatibility is where the products or services can be installed and used without harming or conflicting with other software or applications (Tung & Chang, 2008). Functionality is where the application performs its tasks and operations as it should without bugs or issues that might give wrong results or outcomes (Shao & Shao, 2012). The security level reflects how much the application protects the data or services against all harmful threats, as the data is very important depending on the applications they are used for, medical, financial, or private media records. (Ben-Zeev et al., 2018). Accessibility features consist of authorization, and accessibility to secured documents and files for efficiently retrieving the data, to restrict unauthorized users from accessing data which is vital to the software or other users (Dünnebeil et al., 2012). Easiness in using the application, which relates to user experience and how easy it is to be used and accessed at the first time (Ayeh, 2015). Information quality shows the usefulness of the information provided by a given product or service based on the user's expectations (Esmat Abdulmajid Wahdain & Mohamad Nazir Ahmad, 2015). And responsiveness consists of the ability of a product or service to react in a particular situation to provide prompt service (Oladimeji et al., 2021). These were some of the indicators that were used in evaluating different applications.

Ideas by Drigas and Pappas (2015) expressed gratitude for the development of mathematics mobile learning applications. This stems from their contribution towards learning algebra, statistics, geometry, mathematical analysis and other calculations. Pierce, Stacey and Barkatsas (2007) established that mobile learning applications have made it easy to harness meta-cognitive abilities and represents thoughts in a better way. Bjerede, Atkins and Dede (2010) posit that mobile learning applications are essential in dealing with matters that involve a lot of problem-solving and critical thinking. The contributions made by using mobile learning applications are numerous and some are continuing to be discovered with time. This is one of the major reasons why it is important to conduct studies related to the use of mobile learning applications, especially in the field of mathematics.

Some different methods and standards determine the quality of mobile learning applications and their user experience. These include ISO/IEC 25010, ISO-9126 and FURPS which mainly focus on the software aspects of the mobile learning applications (Başaran & Haruna, 2017; Kay & Knaack, 2007). ISO-9126 Product quality was an international standard for the evaluation of software quality till 2011 when it was replaced by ISO/IEC 25010. The ISO/IEC 25010 standard was established in 2011 to standardize the software properties that software developers have to put their attention to while evaluating their platforms. But most of the existing studies that evaluate the quality of mobile learning applications highly focus on technical aspects. Little has been done to provide a list of the best 5 mobile applications by developing a web application that considers both technical and non-technical aspects of the quality of mobile learning applications. This study combines both technical and non-technical aspects of the quality of mobile learning applications to examine how they can enhance mathematics learning and user experience. Hence, the study focuses on the development of a web application for ranking 5 mobile applications for mathematics.

Research Problems

The availability of numerous mobile learning applications for mathematics does not guarantee a high-quality and improved user experience. This follows insights that showed that some of the existing mobile learning applications have not contributed much to learning (Büyüközkan & Güleryüz, 2016; Trestian, et al., 2012). This is highly true with regards to observations that exhibit that quite a several mobile learning applications for mathematics have high ratings which do not match their contributions towards improving learning (Leacock & Nesbit, 2007).

Başaran and Haruna (2017) strongly argue that some users are opting not to use mathematics mobile learning applications (MMLA) because they are not easy to use. Moreover, Drigas and Pappas (2015) also contend that numerous MMLA are difficult to use and involve a lot of manual selection. This increases the time users spend before starting to have the final access to the application. To make matters worse, there is a lot of dissatisfaction surrounding the use of MMLA. This is attributed to ideas that contend that MMLA are not much different from traditional mathematics learning methods (Başaran, 2017; Trestian et al., 2012). That is, they are of low quality and do not contribute much towards improving user satisfaction.

As a result, it can thus be seen that there is a huge need to develop and select high quality and user enhancing experience MLAs. The other challenge is that this topic is an emerging issue and is dominating headlines in the study of MLAs. Hence, much is therefore needed to study how mathematics learning quality and user experience can be improved notably by using topics that guarantees a high level of success (Başaran & Aduradola, 2018). This study thus seeks to use a TOPSIS approach to select high-quality and user enhancing experiences of mobile learning applications for mathematics.

Research Aim

The main objective of the study is to use the TOPSIS approach to select high-quality and user enhancing experiences of mobile learning applications for mathematics. The study also seeks to develop a framework that can be used to set standards upon which the best MMLAs can be developed based on quality and user enhancing experience. This also includes identifying problems that are undermining the use MMLAs and offering solutions to deal with these challenges. Thus, the study investigates to find the best high-quality and user enhancing experience mobile application for learning mathematics. And explore about the possibility of a framework that can be used to rank mathematics mobile learning applications and set standards upon which the best mathematics mobile learning applications can be developed based on quality and user enhancing experience.

Significance of the Study

By addressing quality challenges affecting the use of MMLAs, the study will aid in enhancing the use and effectiveness of MMLAs thereby improving learning across all learning platforms. In addition, the study also helps in setting standards concerning ISO practices upon which the quality and useability of MMLAs can be determined. Moreover, it plays an important role in the study of mobile applications through the use of TOPSIS, AHP and FAHP. That is, it contributes towards improving existing empirical frameworks on TOPSIS, AHP and FAHP. This study is done to help students and teachers in screening and selecting suitable and reliable mathematical learning application

Limitation of the Study

The results of this study are mainly based on 6 mobile applications for learning mathematics. As a result, the major limitation of this study is that the results cannot be generalized and applied to other mobile learning applications.

CHAPTER II
LITERATURE REVIEW

Introduction

The ongoing developments and researches in the field of Information and Communications Technology have a positive impact on our lives, especially in the educational sector. Where lot of new educational applications were created to facilitate the education process, such as mathematical solving mobile applications, to simplify and assist the instructional methods and expand learning scopes (Jeno et al., 2019). These days mobile phone and their applications are widely spread, nearly most if not all the students have their mobile. And the number of educational mobile applications is enormously huge, which make it hard to evaluate each of the application manually to pick the best one. The rating of an application on the google app or apple store alone cannot give the full evaluation of that application (Troussas et al., 2020). As part of efforts to use fuzzy TOPSIS to develop a web application that can be used to rank mathematics mobile applications, this chapter explores both the underlying theoretical and empirical insights on mobile applications and their integration into learning mathematics, drawbacks and insights about fuzzy TOPSIS as a platform of promoting the development of high quality and user enhancing experience mobile applications.
(Roy & Shaw, 2021) presented a study where they used fuzzy and best-worst method (BWM) and adopted a new fuzzy BWM to evaluate nonlinear problems in optimization techniques. BMW consisted of 5 steps, starting from creating the decision-making index system, determining the best and worst indicator by the expert user, after that it compares the best indicators with other indicators through linguistic variables and triangular fuzzy number calculations. After that it compares the worst indicator with other indicators, to finally Determine the fuzzy weight of the different indicators or criteria. Sensitivity analysis examinations were applied to this model to increase its value. They also used software functionality, convenience, quality, security, compatibility and performance expectation as factors for evaluating the mobile banking applications. Their model can be used from benchmarking mobile banking phone applications, and contribute to choosing the best application for customers or financial establishments. TOPSIS was first developed by (Hwang & Yoon, 1981) as a MCDM technique for solving and evaluating MCDM problems.

(Wan et al., 2021) noted that TOPSIS technique is used for picking top substitutes within the best options relying on shortest and longest distances from the top substitutes and other options. And this method is known by its simplicity and ability to produce an indisputable ranking order.

Meanwhile, there exist different ways which can be used to determine the quality of mobile learning applications as well as their contributions towards improving user experience. These include ISO/IEC 25010, ISO-9126 and FURPS which mainly focus on the software aspects of the mobile learning applications (Başaran & Haruna, 2017; Kay & Knaack, 2007). But most of the existing studies that evaluate the quality of mobile learning applications highly focus on technical aspects. Little has been done to consider both technical and non-technical aspects of the quality of mobile learning applications. This study combines both technical and non-technical aspects of the quality of mobile learning applications to examine how they can enhance mathematics learning and user experience.

The Concept of Multiple Criteria Decision Making

It is no doubt that there are circumstances which are surrounded by a lot of decisions that have to be made probably at the same time. Such decisions are often conflicting and result in the need to establish a criterion of making the best and most relevant decision. Hence, resulting in what is termed Multiple Criteria Decision Making (MCDM). MCDM plays a huge substantial role in automating the decision-making process of real-life problems, by ranking substitutes or available options and choosing the optimal one using specific algorithms created from different selected criteria. it can be used in different fields such as economics, engineering, the management or any other area that have multiple choices or decisions. MCDM is formed from different consecutive steps, firstly identifying the decision-making problem, secondly choosing and identifying the criteria list, then creating decision metric, fourthly computing the specific weight for each criterion within the list, and finally ranking the alternatives (Hasan et al., 2022).

The notable feature about MCDM is that they comprise a combination of expert views and the use of historical data to make decisions (Huang, Keisler & Linkov, 2011). That is, MCDM quantifies subjective judgements and this implies that the decision to choose the best MLAM is part of MCDM. MCDM is composed of several approaches and these are VIKOR, TOPSIS, Elimination and Choice Translating Reality (ELECTRE), Best Worst Method (BWM) Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), and Analytic Hierarchy Process (AHP) (Liang et al., 2021). The drawback of ELECTRE is that it has very complex computations and time costing operations. However, it is important to note that the weights of the choices made vary with their relative values. Kasim, Ibrahim and Bataineh (2010) consider that such relative values are bound to change because the decisions made are themselves relative. As a result, problems of subjectivity and imprecision are bound to be encountered in any MCDM activity. MCDM apply in a lot of circumstances and areas such as companies whose objectives are either to increase market share, improve technical abilities, grow, increase sales revenue, or reduce costs etc.; power transmission where the emphasis is to choose essential areas to develop electrical structures, enhance reliability, ensure sound health, or reduce costs etc.; in nuclear power plants where there is either a need to cut costs, minimize environmental damage, ensure sound health or safety etc. İn mathematics, the MCDM can be related to costs, convenience, reliability, accuracy, dependability, accessibility etc. These MCDM aspects among others are essential and must be given due attention if students are to benefit from the use of MMLAs.

