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ANALYSIS OF STUDENTS' PREFERENCES ON MATHEMATICS MOBILE APPLICATIONS USING FUZZY TOPSIS BASED ON RATINGS OF SUB-CRITERIA

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Abstract:

This study addresses the challenge of selecting the most effective Mathematics mobile applications amidst a growing array of tools with varied features and user experiences. It presents an analysis of students' preferences using the Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method, based on ratings of various sub-criteria. This research involved collecting and aggregating student feedback on different applications, assessing criteria such as functionality, quality, features and efficiency. Mathematics mobile applications that are frequently used by students are Symbolab, Photomath, Mathway, Malmath, and Cymath. There is a problem identified in this study which the secondary data from Jumadi and Imran (2023) that uses Fuzzy Grade Matrix does not meet the criteria to apply Fuzzy TOPSIS. Therefore, aggregation of sub criteria is done to apply the Fuzzy TOPSIS effectively. There are three objectives in this study which are to transform sub-criteria to criteria using aggregated method, to determine each criterion's fuzzy weight, to rank the mathematical mobile applications using Fuzzy TOPSIS based on ratings of sub-criteria. The use of fuzzy set addressed the inherent uncertainties and subjectivities in these ratings, providing a more accurate and reliable assessment. Subsequently, the Fuzzy TOPSIS method was applied to rank the applications that consists of nine steps in the methodology. Mathematics mobile applications were analyzed, and the rankings are as Symbolab $\approx$ Photomath $\succ$ Mathway $\succ$ Cymath $\succ$ Malmath. This shows that Symbolab and Photomath are the most preferred Mathematics mobile applications. For criteria, the rankings are as functionality $(X4)$ $\succ$

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quality ($X3$) ≻ features ($X1$) ≻ efficiency ($X2$). This implies that when it comes to assessing these applications by students, the most crucial criteria are functionality. The findings provide valuable insights for educators and developers, aiding in the selection and improvement of mathematics learning tools.

Keywords:

Applications; Fuzzy Topsis; Learning; Mathematics; Students; Preferences.

Introduction

In this rapidly evolving landscape of education, technology in education has increased in different ways to help students and also lecturers. Mobile applications are one of the recent technologies that are a help in the education field. Mobile applications are types of application that can be downloaded on different types of devices that can be used either offline or online. So, the application can be used anywhere at any time. It will be convenient for students as the application is mobile, which the students can use at different locations for different occasions based on the applications' function.

Nowadays, there are many types of mathematics mobile applications that are useful for students. Each of the mathematics mobile applications is different from each other as each of them have specific subjects or uses for it. Based on research from Drigas and Pappas (2015) researchers have developed online learning and mobile applications for Mathematics subjects like Algebra, Geometry, Mathematical Analysis, Statistics and more. Mathematics mobile applications allow users to explore functions in the applications based on user needs. The user needs to know the function of the application to solve the users' needs. Mathematics mobile applications vary from specific calculator to graphical calculator to many other different functions for mathematics subjects. For example, the mathematics mobile applications that are frequently used by students are Symbolab, Photomath, Mathway, Malmath, and Cymath. Despite the availability of many apps, students often face difficulty choosing the most suitable one due to inconsistent performance, usability differences, and a lack of comprehensive evaluation across various quality dimensions. This gap highlights the need for a structured approach to assess and rank these applications effectively. The majority of fuzzy TOPSIS methods take into account the ratings of alternatives for each primary criterion, but there is a shortage of studies that utilize ratings based on sub-criteria.

For this study, Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) that a MCDM method developed by Hwang and Yoon (1981) will be used to study analysis on students' preferences on mathematics mobile applications. By using fuzzy TOPSIS, this study will help students in choosing the best mathematics mobile application that suits the most specific uses by ranking the applications. The Fuzzy TOPSIS methodology, grounded in fuzzy set theory, allows for a nuanced and comprehensive evaluation of the varied criteria influencing students' choices in the realm of mathematics applications. By employing Fuzzy TOPSIS in this study, it is evident that while Fuzzy TOPSIS requires criteria for its calculations, this study incorporates sub-criteria due to its application in previous studies by Jumadi and Imran (2023) using the Fuzzy Grade Matrix. Therefore, it was necessary to aggregate the sub-criteria into criteria to effectively perform the Fuzzy TOPSIS analysis.

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Literature Review

The field of Mathematics education has changed as a result of the formation of mobile learning applications into formal learning environments. Given the widespread use of smartphones and tablets, educators are looking into creative ways to improve the mathematical learning experiences of their students. In order to shed light on the efficacy, difficulties, and possible effects of mobile learning applications for Mathematics education, this review of the literature explores the body of research in this area. Mobile devices function with the name mobile that can be used anywhere. Therefore, mathematics mobile applications can improve learning anytime, anywhere by giving users access to educational materials even when they're not in class. Students can reduce their idle time thanks to this flexibility, which could improve their work-education balance (Motiwalla, 2007). Mathematics mobile applications start growing slowly one-by-one with different functions. Based on a research, the applications start with simple applications and grow more in depth in another Mathematical area such as Algebra, Statistics and others (Athanasios, et al,2015). As users become familiar with simple applications, their interest often expands towards more specialized mathematical areas. This trend suggests a growing demand for diverse and comprehensive mathematical tools to cater to various educational and professional needs. Developers can continually strive to enhance these applications, providing users with versatile tools to explore and apply mathematical concepts efficiently. In addition, mathematics mobile applications can also help students in increasing general metacognitive skills, improve their understanding of mathematical concepts, help to solve problems, and give dynamic representations of various ideas (Pierce et al., 2007).

Fuzzy TOPSIS which refers to (Technique for Order Preference by Similarity to Ideal Solution) is being frequently used by many researchers that involves decision criteria. Based on research by Azaman, Bidin, Sharif, & Ku Akil (2023), it tells us that there are many influential factors in selection of university. So, by using Fuzzy TOPSIS to their research, it can determine the most important factor influencing students' choice of university and will help the study to rank the criteria so the study can benefit those who are related to the study such as students and universities. A similar study by Muhammat Pazil et al., (2018) also explored key factors in university selection; however, their research focused on comparing IPTA and IPTS, distinguishing it from the current study. For the topic related to choosing university is popular research nowadays, that needed Fuzzy TOPSIS method to solve the problem because it is related to MCDM problem which offers a powerful framework to systematically analyze and rank alternatives in the presence of uncertainty and imprecise information.

On another journal, the objective of the research is to use the Fuzzy TOPSIS approach to select high-quality and user-enhancing experiences of mobile learning applications for Mathematics (Basaran & Homsi, 2022). The research is related to this journal which gave more information to support this project. The types of data that were used for the study are combinations of primary and secondary data. The synergy between primary and secondary data enhances the depth and breadth of research studies, combining the strengths of detailed primary data with the efficiency and broader context provided by secondary data (Enonge et al., 2021). The primary data is collected by interviewing experts and secondary data was collected from Google Play Store and Apple Store. The conclusion for the research is that by using Fuzzy TOPSIS it will help to achieve the aim and improve the use and effectiveness of mathematics mobile learning applications and learning quality across platforms. This will also increase students' motivation to learn and engage in more than traditional teaching methods (Drigas & Pappas, 2015).

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There are varieties of Fuzzy method for MCDM method such as Fuzzy TOPSIS, Fuzzy grade matrix, Fuzzy AHP, Fuzzy DEMATEL and others. Based on a journal from Moayeri et al., (2015), the aim of the research is to use the Fuzzy AHP and Fuzzy TOPSIS methods for selecting Mathematics teachers in education and institutions. The research contains two different MCDM methods which are combination of Fuzzy AHP and Fuzzy TOPSIS. Thus, this will help in increasing information and understanding in depth for this study as this study involves data from Fuzzy grade matrix and needed to develop to Fuzzy TOPSIS. The calculation for Fuzzy AHP and Fuzzy TOPSIS is compared and the most appropriate is chosen from the methods. The conclusion for the study is that both methods had the same outcome and based on that, the best alternative was chosen. Drawing upon an extensive review of relevant journals in the field, it shows that Fuzzy TOPSIS is the most popular method to use to solve MCDM problem as Fuzzy TOPSIS is evidently a frontrunner in providing robust solutions and offers advantages such as ease of implementation for decision-makers facing multifaceted criteria and varying degrees of uncertainty (Han & Trimi, 2018).

Methodology

Fuzzy Set Theory

This study utilized the Fuzzy TOPSIS approach to evaluate students' preferences for Mathematics Mobile Learning Application. Based on the secondary data that were collected from Jumadi and Imran (2023), this study involved 33 male and 67 female students. This study investigates to rank the mathematical mobile applications using Fuzzy TOPSIS based on ratings of sub-criteria. In the second stage, which includes nine phases, the Fuzzy TOPSIS method was calculated.

Table 1: Main Criteria And Sub-Criteria To Evaluate Mathematics Mobile Learning Applications' Selection (Jumadi & Imran, 2023).

Main Criteria	Sub-criteria
Features (X_1)	Approachability (X_{11}) Discoverable (X_{12}) Well-organized (X_{13})
Efficiency (X_2)	Availability (X_{21}) Security (X_{22}) Runtime (X_{23})
Quality (X_3)	Effectiveness (X_{31}) Error handling (X_{32}) User-friendly (X_{33})
Functionality (X_4)	Appropriateness (X_{41}) Lernability (X_{41}) Reliability (X_{41})

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Table 2: The Fuzzy Linguistic Character And Triangular Fuzzy Number For Main Criteria (Kabir & Hasin, 2012).

Linguistic Character	Triangular Fuzzy Number
Very Low (VL)	(0,0,0.1)
Low (L)	(0, 0.1, 0.3)
Medium Low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1)
Very High (VH)	(0.9, 1, 1)

Table 3: The Fuzzy Linguistic Character And Triangular Fuzzy Number For Every Sub-criteria Weight (Turker Et Al., 2019).

Linguistic Character	Triangular Fuzzy Number
Very Good (VG)	(9,10,10)
Good (G)	(7,9,10)
Medium Good (MG)	(5,7,9)
Fair (F)	(3,5,7)
Medium Poor (MP)	(1,3,5)
Poor (P)	(0,1,3)
Very Poor (VP)	(0,1,1)

Fuzzy TOPSIS with Ratings based on Benefit and Cost Sub-criteria

The methodology of the proposed model is applied in the following steps to solve problems of decision making.

Step 1: Determination of linguistic terms, membership functions and the weightage of evaluation criteria.

The linguistic variables for all criteria must be identified. This is because a set of membership functions will be indicated by each linguistic variable. Thus, linguistic phrases are taken into consideration when deciding the weight to give the evaluation criteria and to rate the alternatives.

Step 2: Create the fuzzy decision matrix.

The linguistic factors and the criteria alternatives are closely related to the decision matrix. Let *m* be the number of alternatives and *n* be the number of criteria. As a result, the following matrix, which has *m* rows and *n* columns, will be the fuzzy decision matrix:

$$\widetilde{D} = \begin{array}{c} \widetilde{A_1} \\ \widetilde{A_2} \\ \widetilde{A_3} \end{array} \begin{bmatrix} \widetilde{d_{11}} & \widetilde{d_{12}} & \widetilde{d_{13}} \\ \widetilde{d_{21}} & \widetilde{d_{22}} & \widetilde{d_{23}} \\ \widetilde{d_{31}} & \widetilde{d_{32}} & \widetilde{d_{33}} \end{bmatrix} \quad (1)$$

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By rows $\widetilde{A_1}, \widetilde{A_2}, \dots\dots, \widetilde{A_m}$ are alternatives which refer to the factors that affecting Mathematics Mobile Learning Applications' selection. By columns, $C_1, C_2, \dots\dots, C_n$ are referred to the criteria that have been considered to rate the alternatives.