Desirable Aspects of Mobile Learning Applications

Though different views can be given concerning the use and importance of mobile learning, it is also no doubt that mobile learning has a lot of desirable aspects. Such aspects make it an important aspect that can easily be integrated into learning.

Mobility Aspects

The key feature that characterizes MLAs is that they allow users to have access to learning platforms at any place in time. This feature or aspect separates MLAs from traditional learning methods and encourages flexibility in learning (Ballı & Korukoğlu, 2009). Ballı & Korukoğlu also noted that learners can enjoy a high level of convincing by using MLAs. Such convince and flexibility are either in the comfort of users' homes or anywhere outside the classroom.

Application Centered

The second feature of MLAs is that they heavily rely on the use of applications and such applications allow them to serve their purpose by functioning in the desired way. Mikaeil et al. (2009) noted that applications vary across all learning platforms with different architecture formats and codes. Such is true with MMLAs when compared to other learning applications as both differ in functionality. However, this does not neglect the fact that they all have to effectively serve their intended purposes and enhance user satisfaction.

Context of the MLAs

Context is an important element in developing MLAs and Bjerede, Atkins & Dede (2010) recommend that providing relevant context fosters MLAs to fulfil their intended purposes. Such can be determined by examining the number of users using the applications as well as reviews given by people (Leacock & Nesbit, 2007). This is why it is important to measure the effectiveness of MLAs across all platforms. Hence, supports the reason why a high rating of at least 4.5 and a benchmark of 100 000 users were used in this study as a criterion for selecting the sample MMLAs.

Size of the Module

Due to many factors such as a website or mobile customization features used to develop the MLAs and other related development restrictions, there is often a limit to the size of modules available on MLAs. For instance, Zolfani et al. (2014) hinted that most MLAs have modules that are 10 minutes long. The size of the modules also varies according to the aspects covered by the module and each module has its separate accessibility platform on the same application. That is, they focus on specific subjects and the longer the subject the more bits the module will occupy.

Ease of Access

Accessing MLAs is often easy and can be done within a matter of seconds or minutes. Whenever users feel the need to access MLAs to retrieve information, they simply open or log in to the application and gain access to learning materials. Users can log in anywhere anytime.

Mobile Applications and their Integration into Learning

Both the digitization of information and the technologically innovative developments that have taken place over the past two decades has greatly impacted learning. One can contend that learning is no longer being restricted to a physical place such as a classroom but is increasingly becoming mobile (Rouhani, Ghazanfari & Jafari, 2012). Generally, a mobile application is any software application that allows the undertaking of certain tasks through the use of a mobile (handheld or wireless) device such as Tablets, smartphones. The main emphasis behind mobile applications is to promote accessibility at any point in time in respect of the usual assigned position or location.

Palloff and Pratt (2001) hinted that the use of MLA through handheld and wireless devices promote collaboration in learning and that the learning process can be individualized. This implies that students can benefit a lot from MLAMs as they can learn mathematics anywhere be it at home or not. This is important because it gives students access to learning materials especially when they do not have physical access to classroom materials or desktop computers.

Virvou and Alepis (2005) mobile learning (m-learning) and electronic learning (e-learning) are greatly influenced by the existence of mobile learning devices (MLDs). This entails that the absence of MLDs can hinder both m-learning and e-learning. This can be supported by insights provided by Motiwalla (2007) which established that developments and the proliferation of mobile learning were being hindered by the lack of MLDs.

Farooq et al. (2002) examined how the use of handheld devices can promote students' participation in online community learning programs. The students were exposed to an online database that they could interact with MOOsburg platform. The findings revealed that students are way more motivated and more engaged to participate in m-learning.

Lehner and Nosekabel (2002) used WELCOME (Wireless E-Learning and Communication Environment) as part of m-learning strategies to examine students' experience and performance. The findings established that mobile learning is a desirable and essential feature of contemporary education. It was also established that mobile learning enhances students' experience, is more effective and supportive especially when integrated with WAP (Wireless Access Protocols).

Bollen, Eimler and Hoppe (2004) focused on the integration of m-learning with SMS technology in universities. The study involved the use of whiteboards and allowed students to ask questions, provide feedback and undertake classroom discussions. The notable feature of this study is that it highlighted the need to categorise students' entire learning process by time, receiver, sender etc. Such can also be extended to the examination of MMLAs. The most interesting development was by Virvou and Alepis (2005) and it involved the development of a tutoring system that allows users to access it using handheld and wireless devices. Such a system captured student performance, records and included an assessment platform. In addition, this has been a solid platform upon which MMLAs and other learning applications have been developed.

From all these insights, deductions can be made that mobile learning is an innovative approach to learning. This stems from its numerous benefits which users or learners are bound to get from using them. As such mobile learning applications can thus be said to enhance among others, convenience, accessibility, speed, interaction, collaboration activities in learning. However, this relies on quite some factors such as the availability of internet access and mobile devices. Also, Bollen, Eimler and Hoppe (2004) established that lack of quality can hinder the use of MLAs. Lehner and Nosekabel (2002) the need to enhance user satisfaction as another key aspect to enhancing the use of MLAs. These issues are part of efforts carried out in this study to rank the best MMLAs using the Fuzzy TOPSIS approach.

Insights into Mobile Learning Applications for Mathematics

The integration of MLAs in mathematics is a great innovative move that works towards improving learners' knowledge and understanding of mathematical aspects. Skillen (2015) posits that the use of MMLAs enhances learners' chances of being successful or performing better in mathematics. As such, the whole process of learning mathematics can be casual and unconstrained as users can use any MLDs such as cell phones and tablets.

Drigas and Pappas (2015) highlighted that MMLAs tend to deal with arithmetic problems faced by learners. This is because MMLAs are designed to suit any individual irrespective of his or her mathematical abilities and most of the modules provided start from elementary aspects or basics of any mathematics subject. Hence, MMLAs can be considered to deal with deeper mathematical issues such as numerical programming, critical thinking, geometrical constriction, charts representation etc. Botzer and Yerushalmy (2007) used Maths4Mobile to look at the use and importance of arranged and social learning angles in learning mathematics. Their results provided support for the additional benefits obtained from using MMLAs over traditional learning methods. The cited reasons pointed towards increased coordination and engagement amongst the students.

Roberts et al. (2015) carried out a study that examine the situational learning environment that involved the use of Nokia mobile phones to learn mathematics. The established findings showed that the use of mobile phones greatly encouraged students to participate in learning mathematics. İn addition, more students were observed to have greatly improved in their academic performance with regards to mathematics. Recommendations were made that the use of mobile phones will encourage unaided learning and hence using MMLAs can play the same role too.

The use of MMLAs attracted and continues to attract the attention of major and reputable bodies which are in support of their use. For instance, the U.S. National Council of Teachers of Mathematics in 2008 encouraged educational institutions to allow students to access MMLAs. Such developments were said to foster speed, creativity and innovation in learning (NCTM, 2008).

Hoyles and Lagrange (2010) gave different arguments concerning the use of MMLAs citing that they can also obstruct the learning process. This is considerably true as students can shift focus towards non-educational activities on mobile applications (Melhuish & Falloon, 2010). Despite the occurrence of these problems, it is still being advocated that MMLAs play an important role in mathematics (Drijvers, 2015). Hence, the study can expect such a notion to play an important in learning mathematics as innovative developments continue to take place in the foreseeable future.

Drawbacks of Using Mobile Applications in Contemporary Learning Situations

It is worthy to note that user satisfaction and quality enhancement are also important aspects to look at when examining both the importance and drawbacks of using MLAs. For instance, Zolfani et al. (2014) contend that the use of MLAs does not guarantee user satisfaction. Such can be evidenced by reviews that are given by users who sometimes complain of using the MLAs. Hence, the number of users using the MLAs is often a good indicator of determining if such MLA is good or bad and if it has problems or not. Ratings are also another strategy that can be used to examine the existence of drawbacks. That is, higher ratings such as 4.5 and 5 or possibly more will offer an indication that the MLA has little or no problems affecting it.

Though MLAs learning applications have a lot of benefits that users can obtain from using them, they are still prone to suffer or pose numerous drawbacks. For instance, Başaran and Haruna (2017) established that most MLAs always fail to live up to expectations. The reason is that they fail to serve the intended purpose. That is, not all MMLAs will offer the desired mathematics learning materials and some materials are relatively few and inaccessible.

On the other hand, it can be pointed out that costs are a key problem that affects the use of MLAs. Both the development and use of MLAs is determined by costs and developers and users will try by all means to minimize costs (Büyüközkan & Güleryüz, 2016). İn doing so, cost minimization can end up affecting the quality of MLAs and some features may require users to pay more money or subscription to gain further access.

The fact that notable MLAs require internet access can prove to be a major problem. Though favour is often shown towards the use of MLAs over traditional learning methods citing convince and ease access (Huang, Keisler & Linkov, 2011), this is conditional. This is because internet access is not always available and its availability is limited to places and determined by the ability to access the internet. Hence, the unavailability of internet access can restrict the use of MLAs.