Step 3: Normalize the fuzzy decision matrix.
Normalization of fuzzy decision matrix is completed using linear scale transformation.

$$q_{ij} = \left(\frac{\widetilde{a_{ij}}}{c_j^+}, \frac{\widetilde{b_{ij}}}{c_j^+}, \frac{\widetilde{c_{ij}}}{c_j^+}\right) \text{ and } c_j^+ = \max c_{ij} \ \ (benefit) \quad (2)$$
$$q_{ij} = \left(\frac{\tilde{a}_j^-}{a_{ij}}, \frac{\tilde{a}_j^-}{b_{ij}}, \frac{\tilde{a}_j^-}{c_{ij}}\right) \text{ and } a_j^- = \min a_{ij} \ \ (\text{cost}) \quad (3)$$

The normalized fuzzy decision matrix can be represented as below:
$$Q = [q_{ij}]_{m\times n}, i = 1,2, \dots. m\,; j = 1,2, \dots J \quad (4)$$

Step 4: Based on the sub-criteria from grade matrix method, perform the aggregation on the sub-criteria to transform to criteria. Total all the weightage of the criteria and alternatives.

Step 5: The weighted normalized fuzzy decision matrix will be calculated.
The calculation for the weighted normalized fuzzy decision matrix V is derived by multiplying the weights, w_{ij} of evaluation criteria with the normalized value r_{ij} from fuzzy decision matrix. The weighted normalized decision matrix can be represented by equation 7:

$$T = [t_{ij}]_{n\times j}, i = 1,2, \dots. n\,; j = 1,2, \dots n \quad (5)$$
Where,
$$t_{ij} = r_{ij}(.)w_i \quad (6)$$

Step 6: Determine the Fuzzy Positive-Ideal Solution (FPIS A^+) and Fuzzy Negative-Ideal Solution (FNIS A^-).

$$A^+ = (t_1, t_2, t_3, \dots\dots, t_n), t = max\{t_{ij}\} \quad (7)$$
$$A^- = (t_1, t_2, t_3, \dots\dots, t_n), t = min\{t_{ij}\} \quad (8)$$

Step 7: The distance of each alternative from FPIS and FNIS will be calculated.
To calculate the distance between two triangular fuzzy numbers, the formula that will be used are:
$$e_t(a, b) = \sqrt{\frac{1}{3}[(a_0 - b_0)^2 + (a_1 - b_1)^2 + (a_2 - b_2)^2]} \quad (9)$$

To find the distance of each alternative from FPIS (b_0, b_1, b_2), must be equal to (1,1,1) while FNIS must be equal to (0,0,0).

$$e_i^+ = \sqrt{\frac{1}{3}[(t_1 - 1)^2 + (t_2 - 1)^2 + (t_3 - b)^2]} \quad (10)$$
$$e_i^- = \sqrt{\frac{1}{3}[(t_1 - 0)^2 + (t_2 - 0)^2 + (t_3 - 0)^2]} \quad (11)$$

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Step 8: Determine the closeness coefficient and the weightage ranking.

$$CC_i = \frac{e_i^-}{e_i^- + e_i^+} \tag{12}$$

For weightage:
Weightage in triangular fuzzy number:
$$w_t = (a, b, d) \tag{13}$$
Weightage in trapezoidal fuzzy number:
$$w_j = (a, b, b, d) \tag{14}$$

To calculate the weightage ranking, the equation below is used:

$$x_0 = \frac{1}{3}\left(a + b + c + d - \left(\frac{dc - ab}{(d + c) - (a + b)}\right)\right) \tag{15}$$

$$y_0 = \frac{1}{3}\left(1 + \left(\frac{c - b}{(d + c) - (a + b)}\right)\right) \tag{16}$$

$$D = \sqrt{x_0^2 + y_0^2} \tag{17}$$

Step 9: The order of all alternatives will be ranked.
The closeness coefficients that have been calculated are used to rank the alternatives. The best option is indicated by the alternative with the highest coefficient.

Implementation
Step 1: Determination of linguistic terms, membership functions and the weightage of evaluation criteria.

100 decision makers were chosen for this study. The decision makers are defined as DM1 until DM100. Linguistic terms for each criterion were determined from the answers of the survey which were categorized from very low to very high. Then, a table containing all the data will be created to facilitate structure. Table 4 shows the list of the first 10 decision makers while the remaining decision makers are listed in the appendix.

Table 4: Importance Level Of Each Criterion By First 10 Decision Makers

Decision Maker	Criteria			
	X_1	X_2	X_3	X_4
DM1	VL	VL	VL	VL
DM2	VH	VH	VH	VH
DM3	MH	VH	VH	VH
DM4	VH	VH	VH	VH
DM5	VH	VH	VH	VH
DM6	VH	VH	VH	VH
DM7	VH	VH	VH	VH
DM8	VH	VH	VH	VH

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DM9	MH	ML	ML	MH
DM10	VH	VH	VH	VH

Then, linguistic variables for weightage will be changed into triangular fuzzy number functions. This is because by using triangular fuzzy numbers, the weightage is easier to calculate. Table 5 below shows the list of the first 10 decision makers while the remaining decision makers are listed in the appendix.

Table 5: Criteria Weightage In Triangular Fuzzy Number By First 10 Decision Makers

Decision Maker	Criteria			
	X_1	X_2	X_3	X_4
DM1	(0,0,0.1)	(0,0,0.1)	(0,0,0.1)	(0,0,0.1)
DM2	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
DM3	(0.5,0.7,0.9)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
DM4	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
DM5	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
DM6	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
DM7	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
DM8	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
DM9	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.5,0.7,0.9)
DM10	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)

Linguistic terms for each ratings level were determined from answers of the survey which was categorized from very good to very poor. Then, a table containing all the data will be created to facilitate structure. Table 6 shows the ratings level of each criterion of the first decision maker while the remaining are listed in the appendix.

Table 6: Ratings Level Of Each Criterion By Decision Maker

Criteria	Sub-criteria	DM1				
		Symbolab	Photomath	Mathway	Malmath	Cymath
X_1	X_{11}	VG	G	VG	G	G
	X_{12}	VG	VG	VG	G	VG
	X_{13}	VG	G	G	MG	MG
X_2	X_{21}	VG	G	G	G	G
	X_{22}	G	G	MG	MG	MG
	X_{23}	G	G	G	MG	MG
X_3	X_{31}	VG	G	VG	G	G
	X_{32}	G	G	G	MG	MG
	X_{33}	G	G	G	G	G
X_4	X_{41}	G	G	G	G	G
	X_{42}	VG	VG	G	MG	G
	X_{43}	VG	VG	G	G	G

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Then, linguistic variable for ratings will be changed into triangular fuzzy number. This is because by using triangular fuzzy number the weightage is easier to calculate. Table 7 shows the ratings level of each criterion in triangular fuzzy number of the first decision maker while the remaining are listed in the appendix.

Table 7: Ratings Level Of Each Criterion By Decision Maker In Triangular Fuzzy Number

Criteria	Sub-criteria	DM1				
		Symbolab	Photomath	Mathway	Malmath	Cymath
X_1	X_{11}	(9,10,10)	(7,9,10)	(9,10,10)	(7,9,10)	(7,9,10)
	X_{12}	(9,10,10)	(9,10,10)	(9,10,10)	(7,9,10)	(9,10,10)
	X_{13}	(9,10,10)	(7,9,10)	(7,9,10)	(5,7,9)	(5,7,9)
X_2	X_{21}	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)
	X_{22}	(7,9,10)	(7,9,10)	(5,7,9)	(5,7,9)	(5,7,9)
	X_{23}	(7,9,10)	(7,9,10)	(7,9,10)	(5,7,9)	(5,7,9)
X_3	X_{31}	(9,10,10)	(7,9,10)	(9,10,10)	(7,9,10)	(7,9,10)
	X_{32}	(7,9,10)	(7,9,10)	(7,9,10)	(5,7,9)	(5,7,9)
	X_{33}	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)
X_4	X_{41}	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)
	X_{42}	(9,10,10)	(9,10,10)	(7,9,10)	(5,7,9)	(7,9,10)
	X_{43}	(9,10,10)	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)

Step 2: Create the fuzzy decision matrix.
This calculation will be repeated for all decision makers and alternatives.

$$\text{DM1 :} \begin{pmatrix} (9,10,10) & (7,9,10) & (9,10,10) & (7,9,10) & (7,9,10) \\ (9,10,10) & (9,10,10) & (9,10,10) & (7,9,10) & (9,10,10) \\ (9,10,10) & (7,9,10) & (7,9,10) & (5,7,9) & (5,7,9) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ (9,10,10) & (9,10,10) & (7,9,10) & (7,9,10) & (7,9,10) \end{pmatrix}$$

Step 3: Normalize the fuzzy decision matrix.
To normalize the fuzzy decision matrix, benefit criteria and cost criteria must be categorized. All sub-criteria are benefit criteria for every decision maker. Therefore, by dividing each fuzzy number by the maximum for each of them, the fuzzy decision matrix can be normalized. This calculation will be repeated for all decision makers and alternatives. Table 7 and 8 show the ratings level before and after normalization of the first decision makers while the remaining are listed in the appendix. As all the sub-criteria are benefit criteria, to normalize, equation (2) is used.

For Symbolab,

$$X_{11} = \left(\frac{9}{10}, \frac{10}{10}, \frac{10}{10}\right)$$
$$X_{11} = (0.9,1,1)$$
$$X_{21} = \left(\frac{9}{10}, \frac{10}{10}, \frac{10}{10}\right)$$

$$X_{31} = \left(\frac{9}{10}, \frac{10}{10}, \frac{10}{10}\right)$$
$$X_{31} = (0.9,1,1)$$
$$X_{41} = \left(\frac{7}{10}, \frac{9}{10}, \frac{10}{10}\right)$$

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$X_{21} = (0.9,1,1)$ $X_{31} = (0.7,0.9,1)$

Table 8: Ratings Level After Normalization

Criteria	Sub-criteria	DM1				
		Symbolab	Photomath	Mathway	Malmath	Cymath
X_1	X_{11} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{12} (B)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)
	X_{13} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)
X_2	X_{21} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{22} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)	(0.56,0.78,1)
	X_{23} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)
X_3	X_{31} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{32} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)
	X_{33} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
X_4	X_{41} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{42} (B)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.7,0.9,1)
	X_{43} (B)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)

Step 4: Based on the sub-criteria from grade matrix method, perform the aggregation on the sub-criteria to transform to criteria. Total all the weightage of the criteria and alternatives.
To perform aggregation on the sub-criteria, the value for each sub-criteria in each criterion for each alternative such as Symbolab, was calculated by summing up the value then averaging the value. This calculation will be repeated for all criteria and decision makers. Table 9 below shows the average of each sub-criteria for each decision maker of the first decision makers while the remaining are listed in the appendix.
By using the average formula:

For Symbolab, X_1,

$$= \frac{X_{11} + X_{12} + X_{13}}{3}$$
$$= \frac{(0.9,1,1) + (0.9,1,1) + (0.9,1,1)}{3}$$
$$= (0.9,1,1)$$