Meanwhile, applications are themselves part of the full composition of what is termed software and hence any problem that is surrounded by the use of softwares can affect the use of MLAs. For instance, software crush problems can make MLAs inaccessible and this can happen most when users are in great need of the application. Most of them require constant updates and may not work with certain mobile devices. For instance, they are certain MLAs that are restricted to IOS while others work only on Android and Windows operating systems.

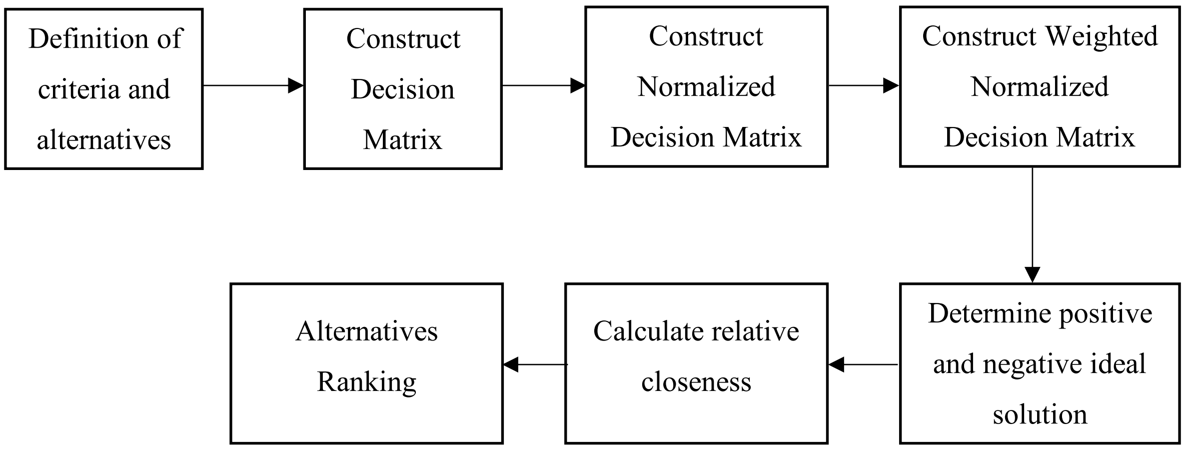
From all these drawbacks, the development of high quality and user enhancing MLAs has to consider all these challenges. As a result, an assumption can be made in this study that mobile applications that have higher ratings such as 4.5 and 5 or possibly more and a high number of users, will offer an indication that the MLA has little or no problems affecting it.

Technique for Order of Preference by Similarity to Ideal Solution

This technique is otherwise known as the TOPSIS approach and came into existence as a result of efforts to provide a framework for choosing the ideal alternative (Zavadskas, Turskis & Kildienė, 2014). The main logic of this technique is based on determining the distances of the decision points subjected to evaluation from the positive and negative ideal solutions and making a rank among them. That is the decision is made based on the most and closest distance between the negative ideal solution and the positive ideal solution (Daghouri, Mansouri & Qbadou, 2018).

Figure 1

TOPSIS Approach



Source: Daghouri, Mansouri and Qbadou (2018, p 292)

The TOPSIS approach presented in Figure 1 is carried out in 7 distinct steps and these steps can be listed as follows:

Step 1: Developing a decision matrix that is based on ***n*** criteri,***m*** alternatives and a set of attributes ***j***.

$$A_{mn}=\{a_{ij}/i\epsilon(1,2,....,m) and\ j\epsilon(1,2,....,n)\} \quad (1)$$

Step 2: Normalising the decision matrix

$$r_{ij}=x_{ij}/\sqrt{\sum_{j=1}^{J} x_{ij}^{2}}\ ,j=1,\ 2,\ 3\ldots\ J\ and\ i=1,\ 2,\ 3\ldots n \tag{2}$$

Step 3: Constructing weighted normalized decision matrix

$$v_{ij}=w_i*r_{ij},j=1,\ 2,\ 3\ldots\ J\ and\ i=1,\ 2,\ 3\ldots n \tag{3}$$

Step 4: Ascertaining negative and positive ideal solutions

$$\text{Where } v^{-}=\{\min(v_{ij})\ if\ j\epsilon J;\max(v_{ij})\ if j\ \epsilon J^{-}\} \tag{4}$$

$A^- = \{v\frac{1}{1}, v\frac{1}{2}, \ldots\ldots, v\frac{1}{n}\}$

$$\text{Where } v_i^{*}=\{\max(v_{ij})\ if\ j\epsilon J;\min(v_{ij})\ if j\ \epsilon J^{-}\} \tag{5}$$

$A^* = \{A_1^*, A_2^*, \ldots\ldots, A_n^*\}$

Step 5: Determining measures that separate the NIS and PIS

$$d_i^{-}=\sqrt{\sum_{j=1}^{n}(v_{ij}-v_j^{-})^2},j=1,\ 2,\ 3\ldots\ J \tag{6}$$

$$d_i^{*}=\sqrt{\sum_{j=1}^{n}(v_{ij}-v_j^{*})^2},j=1,\ 2,\ 3\ldots\ J \tag{7}$$

Step 6: Determining the deal coefficient that is close to the solution

$$CC_i=\frac{d_i^{-}}{d_i^{*}+d_i^{-}}\quad i=1,\ 2,\ 3\ldots\ J$$

Step 7: Ranking the preferences

The transformation process of fuzzy member functions is based on the assumption or rule that an equal membership function ranging from 0.25-0.30 can be assigned to each rank (Torfi, Farahani & Rezapour, 2010). For instance, a low triangular fuzzy member of 0.000 can be assigned to a very low fuzzy variable (see Figure 2 and Table 1). While Table 2 shows the linguistic variables used for the fuzzification of weights.

Figure 2

Fuzzy Triangular Membership Functions

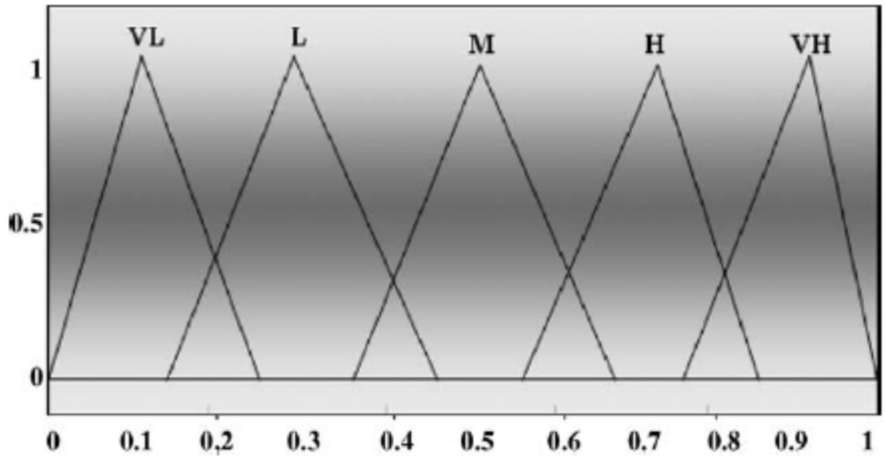


Table 1

Transformation For Fuzzy Membership Functions.

Rank	Sub-criteria grade	Membership function
Very low (VL)	1	(0.00,0.10,0.25)
Low (L)	2	(0.15,0.30,0.45)
Medium (M)	3	(0.35,0.50,0.65)
High (H)	4	(0.55,0.70,0.85)
Very high (VH	5	(0.75,0.90,1.00

Source: Torfi, Farahani and Rezapour, S. (2010, p.523).

Table 2

Linguistic Variables for The Weight.

Rank	Rating	Membership function
Unnecessary (U)	1	(0,0.1,0.25)
Not Important (NI)	2	(0.15,0.30,0.45)
Important (I)	3	(0.35,0.5,0.65)
Very Important (VI)	4	(0.55,0.7,0.85)
Essential (E)	5	(0.75,0.9,1.0)

Considerations must be made that the TOPSIS approach relies significantly on that there is either a monotonic decrease or increase in the criteria (Hwang & Yoon, 1981). As a result, the TOPSIS approach is often considered to be a compensatory framework between good and poor results. But the good results are considered to outweigh poor results (Huang, Keisler & Linkov, 2011). İn this study, the application of the TOPSIS approach can be based on determining the best MLAM which is either reliable, fast, easy to use, such as high quality, cheaper, covers a lot of topics etc. However, all these elements can be embodied under user experience and hence focus will be mainly on choosing the best and high-quality MLAM that enhances user experience.

Related Studies

Ballı and Korukoğlu (2009) are also in support of the combined use of TOPSIS and FAHP methods. But highlighted that this is also conditional on the need to either assign weights or ultimately ranks the judgements. With little focus being given on the use of the TOPSIS approach to rank MMLAs, this study, therefore, deems the use of the TOPSIS approach is best suitable to developing a web application for ranking MMLAs.

Torfi, Farahani and Rezapour (2010) did an analysis on the use of the Fuzzy TOPSIS and AHP approaches to assign weights and rank alternatives respectively. The results showed that both approaches are viable in dealing with MCDM issues. Hence, the same expectations can be individually made concerning the TOPSIS approach.

Rouhani, Ghazanfari and Jafari (2012) used the fuzzy TOPSIS to evaluate the most suitable business intelligence for enterprise systems out of a sample of 34 systems. This involved the computation of evaluation scores and the assigning of ranks to the systems. This approach was justified in its use citing that it allows the selection, assessment and purchasing. The findings were in line with this proposition and considerations can be made that the same can be made with regards to MMLAs. But the focus will primarily be on quality and user enhancing aspects of the MMLAs.