Table 9: Average Of Each Sub-criteria For Each Decision Maker

Criteria	Sub-criteria	DM1				
		Symbolab	Photomath	Mathway	Malmath	Cymath
X_1	X_{11} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{12} (B)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)
	X_{13} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)
	AVG	(0.9,1,1)	(0.77,0.93,1)	(0.83,0.97,1)	(0.65,0.86,1)	(0.72,0.89,1)
X_2	X_{21} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{22} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)	(0.56,0.78,1)
	X_{23} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)

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	AVG	(0.77,0.93,1)	(0.7,0.9,1)	(0.65,0.86,1)	(0.61,0.82,1)	(0.61,0.82,1)
X_3	X_{31} (B)	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{32} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.56,0.78,1)
	X_{33} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
	AVG	(0.77,0.93,1)	(0.7,0.9,1)	(0.77.0.93,1)	(0.65,0.86,1)	(0.65,0.86,1)
X_4	X_{41} (B)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
	X_{42} (B)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)	(0.56,0.78,1)	(0.7,0.9,1)
	X_{43} (B)	(0.9,1,1)	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
	AVG	(0.83,0.97,1)	(0.83,0.97,1)	(0.7,0.9,1)	(0.65,0.86,1)	(0.7,0.9,1)

To calculate aggregation of ratings level for each criterion and alternative.
For Symbolab, X_1,

$$\sum X_1 = (min, avg, max)$$

Table 10: Aggregate Of Ratings Level For Each Criterion And Alternatives

R	X_1	X_2	X_3	X_4
Symbolab	(0.3,0.008951,1)	(0.13,0.009023,1)	(0.07,0.008971,1)	(0.07,0.008971,1)
Photomath	(0.2,0.00895,1)	(0.2,0.008897,1)	(0.2,0.008852,1)	(0.2,0.008852,1)
Mathway	(0.21,0.008678,1)	(0.07,0.008721,1)	(0.07,0.008675,1)	(0.07,0.008675,1)
Malmath	(0.32,0.008236,1)	(0.2,0.008407,1)	(0.13,0.008393,1)	(0.13,0.008393,1)
Cymath	(0.21,0.008232,1)	(0.13,0.008406,1)	(0.13,0.008429,1)	(0.13,0.008428,1)

To calculate aggregation of weightage for each criterion.

$$\sum X_1 = (min, avg, max), \sum X_2 = (min, avg, max),$$
$$\sum X_3 = (min, avg, max), \sum X_4 = (min, avg, max)$$

Table 11: Aggregate Of Weightage For Each Criterion

W	X_1	X_2	X_3	X_4
Aggregated	(0,0.77,1.0)	(0, 0.853, 1.0)	(0, 0.825, 1.0)	(0, 0.901, 1.0)

Step 5: The weighted normalized fuzzy decision matrix will be calculated.
Let R be aggregate for ratings level in matrix form and W be aggregate for weightage in matrix form. To obtain the weighted normalized fuzzy decision matrix, R is multiplied by W to create V, the weighted normalized fuzzy decision matrix which is calculated using equation (6).

$$R = \begin{pmatrix} (0.3,0.008951,1) & (0.13,0.009023,1) & (0.07,0.008971,1) & (0.07,0.008971,1) \\ (0.2,0.00895,1) & (0.2,0.008897,1) & (0.2,0.008852,1) & (0.2,0.008852,1) \\ (0.21,0.008678,1) & (0.07,0.008721,1) & (0.07,0.008675,1) & (0.07,0.008675,1) \\ (0.32,0.008236,1) & (0.2,0.008407,1) & (0.13,0.008393,1) & (0.13,0.008393,1) \\ (0.21,0.008232,1) & (0.13,0.008406,1) & (0.13,0.008429,1) & (0.13,0.008428,1) \end{pmatrix}$$

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$$W = \begin{pmatrix} (0{,}0.77{,}1.0) \\ (0, 0.853, 1.0) \\ 0, 0.825, 1.0) \\ (0, 0.901, 1.0) \end{pmatrix}$$

$$V = \begin{pmatrix} (0, 0.0069, 1) & (0, 0.0077, 1) & (0, 0.0074, 1) & (0, 0.0081, 1) \\ (0, 0.0069, 1) & (0, 0.0076, 1) & (0, 0.0073, 1) & (0, 0.0080, 1) \\ (0, 0.0067, 1) & (0, 0.0074, 1) & (0, 0.0072, 1) & (0, 0.0078, 1) \\ (0, 0.0063, 1) & (0, 0.0072, 1) & (0, 0.0069, 1) & (0, 0.0076, 1) \\ (0, 0.0063, 1) & (0, 0.0072, 1) & (0, 0.0070, 1) & (0, 0.0076, 1) \end{pmatrix}$$

Table 12: The Weighted Normalized Fuzzy Decision Matrix

V	X_1	X_2	X_3	X_4
Symbolab	(0, 0.0069, 1)	(0, 0.0077, 1)	(0, 0.0074, 1)	(0, 0.0081, 1)
Photomath	(0, 0.0069, 1)	(0, 0.0076, 1)	(0, 0.0073, 1)	(0, 0.0080, 1)
Mathway	(0, 0.0067, 1)	(0, 0.0074, 1)	(0, 0.0072, 1)	(0, 0.0078, 1)
Malmath	(0, 0.0063, 1)	(0, 0.0072, 1)	(0, 0.0069, 1)	(0, 0.0076, 1)
Cymath	(0, 0.0063, 1)	(0, 0.0072, 1)	(0, 0.0070, 1)	(0, 0.0076, 1)

Step 6: Determine the Fuzzy Positive-Ideal Solution (FPIS A^+) and Fuzzy Negative-Ideal Solution (FNIS A^-).
Then, select the maximum value (A^+) and minimum value (A^-) for each column. This calculation is repeated for all criteria.