Zolfani et al. (2014) also used the TOPSIS and FAHP to analyse the food industry's product life cycles in Iran. The study used MCDM methods to demonstrate that the best cycle can be obtained with little or no effort. The FAHP was noted to offer the best decision without using a lot of effort. But the given recommendations pointed out that the TOPSIS methods can offer better results when used in a different context. Such a context in this study will refer to MMLAs.

Mikaeil et al. (2009) combined the use of the TOPSIS approach and FAHP to decide on the best possible decision to make under different circumstances surrounded by different value judgements. The results showed that the TOPSIS approach is better when used to rank the decisions while the FAHP works better in assigning weights. This entails that the TOPSIS approach will work better in this study for ranking the best MMLAs.

Yunusa (2017) examined the use of fuzzy TOPSIS and FAHP in addressing user satisfaction and quality issues involved in using MMLAs. The study focused on five MMLAs with higher user ratings of 5 available on Google Play Store (Mathspapa, Mathematics, Cymaths,Malmaths and Mathsway). The findings revealed that the best and less time-consuming MMLAs can be selected by using TOPSIS and FAHP. Mathspapa was ranked last while Mathematics was ranked first followed by Cymaths, Mathsway and Malmaths.

(Rajak & Shaw, 2019) did a study to develop a model for mobile health applications selection using mixed methods of fuzzy TOPSIS and AHP. These applications innovatively managed users' health by becoming more aware of their health status, fitness, diet follow up, or other types of health concerns. Their study aims to assist health service software developers and users to pick the most important factors while selecting their applications, and explaining their methods through numerical techniques. The researchers used AHP and fuzzy-TOPSIS framework to rank and evaluate these applications, and to make their research more generalized they dealt with different factors having qualitative nature. So, they had to use MCDM methods. Such as fuzzy to handle indistinctness with subjective judgments. It assists health service providers as well as users to identify the relevant factors for choosing mHealth applications. Secondly, the study explains the procedure of mHealth application selection through a numerical case example. As the number of health mobile applications has been increased drastically these days, it became confusing and hectic to choose the ideal one to use. They had to choose through different criteria from literature review and expert opinions such as User satisfaction, compatibility, functionality, security, accessibility, ease to learn and use, empathy information quality, and responsiveness. The AHP calculated the weights of the different criteria while fuzzy TOPSIS obtained the ranking of the different applications. the top criteria of the selection process were user satisfaction, functionality, easiness to learn and use, and information quality. The researchers used these applications, Cody, hot5 fitness, pact, carrot fit, human, moves, loseit, noom weight loss coach, healthy out, and zipongo. Health out got the highest rank followed by Noom weight loss coach.

Summary of Related Studies

MMLAs are an innovative approach and their integration in education offers a widespread number of benefits. Such benefits tend to be more when weighed against traditional learning methods. One can thus contend that aspects relating to convenience, easy access, mobility and time are major beneficial attributes of using MMLAs. However, there are also a series of problems that can undermine the use of MMLAs. These problems relate to the purpose over actual results, quality, reliability, user satisfaction, software, costs, accessibility (internet access) aspects of MMLAs. Any challenge about these aspects can hinder the use of MMLAs. The notable idea is that both the use of the Fuzzy TOPSIS and FAHP methods vary with the former working best approaches towards ranking alternatives and assigning weights. This brings us to the main aim of this study which is to develop a web application for ranking MMLAs. Hence, in such a case, the use of the TOPSIS is deemed best and viable.

CHAPTER III
METHODOLOGY

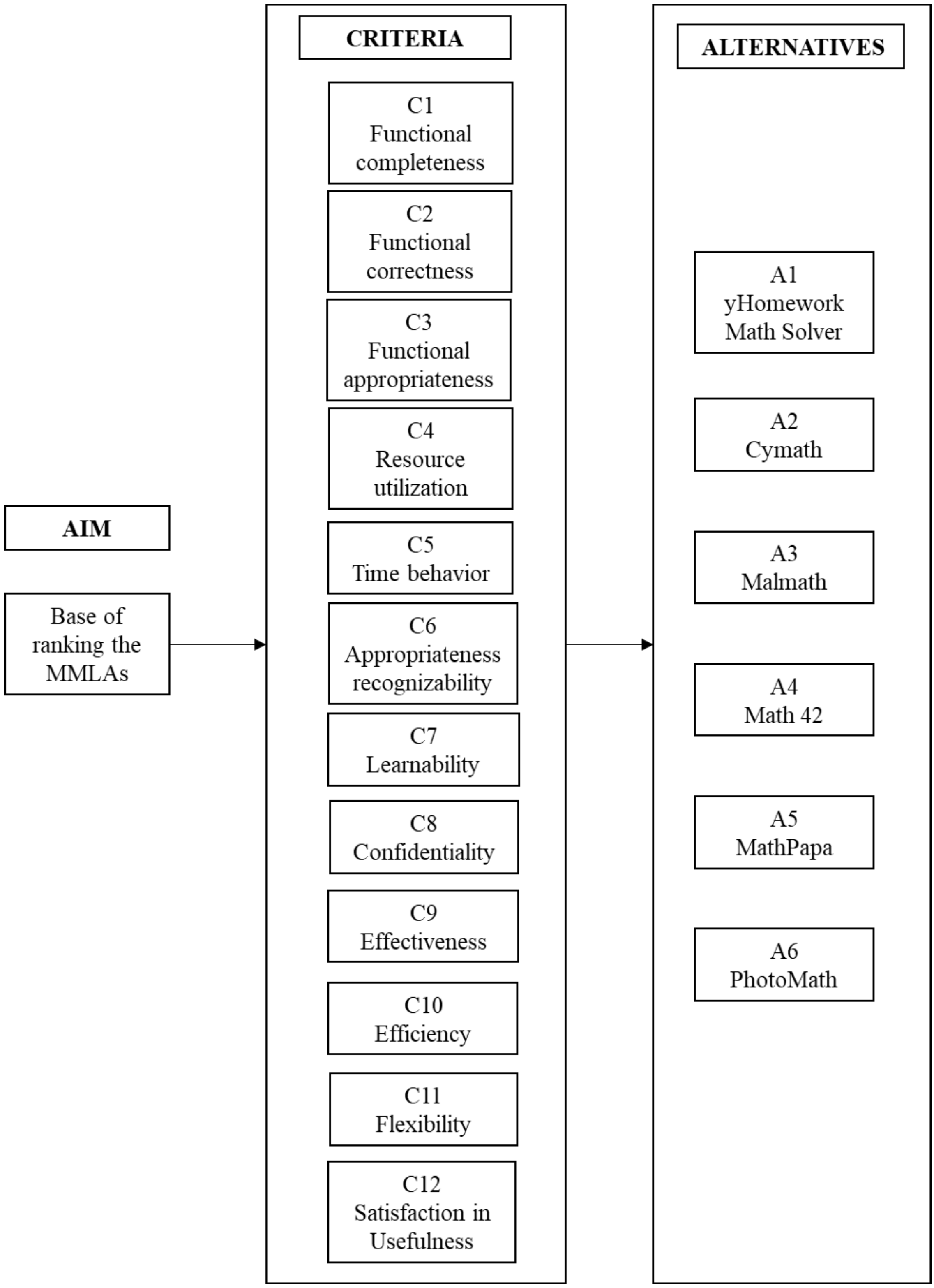
The Selection and Evaluation Model

The emphasis behind the development of a quality and user satisfaction model was based on established research issues which revealed that existing MLAs have not contributed much to learning. Such was further reinforced by observations made which pinpointed that there is a mismatch between MLAMs user ratings and their contributions towards improving learning. This is notably true with regards to the quality of MLAMs which has been established to be in most cases below par. Figure 3 below shows the hierarchy structure for decision-making processes for MLAM's divided into four levels. The first one is creating the aim of the process, then selecting the main criteria (features and aspects), after that selecting the sub-criteria, so that finally the algorithm can choose one of the alternatives presented to the problem.

The study further established that a notable number of MLAMs are exhibit shortfalls in quality concerning pedagogical, technical and economic aspects. The decision-making process was executed by the researcher and together with the assigned supervisor. Resultantly, user satisfaction aspects were mainly centered on non-technical aspects of the MLAMs. Meanwhile, ISO 9126 was used as a baseline for determining the technical aspects of the MLAMs. Consequently, the following model was developed as a platform upon which a web ranking software of the MLAMs was developed.

Figure 3

Hierarchy structure for decision making processes for MLAM

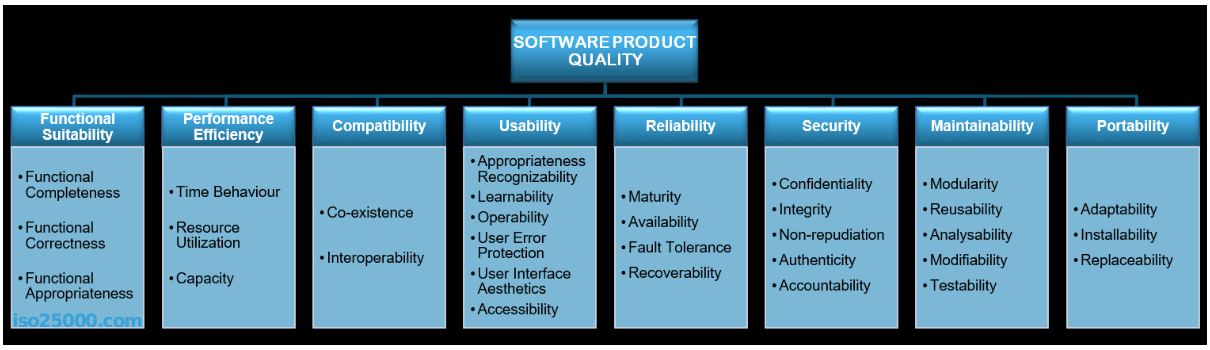


ISO/IEC 25010 on product quality

ISO/IEC 25010 is an international product quality standard that was established in 2011 to standardize the evaluation platforms for picking the best application within a group of applications that do similar processes. This can be used by developers as well so that they can focus on the key performance indicators that make an application stand up and cover most of the requirements efficiently and effectively. Therefore, this standard should consider the software to be of high quality based on its ability to meet most or all of eight product quality features. These quality features set under ISO/IEC 25010 are presented in Figure 4.