Table 13: Maximum Value (A^+) And Minimum Value (A^-)

Criteria	X_1	X_2	X_3	X_4
Symbolab	(0, 0.0069, 1)	(0, 0.0077, 1)	(0, 0.0074, 1)	(0, 0.0081, 1)
Photomath	(0, 0.0069, 1)	(0, 0.0076, 1)	(0, 0.0073, 1)	(0, 0.0080, 1)
Mathway	(0, 0.0067, 1)	(0, 0.0074, 1)	(0, 0.0072, 1)	(0, 0.0078, 1)
Malmath	(0, 0.0063, 1)	(0, 0.0072, 1)	(0, 0.0069, 1)	(0, 0.0076, 1)
Cymath	(0, 0.0063, 1)	(0, 0.0072, 1)	(0, 0.0070, 1)	(0, 0.0076, 1)
A^+	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
A^-	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)

Step 7: The distance of each alternative from FPIS and FNIS will be calculated.
By using equation (10), FPIS is calculated and by using equation (11), FNIS is calculated. This step is repeated for all five alternatives.
Symbolab:

$$e(B_1^+X_1) = \sqrt{\frac{1}{3}[(0-1)^2 + (0.0069-1)^2 + (1-1)^2]} = 0.8137$$

$$e(B_1^+X_2) = \sqrt{\frac{1}{3}[(0-1)^2 + (0.0077-1)^2 + (1-1)^2]} = 0.8134$$

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$$e(B_1^+X_3) = \sqrt{\frac{1}{3}[(0-1)^2 + (0.0074-1)^2 + (1-1)^2]} = 0.8135$$

$$e(B_1^+X_4) = \sqrt{\frac{1}{3}[(0-1)^2 + (0.0081-1)^2 + (1-1)^2]} = 0.8132$$

$$e(B_1^-X_1) = \sqrt{\frac{1}{3}[(0-0)^2 + (0.0069-0)^2 + (1-0)^2]} = 0.5774$$

$$e(B_1^-X_2) = \sqrt{\frac{1}{3}[(0-0)^2 + (0.0077-0)^2 + (1-0)^2]} = 0.5774$$

$$e(B_1^-X_3) = \sqrt{\frac{1}{3}[(0-0)^2 + (0.0074-0)^2 + (1-0)^2]} = 0.5774$$

$$e(B_1^-X_4) = \sqrt{\frac{1}{3}[(0-0)^2 + (0.0081-0)^2 + (1-0)^2]} = 0.5774$$

Table 14: Distance Between Each Alternative's Criteria And The FPIS (A^+)

Criteria	X_1	X_2	X_3	X_4
Symbolab	0.8137	0.8134	0.8135	0.8132
Photomath	0.8137	0.8134	0.8135	0.8132
Mathway	0.8138	0.8135	0.8136	0.8133
Malmath	0.8139	0.8136	0.8137	0.8134
Cymath	0.8139	0.8136	0.8136	0.8134

Table 15: Distance Between Each Alternative's Criteria And The FNIS (A^-)

Criteria	X_1	X_2	X_3	X_4
Symbolab	0.5774	0.5774	0.5774	0.5774
Photomath	0.5774	0.5774	0.5774	0.5774
Mathway	0.5774	0.5774	0.5774	0.5774
Malmath	0.5774	0.5774	0.5774	0.5774
Cymath	0.5774	0.5774	0.5774	0.5774

Step 8: Determine the closeness coefficient and the weightage ranking.
By using equation (12), the closeness coefficient for each alternative was calculated. This calculation is repeated for every alternative. To rank the weightage, firstly the weightage must be changed into trapezoidal fuzzy number using equation (13) as it originates from fuzzy triangular number.

For each alternative,
From FPIS (Table 17),

$$e_i^+ = \sum X_1 + X_2 + X_3 + X_4$$

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From FNIS (Table 18),

$$e_i^- = \sum X_1 + X_2 + X_3 + X_4$$

Table 16: Sum Of FNIS (A^-) And FPIS (A^+)

	e_i^+	e_i^-
Symbolab	3.2538	2.3096
Photomath	3.2538	2.3096
Mathway	3.2542	2.3096
Malmath	3.2546	2.3096
Cymath	3.2545	2.3096

For closeness coefficient for each alternative:

$$CC_1 = \frac{2.3096}{2.3096 + 3.2538} = 0.415142$$
$$CC_2 = \frac{2.3096}{2.3096 + 3.2538} = 0.415142$$
$$CC_3 = \frac{2.3096}{2.3096 + 3.2542} = 0.415112$$
$$CC_4 = \frac{2.3096}{2.3096 + 3.2546} = 0.415082$$
$$CC_5 = \frac{2.3096}{2.3096 + 3.2545} = 0.415090$$

Table 17: Closeness Coefficient For Each Alternative

	e_i^+	e_i^-	CC_i
Symbolab	3.2538	2.3096	0.415142
Photomath	3.2538	2.3096	0.415142
Mathway	3.2542	2.3096	0.415112
Malmath	3.2546	2.3096	0.415082
Cymath	3.2545	2.3096	0.415090

For weightage ranking:

Table 18: Weightage Of Criteria In Triangular Fuzzy Number

W	X_1	X_2	X_3	X_4
Triangular fuzzy number	(0,0.77,1.0)	(0, 0.853, 1.0)	(0, 0.825, 1.0)	(0, 0.901, 1.0)

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Based on equation (13) and (14), weightage of criteria in triangular fuzzy number is converted to trapezoidal fuzzy number.