Figure 4

Aspects of ISO/IEC 25010 software product features (iso25000.com)



- **Functional suitability:** The application must be capable of meeting the user requirement needs, in a fast and correct manner every time. In other words, the application must meet all of its objectives and tasks and export the results with high accuracy and precision.

- **Performance efficiency:** entails that the application should run and perform all of its tasks without consuming the least resources, such as memory and processing tasks. Thus, finishing its processes as fast as possible. Economides (2008) considers the capacity of an application where it meets the required tasks at its maximum limits.

- **Compatibility:** it illustrates the degree how much the application can function correctly and exchange information with other ends (hardware or software) while sharing the same system and environment. This characteristic is composed of the following sub characteristics:

- o Co-existence. That refers to the level at which software can perform its functions normally without any delays or misfunctioning of itself or other applications while sharing other applications on the same resources, system or environment
- o Interoperability. The possibility of two or more systems, or applications that can exchange information within themselves and use this information inside their process.

- **Usability:** grasp the level by which an application can be used by users to achieve tasks and goals with high effectiveness, efficiency and satisfaction. It is formed of the following characteristics:
  - o Appropriateness recognizability. The level where users can recognize whether an application is appropriate for their needs.
  - o Learnability. is the learning difficulty level where an application can be used by users to fulfil their needs from first time usage without misusing it.
  - o Operability. The degree to which an application has attributes and features that allow the users to edit some of its settings to control its functionality.
  - o User error protection. The degree to which the applications limit the user from making errors.
  - o User interface aesthetics. The degree to which an application has a user interface that enables attractive and substantial interaction for the user.
  - o Accessibility. The degree to which an application can be used by a broad range of people to achieve a specified task.

- **Reliability:** It refers to the level where an application performs specified functions under specified conditions for a specified time. This characteristic is composed of the following characteristics:
  - o Maturity. The level that the application is still fully functioning within a given period.
  - o Availability. The degree or level when the application is available and active when to be run.

- Fault tolerance. The level where an application still functions is intended despite the presence of hardware or software faults.
- Recoverability. The level where an event of an interruption, break, or a failure, an application can recover the data directly affected and re-establish the desired state.

- **Security:** Refers to the degree to which an application protects information and data so that users or other systems have the level of data access suitable to their types and levels of authorization. It consists of the following characteristics:
  - Confidentiality. The level guarantees that data are accessible only to authorized users to gain access.
  - Integrity. The level of preventing unauthorized access to, or modification of the system.
  - Non-repudiation. The level where events can be confirmed to happen so that these events cannot be rejected later.
  - Accountability. The level of the actions of an entity can be traced inimitably to the entity.
  - Authenticity. The level where the source identity can be proved to be claimed.

- **Maintainability:** Characterizes the effectiveness and efficiency levels where an application can be modified or edited when it needed to. It consists of the following features:
  - Modularity. The level where the system is formed from distinct independent components. In other words, if one component changes, it will have a negligible effect on other components.
  - Reusability. The level of an entity that can be used in more than one structure, or in building other assets.
  - Analyzability. The level of effectiveness and efficiency with which it is possible to assess the impact on a product or system of a proposed change to one or more of its parts, or to diagnose a product for defects or causes of failure, or to identify parts for modification.
  - Modifiability. The level of modification that an application can undergo without decreasing the application quality.

- Testability. The level where test criteria can be tested where these tests can be done to determine whether those criteria can be verified.

- **Portability:** It is the level at which an application or component can be relocated from one place or environment to another. It consists of the following features:
  - Adaptability. The level where an application can be easily adapted and used for different usage environments.
  - Install ability. The level of easiness of an application that can be successfully installed or uninstalled in a specified environment.
  - Replaceability. The level where an application can replace another specified software product for the same purpose in the same environment.

Samples of Mobile Learning Applications for Mathematics

Table 3 presented the total of 6 MMLAs with user ratings of at least 4.5 and 100 000 downloads were selected from Google Play Store and Apple Store. Thus, these 6 MMLAs constitute a sample of MMLAs that were used in this study to create a platform upon which the best mathematics mobile applications in terms of high-quality and user enhancing experience can be selected.

Table 3

Samples of MMLAs

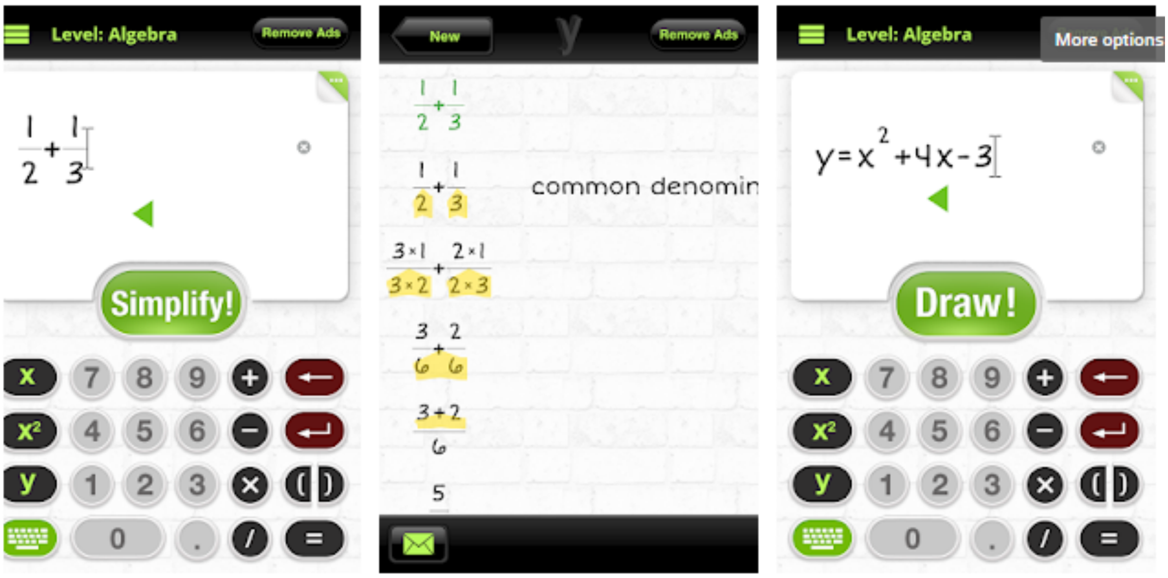
Math application	Google Store		Apple Store	
	User ratings	Downloads in 2018	User ratings	Downloads in 2018
yHomework Math Solver	4.2	1 000 000+	4.6	3 000 000+
Cymath	4.5	100 000+	4.3	100 000+
Malmath	4.6	500 000+	N/A	N/A
Math 42	4.6	500 000+	4.5	3 400 000+
MathPapa	4.7	500 000+	4.7	500 000+
PhotoMath	4.7	50 000 000+	4.8	100 000 000+

yHomework - Math Solver

This application specifically focuses on dealing with algebra issues but also incorporates mathematical topics involving the use of graphs, solving inequalities and other types of equations. The screen shot of vHomework is presented in Figure 5, where it shows the input which the user requires to enter, such as an equation and it automatically computes its answer.

Figure 5

Screenshot Of Yhomework - Math Solver



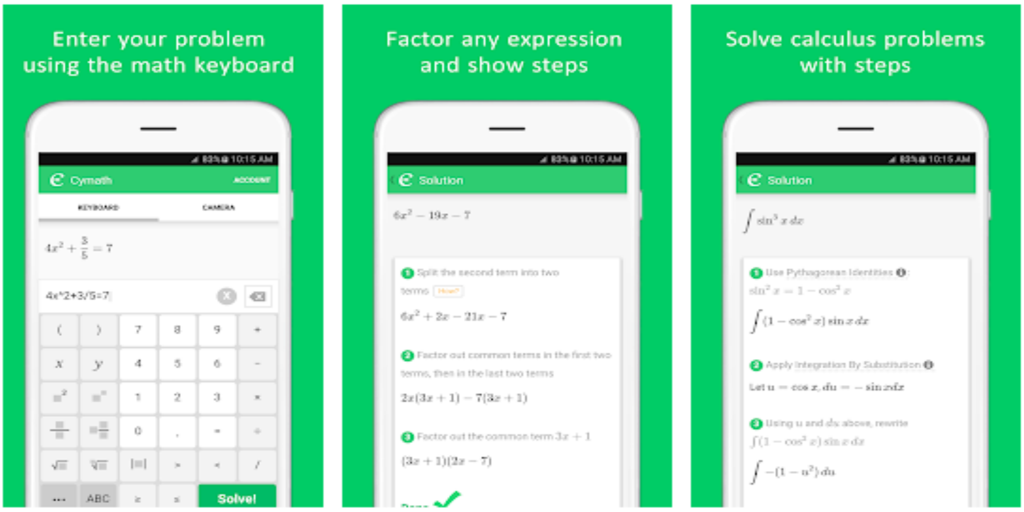
Source: Google Playstore (2019)

Cymath

Cymath is a mathematics application that solves math problems such as algebra (eg. quadratic equations, complex numbers, exponents, logarithms factoring etc.) and calculus (eg. trigonometric substitution, integration, u-substitution, chain rule etc.) using the same mathematical engines. As presented in Figure 6, it simply allows users to enter the mathematical problem and then automatically computes the answer for them.

Figure 6

Screenshot Of Cymath



Source: Google Playstore (2019)

Malmath

MalMath displayed in Figure 7 is a math problem solver with step-by-step description and graph view. It is free and works offline. It helps in dealing with topics involving the solving of integrals, derivatives, limits, trigonometry, logarithms, equations, algebra etc. It helps students to understand the solving process or have problems with their homework. It is helpful for high school and college students, teachers and parents.

Figure 7

Screenshot Of Malmath

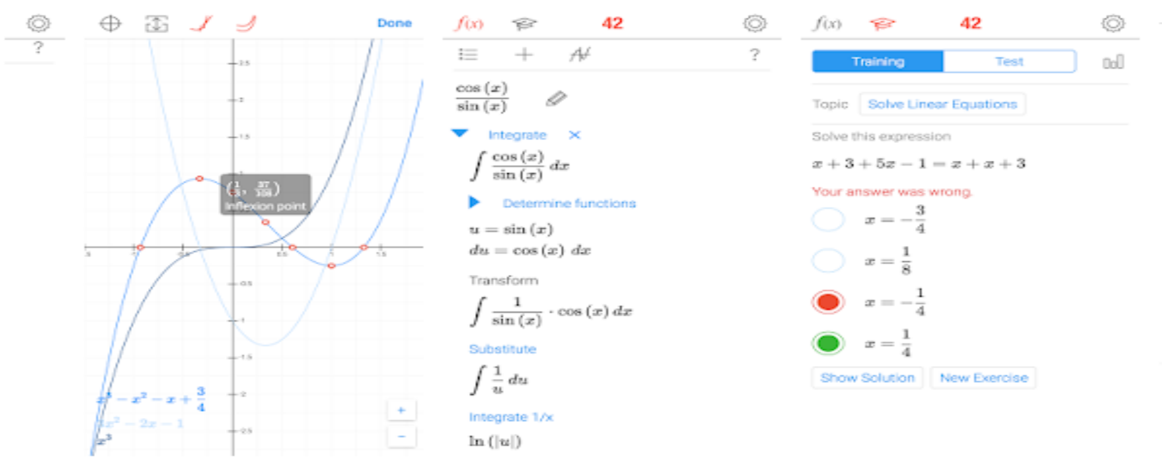
Source: Google Playstore (2019)

Math 42

MATH 42 helps with (1) intelligent approaches to the solution, (2) step-by-step solutions of their problems (3) an Assessment Center. Figure 8 shows that it also includes features such as Intuitive entry of formulas intelligent suggestions on how to approach a problem and detailed step-by-step solution.

Figure 8

Screenshot of Math 42



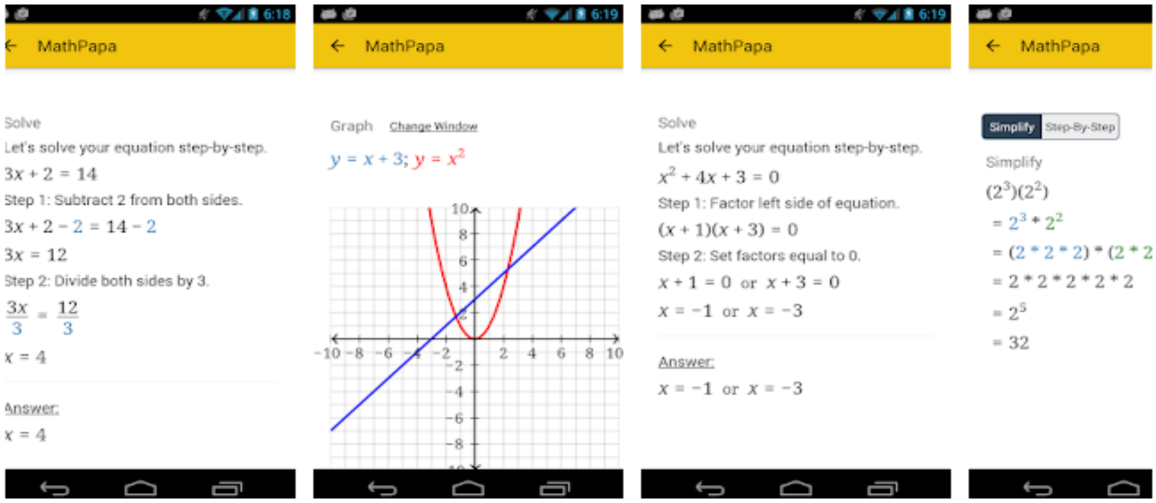
Source: Google Playstore (2019)

MathPapa

MathPapa presented in Figure 9 can solve your equations (showing the steps) and help you when you're stuck on your math homework. Some of its key features involve solving linear equations and quadratic equations, linear and quadratic inequalities, graphs equations etc.

Figure 9

Screenshot of MathPapa



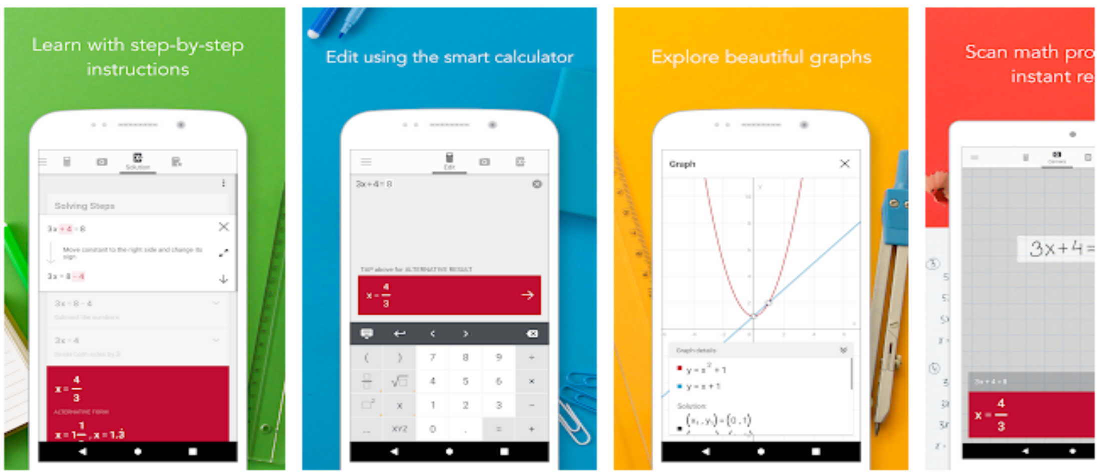
Source: Google Playstore (2019)

PhotoMath

PhotoMath presented in Figure 10 lets users learn how to solve math problems, check homework assignments and study for upcoming exams and ACTs/SATs. Photomath is FREE and works without wi-fi. It also instantly scans printed text AND handwritten math problems using your device's camera or type and edit equations with our scientific calculator.

Figure 10

Screenshot of PhotoMath



Source: Google Playstore (2019)

Research approach

The underlying study was systematically undertaken by adhering to chronologically laid out steps listed as follows;

- Reviewing related studies with the sole aim of identifying both theoretical and empirical gaps surrounding the need to contribute meaningful ideas to the academic body of knowledge. That is, justify the use of the fuzzy TOPSIS to develop a web application that can be used to rank mathematics mobile applications.
- Conceptualization of ideas based on the deduced theoretical and empirical ideas as well as identified gaps.
- Creation of an evaluation framework and the establishment of a platform for ranking the MMLAs.
- Using the fuzzy TOPSIS to develop a web application and rank the MLAMs.
- Discussing the obtained findings, establishing conclusions from the deduced conclusions, and offering recommendations and suggestions for future improvements.

CHAPTER IV
Results

In terms of research purpose, design concepts, and problem-solving methods, the current study has been found practical, where it analyses factors for selecting the most desirable math solving applications from the standpoint of end-users. The ranking process starts with the two decision-makers evaluating six alternatives by using the twelve criteria derived from ISO/IEC 25010 software quality standard metrics. The linguistic scale given in Table 1 was used to evaluate the criteria by the experts. The two decision matrices of the evaluated alternatives were given in Table 4 and Table 5 respectively. Later, the evaluation of the decision-makers was converted into fuzzy scales. Fuzzy decision matrices for decision-maker 1 and decision-maker 2 were shown in Table 6 and Table 7, respectively. By using the linguistic weights given in Table 2, the weighted decision matrix was calculated and is specified in Table 8. The weighted decision matrix is then normalized and ideal solutions were calculated which were given in Table 9. The normalized positive and negative ideal solution matrices are shown in Table 10 and Table 11 respectively. Table 12 shows the closeness to the ideal solutions from highest to lowest and the final ranking of the alternatives. The results revealed that PhotoMath(A6) > Malmath (A3)> Math 42(A4)> Cymath(A2)> MathPapa(A5)> yHomework Math Solver (A1) where PhotoMath has the highest rank whereas yHomework Math Solver has the lowest rank in terms of selected criteria according to fuzzy TOPSIS ranking procedure.