Table 19: Weightage Of Criteria In Trapezoidal Fuzzy Number

W	Trapezoidal fuzzy number
X_1	(0, 0.77, 0.77, 1)
X_2	(0, 0.853, 0.853, 1)
X_3	(0, 0.825, 0.825, 1)
X_4	(0, 0.901, 0.901, 1)

By using equation (15), (16), (17), weightage of criteria ranking can be calculated. This calculation is repeated for all weightages.
For X_1;

$$x_0 = \frac{1}{3}\left(2.54 - \left(\frac{0.77 - 0}{(1.77) - (0.77)}\right)\right)$$
$$= \frac{1}{3}(1.77)$$
$$= 0.59$$
$$y_0 = \frac{1}{3}\left(1 + \left(\frac{0}{(1.77) - (0.77)}\right)\right)$$
$$= \frac{1}{3}$$
$$D = \sqrt{(0.59)^2 + \left(\frac{1}{3}\right)^2}$$
$$= 0.677651$$

Table 20: Weightage Of Criteria Ranking Calculation

W	D
X_1	0.6778
X_2	0.6083
X_3	0.6937
X_4	0.7160

Step 9: The order of all alternatives and weightage will be ranked.
This coefficient has a range of 0 to 1, with values closer to 1 denoting more desirable options because they are farther from the negative ideal solution and closer to the ideal solution. Based on the specified criteria and their weights, the option with the highest closeness coefficient is therefore considered to be the best option.

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Table 21: Closeness Coefficient For Each Alternative Ranking

	CC_i	Rank
Symbolab	0.415142	1
Photomath	0.415142	1
Mathway	0.415112	2
Malmath	0.415082	4
Cymath	0.415090	3

Table 22: Weightage Ranking

W	D	Rank
X_1	0.6778	3
X_2	0.6083	4
X_3	0.6937	2
X_4	0.7160	1

Table 23: Comparison Of Closeness Coefficient For Each Alternative Ranking Order Between Using Fuzzy Topsis And Fuzzy Grade Matrix

	Ranking order from Fuzzy Grade Matrix (Jumadi & Imran, 2023)	Ranking order using Fuzzy TOPSIS
Symbolab	1	1
Photomath	2	1
Mathway	3	2
Malmath	4	4
Cymath	5	3

Table 24: Comparison of Criteria Ranking For Each Criterion Between Using Fuzzy Topsis And Fuzzy Grade Matrix

W	Ranking order from Fuzzy Grade Matrix (Jumadi & Imran, 2023)	Ranking order using Fuzzy TOPSIS
X_1(Features)	4	3
X_2(Efficiency)	2	4
X_3(Quality)	3	2
X_4(Functionality)	1	1

Results and Discussion

The results can be ranked as indicated in the table below using Fuzzy Topsis computation on Mathematics mobile applications. Therefore, based on the calculation, Symbolab and Photomath have the highest closeness coefficient which is 0.415142 where it is nearer to 1. This shows that Symbolab and Photomath are the most ideal mathematics mobile applications to be used. Malmath claims the last place which is the fourth place with the closeness

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coefficient of 0.415082 where it is the farthest to 1. This shows that Malmath is the least ideal mathematics mobile application to be used. For overall ranking, the ranking is followed as Symbolab ≈ Photomath ≻ Mathway ≻ Cymath ≻ Malmath. Compared to previous study from Jumadi and Imran (2023) which uses Fuzzy Grade Matrix, the results are as follows Symbolab, Photomath, Mathway, and Malmath, with Cymath. This shows that there are similar results between using Fuzzy TOPSIS and Fuzzy Grade Matrix. For criteria ranking, X_4 which the criteria is functionality has the highest weightage which is 0.7160. This shows that functionality has the highest evaluation based on the decision makers. This also shows that users mostly will look at the applications functionality when choosing the applications. X_2, which the criteria is efficiency has the lowest weightage ranking at 0.6083. This indicates that users consider efficiency the least important criteria when choosing which mathematics mobile application to use. For overall criteria ranking, the ranking is functionality $(X_4) \succ$ quality $(X_3) \succ$ features $(X_1) \succ$ efficiency (X_2). Compared from previous study from Jumadi and Imran (2023) which uses Fuzzy Grade Matrix, the results are as follows functionality, efficiency, quality and features. By using Fuzzy TOPSIS and Fuzzy Grade Matrix both got the results functionality as the highest ranking, but the other criteria are different.

Conclusion And Recommendations

This project has effectively applied the Fuzzy TOPSIS method to analyze students' preferences for Mathematics mobile applications, using ratings based on various sub-criteria. By leveraging Fuzzy TOPSIS, this study addressed the inherent uncertainties and subjectivities in student feedback, resulting in a more precise and reliable evaluation process. Based on the findings, all objectives for this study have been successfully achieved. The first objective is to transform sub-criteria to criteria using aggregated method. This objective is achieved through step four, which is based on the sub-criteria from grade matrix method, perform the aggregation on the sub-criteria to transform to criteria and total all the weightage of the criteria and alternatives. It is crucial to aggregate sub-criteria to criteria because by using Fuzzy TOPSIS method, it only needs to use criteria to evaluate the alternatives. The second objective is to determine each criterion's fuzzy weight. This objective is also accomplished through step four. Lastly, the third objective is to rank the Mathematical mobile applications using Fuzzy TOPSIS based on ratings of sub-criteria. This objective is obtained after calculating using all the steps from the methods in this study. Therefore, Mathematical mobile applications can be ranked as Symbolab ≈ Photomath ≻ Mathway ≻ Cymath ≻ Malmath. This shows that Symbolab and Photomath are the most preferred Mathematics mobile applications to be used among other alternatives. User will be easier to choose from the alternatives as ranking clearly demonstrates its superior performance in key criteria such as functionality, quality, features and efficiency. Based on the criteria ranking, X_4, which criteria, functionality rank the highest. This shows that when students are assessing mathematics mobile applications, functionality is the most important consideration. It implies that students consider the application's functionality and how well it accomplishes its goals. This emphasizes the importance of prioritizing functional capabilities when designing and choosing educational tools to improve user satisfaction and learning outcomes. Recommendations for future researchers are to expand the scope by conducting similar studies across different subjects and educational levels to gain broader insights into student preferences for mobile learning applications. In conclusion, this research underscores the importance of systematically evaluating educational technologies through a structured, objective methodology. Fuzzy TOPSIS has been shown to be a useful tool for this study, providing a strong framework for the evaluation and choice of educational resources in the digital age.