Studies that employ MCDM techniques to evaluate the quality of mobile apps, particularly for Mathematics are quite limited. This constitutes the essential driving motivation to conduct such research. The study has some superior features as compared to the earlier studies in the literature. The authors of an earlier study in (Başaran & Haruna, 2017) only considered five alternatives and merely one decision-maker whereas this research included six alternatives and two decision-makers. Another study applied ELECTRE I to five alternatives with only one decision-maker (Basaran & Aduradola, 2018) whereas the number of decision-makers in this study is two and the number of alternatives is more. It was inferred that the fuzzy TOPSIS method can be quite effortlessly employed. The fuzzy TOPSIS procedure is a popular technique used in other studies where researchers used fuzzy TOPSIS methods to evaluate four general learning applications with 175 students using 25 criteria (Sam et al., 2021) Earlier relevant studies have integrated FAHP and conventional TOPSIS techniques (Başaran & Haruna, 2017) or used TOPSIS to evaluate 6 language learning apps with six experts and 17 criteria (Ibrahim et al., 2019), (Zhao et al., 2021) whereas in the absence of precise performance ratings fuzzy TOPSIS is the prominent technique over conventional TOPSIS which justifies the use of fuzzy TOPSIS in this study.

Table 4

Dm1 Decısıon Matrıx

DM_1	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**	**C_{10}**	**C_{11}**	**C_{12}**
A_1	H	H	L	VH	M	L	VH	L	H	M	H	VH
A_2	L	VL	VH	H	VH	VL	H	L	M	VH	M	H
A_3	H	M	VH	L	VL	H	VL	M	VH	M	VH	L
A_4	VL	VH	M	VH	H	H	M	VH	H	VL	M	M
A_5	VH	H	VL	M	VH	M	VH	H	VL	VH	VL	VH
A_6	H	VL	H	VL	M	VH	H	VL	L	L	VL	H

Table 5

Dm2 Decısıon Matrıx

DM_2	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**	**C_{10}**	**C_{11}**	**C_{12}**
A_1	VH	M	L	L	VH	H	H	L	M	VH	H	H
A_2	H	VH	L	VL	H	VL	L	VH	VH	H	M	M
A_3	L	M	M	H	L	M	H	VH	VL	VL	VH	VH
A_4	M	VL	VH	H	VH	VH	VL	M	H	M	H	M
A_5	VH	VH	H	M	M	H	VH	VL	VH	VH	VL	VL
A_6	H	L	VL	VH	VL	VL	H	H	M	H	L	VL

Table 6

Fuzzy Dm1 Decısıon Matrıx

W	E	VI	NI	E	I	NI	E	I	I	E	VI	E
DM1	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
A1	(0.65,0.8,0.95)	(0.65,0.8,0.95)	(0,0.1,0.2)	(0.9,1,1)	(0.35,0.5,0.65)	(0,0.1,0.2)	(0.9,1,1)	(0,0.1,0.2)	(0.65,0.8,0.95)	(0.35,0.5,0.65)	(0.65,0.8,0.95)	(0.9,1,1)
A2	(0,0.1,0.2)	(0,0,0.1)	(0.9,1,1)	(0.65,0.8,0.95)	(0.9,1,1)	(0,0,0.1)	(0.65,0.8,0.95)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.9,1,1)	(0.35,0.5,0.65)	(0.65,0.8,0.95)
A3	(0.65,0.8,0.95)	(0.35,0.5,0.65)	(0.9,1,1)	(0,0.1,0.2)	(0,0,0.1)	(0.65,0.8,0.95)	(0,0,0.1)	(0.35,0.5,0.65)	(0.9,1,1)	(0.35,0.5,0.65)	(0.9,1,1)	(0,0.1,0.2)
A4	(0,0,0.1)	(0.9,1,1)	(0.35,0.5,0.65)	(0.9,1,1)	(0.65,0.8,0.95)	(0.65,0.8,0.95)	(0.35,0.5,0.65)	(0.9,1,1)	(0.65,0.8,0.95)	(0,0,0.1)	(0.35,0.5,0.65)	(0.35,0.5,.65)
A5	(0.9,1,1)	(0.65,0.8,0.95)	(0,0,0.1)	(0.35,0.5,0.65)	(0.9,1,1)	(0.35,0.5,0.65)	(0.9,1,1)	(0.65,0.8,0.95)	(0,0,0.1)	(0.9,1,1)	(0,0,0.1)	(0.9,1,1)
A6	(0.65,0.8,0.95)	(0,0,0.1)	(0.65,0.8,0.95)	(0,0,0.1)	(0.35,0.5,0.65)	(0.9,1,1)	(0.65,0.8,0.95)	(0,0,0.1)	(0,0.1,0.2)	(0,0.1,0.2)	(0,0,0.1)	(0.65,0.8,0.95)
w	(0.75,0.9,1)	(0.55,0.7,0.85)	(0.15,0.3,0.45)	(0.75,0.9,1)	(0.35,0.55,0.65)	(0.15,0.3,0.45)	(0.75,0.9,1)	(0.35,0.55,0.65)	(0.35,0.55,0.65)	(0.75,0.9,1)	(0.55,0.7,0.85)	(0.75,0.9,1)

Table 7

Fuzzy Dm2 Decısıon Matrıx

W	E	VI	NI	E	I	NI	E	I	I	E	VI	E
DM2	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
A1	(0.9,1,1)	(0.35,0.5,0.65)	(0,0.1,0.2)	(0,0.1,0.2)	(0.9,1,1)	(0.65,0.8,0.95)	(0.65,0.8,0.95)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.9,1,1)	(0.65,0.8,0.95)	(0.65,0.8,0.95)
A2	(0.65,0.8,0.95)	(0.9,1,1)	(0,0.1,0.2)	(0,0,0.1)	(0.65,0.8,0.95)	(0,0,0.1)	(0,0.1,0.2)	(0.9,1,1)	(0.9,1,1)	(0.65,0.8,0.95)	(0.35,0.5,0.65)	(0.35,0.5,0.65)
A3	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.65,0.8,0.95)	(0,0.1,0.2)	(0.35,0.5,0.65)	(0.65,0.8,0.95)	(0.9,1,1)	(0,0,0.1)	(0,0,0.1)	(0.9,1,1)	(0.9,1,1)
A4	(0.35,0.5,0.65)	(0,0,0.1)	(0.9,1,1)	(0.65,0.8,0.95)	(0.9,1,1)	(0.9,1,1)	(0,0,0.1)	(0.35,0.5,0.65)	(0.65,0.8,0.95)	(0.35,0.5,0.65)	(0.65,0.8,0.95)	(0.35,0.5,0.65)
A5	(0.9,1,1)	(0.9,1,1)	(0.65,0.8,0.95)	(0.35,0.5,0.65)	(0.35,0.5,0.65)	(0.65,0.8,0.95)	(0.9,1,1)	(0,0,0.1)	(0.9,1,1)	(0.9,1,1)	(0,0,0.1)	(0,0,0.1)
A6	(0.65,0.8,0.95)	(0,0.1,0.2)	(0,0,0.1)	(0.9,1,1)	(0,0,0.1)	(0,0,0.1)	(0.65,0.8,0.95)	(0.65,0.8,0.95)	(0.35,0.5,0.65)	(0.65,0.8,0.95)	(0,0.1,0.2)	(0,0,0.1)

Table 8

Weighted Decision Matrix

DM	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
A1	(0.65,0.9,1)	(0.35,0.65,0.95)	(0,0.1,0.2)	(0,0.55,1)	(0.35,0.75,1)	(0,0.45,0.95)	(0.65,0.9,1)	(0,0.1,0.2)	(0.35,0.65,0.95)	(0.35,0.75,1)	(0.65,0.8,0.95)	(0.65,0.9,1)
A2	(0,0.45,0.95)	(0,0.5,1)	(0,0.55,1)	(0,0.4,0.95)	(0.65,0.9,1)	(0,0,0.1)	(0,0.45,0.95)	(0,0.55,1)	(0.35,0.75,1)	(0.65,0.9,1)	(0.35,0.5,0.65)	(0.35,0.65,0.95)
A3	(0,0.45,0.95)	(0.35,0.5,0.65)	(0.35,0.75,1)	(0,0.45,0.95)	(0,0.05,0.2)	(0.35,0.65,0.95)	(0,0.4,0.95)	(0.35,0.75,1)	(0,0.5,1)	(0,0.25,0.65)	(0.9,1,1)	(0,0.55,1)
A4	(0,0.25,0.65)	(0,0.5,1)	(0.35,0.75,1)	(0.65,0.9,1)	(0.65,0.9,1)	(0.65,0.9,1)	(0,0.25,0.65)	(0.35,0.75,1)	(0.65,0.8,0.95)	(0,0.25,0.65)	(0.35,0.65,0.95)	(0.35,0.5,0.65)
A5	(0.9,1,1)	(0.65,0.9,1)	(0,0.4,0.95)	(0.35,0.5,0.65)	(0.35,0.75,1)	(0.35,0.65,0.95)	(0.9,1,1)	(0,0.4,0.95)	(0,0.5,1)	(0.9,1,1)	(0,0,0.1)	(0,0.5,1)
A6	(0.65,0.8,0.95)	(0,0.05,0.2)	(0,0.4,0.95)	(0,0.5,1)	(0,0.25,0.65)	(0,0.5,1)	(0.65,0.8,0.95)	(0,0.4,0.95)	(0,0.3,0.65)	(0,0.45,0.95)	(0,0.05,0.2)	(0,0.4,0.95)

Table 9

Normalized Weighted Decision Matrix With Ideal Solutions

Ideal	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
A1	(0.4875, 0.81,	(0.1925,0.455,0.8075)	(0,0.03,0.09)	(0,0.495,1)	(0.1225,0.4125,0.65)	(0,0.135,0.4275)	(0.4875,0.81,1)	(0,0.055,0.13)	(0.1225,0.3575,0.6175)	(0.2625,0.675,1)	(0.3575,0.56,0.8075)	(0.4875,0.81,1)
A2	(0,0.405,	(0,0.35,0.85)	(0,0.165,0.45)	(0,0.36,0.95)	(0.2275,0.495,0.65)	(0,0,0.045)	(0,0.405,0.95)	(0,0.302,0.65)	(0.1225,0.4125,0.65)	(0.4875,0.81,1)	(0.1925,0.35,0.5525)	(0.2625,0.585,0.95)
A3	(0,0.405,	(0.1925,0.35,0.5525)	(0.0525,0.225,0.45)	(0,0.405,0.95)	(0,0.0275,0.13)	(0.0525,0.195,0.4275)	(0,0.36,0.95)	(0.1225,0.4125,0.65)	(0,0.275,0.65)	(0,0.225,0.65)	(0.495,0.7,0.85)	(0,0.495,1)
A4	(0,0.225,	(0,0.35,0.85)	(0.0525,0.225,0.45)	(0.4875,0.81,1)	(0.2275,0.495,0.65)	(0.0975,0.27,0.45)	(0,0.225,0.65)	(0.1225,0.4125,0.65)	(0.2275,0.44,0.6175)	(0,0.225,0.65)	(0.1925,0.455,0.8075)	(0.2625,0.45,0.65)
A5	(0.675,0.	(0.3575,0.63,0.85)	(0,0.12,0.4275)	(0.2625,0.45,0.65)	(0.1225,0.4125,0.65)	(0.0525,0.195,0.4275)	(0.675,0.9,1)	(0,0.22,0.6175)	(0,0.275,0.65)	(0.675,0.9,1)	(0,0,0.085)	(0,0.45,1)
A6	(0.4875, 0.72,	(0,0.035,0.17)	(0,0.12,0.4275)	(0,0.45,1)	(0,0.1375,0.4225)	(0,0.15,0.45)	(0.4875,0.72,0.95)	(0,0.22,0.6175)	(0,0.165,0.4225)	(0,0.405,0.95)	(0,0.035,0.17)	(0,0.36,0.95)
A +	(0.675,0.	(0.3575,0.65,0.85)	(0.0525,0.225,0.45)	(0.4875,0.81,1)	(0.2275,0.495,0.65)	(0.0525,0.195,0.45)	(0.675,0.9,1)	(0.1225,0.4125,0.65)	(0.1225,0.4125,0.65)	(0.675,0.9,1)	(0.495,0.7,0.85)	(0.4875,0.81,1)
A^-	(0,0.225,	(0,0.035,0.17)	(0,0.03,0.09)	(0,0.36,0.95)	(0,0.0275,0.13)	(0,0.135,0.4275)	(0,0.225,0.65)	(0,0.055,0.13)	(0,0.165,0.4225)	(0,0.225,0.65)	(0,00.085)	(0,0.36,0.95)

Table 10

Normalızed Posıtıve Ideal Solutıon Matrıx

FPIS	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	d+i
A1	0.14077908	0.22114758	0.41054080	0.42242603	0.10237798	0.07088723	0.14077908	0.63498688	0.06388466	0.32763356	0.16645820	0.00000000	2.70190108
A2	0.34985711	0.36414569	0.06722165	0.53312170	0.00000000	0.45052053	0.63198101	0.13077493	0.00000000	0.14077908	0.49143497	0.26457513	3.42441182
A3	0.63198101	0.43310651	0.00000000	0.49572548	0.71148319	0.02250000	0.66781360	0.00000000	0.15462320	0.85440037	0.00000000	0.42242603	4.39405939
A4	0.85440037	0.36414569	0.00000000	0.00000000	0.00000000	0.07937254	0.85440037	0.00000000	0.07407766	0.85440037	0.30386400	0.51862800	3.90328902
A5	0.00000000	0.02000000	0.11157957	0.51862800	0.10237798	0.02250000	0.00000000	0.20764051	0.15462320	0.00000000	1.07559286	0.45696690	2.66990902
A6	0.21591376	0.93980162	0.11157957	0.45696690	0.44363790	0.05425634	0.21591376	0.20764051	0.34353251	0.63198101	0.99312638	0.53312170	5.14747195

Table 11

Normalızed Negatıve Ideal Solutıon Matrıx

FINS	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	d-i
A1	0.737525423	0.771465056	0.000000000	0.143961800	0.650866410	0.000000000	0.737525423	0.000000000	0.282989988	0.589888761	0.937127704	0.533121703	5.384472269
A2	0.349857114	0.749416440	0.384480169	0.000000000	0.711483193	0.405624518	0.349857114	0.575896041	0.343532507	0.737525423	0.594481567	0.271281680	5.473435765
A3	0.349857114	0.073663180	0.410540802	1.034952088	0.000000000	0.067221648	0.328975683	0.634986877	0.252697942	0.000000000	1.075592860	0.143961800	4.372449993
A4	0.000000000	0.749416440	0.403670638	0.533121703	0.711483193	0.147986486	0.000000000	0.634986877	0.361803929	0.000000000	0.861036197	0.347949350	4.751454812
A5	0.562352490	0.609248723	0.349293931	0.347949350	0.650866410	0.067221648	0.854400375	0.514666154	0.252697942	0.854400375	0.000000000	0.102956301	5.166053698
A6	0.643617705	0.000000000	0.349293931	0.102956301	0.312500000	0.027041635	0.643617705	0.514666154	0.000000000	0.349857114	0.091923882	0.000000000	3.035474426

Table 12

Fınal Rankıng Of Alternatıves

Rank	d-i	d+i	D+i+D-i	Cci	Rank
yHomework Math Solver (A1)	2.701901083	5.384472269	8.086373351	0.334130143	6
Cymath(A2)	3.42441182	5.473435765	8.897847585	0.384858449	4
Malmath (A3)	4.394059393	4.372449993	8.766509386	0.501232497	2
Math 42(A4)	3.903289017	4.751454812	8.654743829	0.450999948	3
MathPapa(A5)	2.669909017	5.166053698	7.835962715	0.340725079	5
PhotoMath(A6)	5.147471948	3.035474426	8.182946373	0.629048721	1

This research followed the stages that other literature used while using fuzzy TOPSIS. It passed through different stages to implement fuzzy TOPSIS, Starting from defining the alternatives, and their criteria, constructing decision matrix, then normalizing it, assigning weights over the normalized decision matrix, determining the positive and negative solutions, till it reached to calculate the relative closeness, that enable the ranking of the picked alternatives as it is displaced in Table 12, where Photomath A6, got the highest closeness coefficient that implies that it is the best mobile application within the selected pool. This research and others before it exhibited the possibility of using a framework for ranking applications. this research used it to rank mathematical mobile learning applications through the use of fuzzy TOPSIS following the ISO standards regulations.

CHAPTER V
CONCLUSION

Conclusion

The main contribution of this study is to compare and evaluate mathematical learning mobile applications for students. The study considered 12 criteria to be used for the evaluating process. Six mathematical mobile applications were chosen to be evaluated and ranked under TOPSIS techniques. User satisfaction, functionality, learnability, and effectiveness were observed as important factors while evaluating MMLAs. The research was implemented because the user ratings of mobile applications at the app stores are not sufficient for revealing the essential quality of the mobile applications. Therefore, developing a multi-criteria decision evaluating to rank mobile mathematics learning applications was needed, this study intends to enhance the use and effectiveness of mobile Mathematics learning applications thereby improving the quality of learning across all learning platforms. In addition, the study also helps in setting standards concerning ISO practices upon which the quality and usability of MMLAs can be determined. It also contributes to the research of mobile applications through the use of fuzzy TOPSIS.

Future Recommendation

Tends to focus on increasing the number of decision-makers, alternatives as well as comparing and contrasting the efficiency of different MCDM methods applied to improve the precision of the selection process. It is recommended that a user-friendly interface or software could be initiated for the service of decision-makers.

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APPENDICES

APPENDIX A

ETHICAL APPROVAL DOCUMENT

NEAR EAST UNIVERSITY

BİLİMSEL ARAŞTIRMALAR ETİK KURULU

07.06.2022

Dear Firass El Homsi

Your project ***"Multı-Crıterıa Decısıon Makıng Of Mobıle Applıcatıon For Mathematıcs Usıng Fuzzy Topsıs Technıque)"*** *has been evaluated. Since only secondary data will be used the project it does not need to go through the ethics committee. You can start your research on the condition that you will use only secondary data.*

Assoc. Prof. Dr. Direnç Kanol

Rapporteur of the Scientific Research Ethics Committee

Direnc Kanol

Note: If you need to provide an official letter to an institution with the signature of the Head of NEU Scientific Research Ethics Committee, please apply to the secretariat of the ethics committee by showing this document

APPENDIX B

PLAGIARISM REPORT

Firass El Homsi Master Thesis

ORIGINALITY REPORT

15%	12%	11%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	neu.edu.tr Internet Source	1%
2	Manindra Rajak, Krishnendu Shaw. "Evaluation and selection of mobile health (mHealth) applications using AHP and fuzzy TOPSIS", Technology in Society, 2019 Publication	1%
3	zenodo.org Internet Source	1%
4	vital.seals.ac.za:8080 Internet Source	1%
5	Guohua Qu, Zhijie Zhang, Weihua Qu, Zeshui Xu. "Green Supplier Selection Based on Green Practices Evaluated Using Fuzzy Approaches of TOPSIS and ELECTRE with a Case Study in a Chinese Internet Company", International Journal of Environmental Research and Public Health, 2020 Publication	1%