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References
Azaman, N. A., Bidin, J., Sharif, N., & Ku Akil, K. A. (2023). Analysing influential factors in university selection using Fuzzy TOPSIS. *Journal of Computing Research and Innovation (JCRINN), 8(2), 45-54*.

Basaran, S., & Homsi, F. E. (2022). Mobile Mathematics Learning Application Selection using fuzzy topsis. *International Journal of Advanced Computer Science and Applications*, *13*(2). https://doi.org/10.14569/ijacsa.2022.0130233

Drigas, A., & Pappas, M. (2015). A review of Mobile Learning applications for Mathematics. *International Journal of Interactive Mobile Technologies (iJIM)*, *9*(3), 18. https://doi.org/10.3991/ijim.v9i3.4420

Enonge, E., Mwangangi, R. I., Emmanuel, R., Valcheva, S., Media, O., macheso, G., Etienne, T., Studykira, Aisha, & Modesta. (2021, April 12). *Primary data vs secondary data: Definition, sources and advantages*. Blog For Data-Driven Business. https://www.intellspot.com/primary-data-vs-secondary-data/

Han, H., & Trimi, S. (2018). A fuzzy topsis method for performance evaluation of Reverse Logistics in social commerce platforms. *Expert Systems with Applications*, *103*, 133–145. https://doi.org/10.1016/j.eswa.2018.03.003.

Hwang, C.-L., & Yoon, K. (1981). Multiple attribute decision making. *Lecture Notes in Economics and Mathematical Systems*. https://doi.org/10.1007/978-3-642-48318-9

Ibrahim, I., Mansor, N. H., & Bidin, J. (2022). Factors Affecting Mental Illness and Social Stress in Students Using Fuzzy TOPSIS. *Journal of Computing Research and Innovation*, *7*(2), 88-100.

Jumadi, N. H., & Imran, N. (2023). *Analysis of Students' Preferences on Mathematics Mobile Applications using Fuzzy Grade Matrix with Degree of Optimism.* Unpublished Final Year Project. College of Computing, Informatics and Mathematics, Universiti Teknologi Mara.

Kabir, G., & Hasin, A. A. (2012). Comparative Analysis of TOPSIS and fuzzy TOPSIS for the Evaluation of Travel Website Service Quality. *DOAJ: Directory of Open Access Journals – DOAJ*.

Kusumawardani, R. P., & Agintiara, M. (2015). Application of fuzzy AHP-topsis method for decision making in Human Resource Manager Selection Process. *Procedia Computer Science*, *72*, 638–646. https://doi.org/10.1016/j.procs.2015.12.173

Moayeri, M., Shahvarani, A., Behzadi, M. H., & Hosseinzadeh-Lotfi, F. (2015). Comparison of fuzzy AHP and Fuzzy Topsis methods for math teachers selection. *Indian Journal of Science and Technology*, *8*(13). https://doi.org/10.17485/ijst/2015/v8i13/54100

Motiwalla, L. F. (2007). *Mobile Learning: A Framework and Evaluation*, *49*(3), 581–596. https://doi.org/10.1016/j.compedu.2005.10.011

Muhammat Pazil, N. S., Mahmud, N., Jamaluddin, S. H., & Shakiren, S. S. (2018). Application of fuzzy topsis in selecting the major factor influencing Malaysians' Choice Of

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
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DOI 10.35631/IJIREV.720025

University (IPTA or ipts). *Journal of Computing Research and Innovation*, *3*(2), 10–16. https://doi.org/10.24191/jcrinn.v3i2.79

Nagpal, R., Mehrotra, D., Kumar Bhatia, P., & Sharma, A. (2015). Rank University websites using fuzzy AHP and fuzzy TOPSIS approach on usability. *International Journal of Information Engineering and Electronic Business*, *7*(1), 29–36. https://doi.org/10.5815/ijieeb.2015.01.04

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers & Education*, 48(2),pp. 285-300. http://dx.doi.org/10.1016/j.compedu.2005.01.006

Sam, C., Naicker, N., & Rajkoomar, M. (2021). Selection of social media applications for ubiquitous learning using Fuzzy Topsis. *International Journal of Advanced Computer Science and Applications*, *12*(2). https://doi.org/10.14569/ijacsa.2021.0120230

Shamsuzzoha, A., Piya, S., & Shamsuzzaman, M. (2021). Application of fuzzy topsis framework for selecting complex project in a case company. *Journal of Global Operations and Strategic Sourcing*, *14*(3), 528–566. https://doi.org/10.1108/jgoss-07-2020-0040

Singh, K., Naicker, N., & Rajkoomar, M. (2021). Selection of learning apps to promote critical thinking in programming students using Fuzzy TOPSIS. *International Journal of Advanced Computer Science and Applications*, *12*(10). https://doi.org/10.14569/ijacsa.2021.0121042

Suleman, A., & Suleman, F. (2010). Ranking by competence using a fuzzy approach. *Quality & Quantity*, *46*(1), 323–339. https://doi.org/10.1007/s11135-010-9357-1

Turker, Y. A., Baynal, K.,&Turker, T. (2019). The Evaluation of Learning Management Systems by Using Fuzzy AHP, Fuzzy TOPSIS and an Integrated Method: A Case Study. *Turkish Online Journal of Distance Education*, 195–218. https://doi.org/10.17718/tojde.557864

Wang, C.-N., Pan, C.-F., Nguyen, H.-P., & Fang, P.-C. (2023). Integrating fuzzy AHP and Topsis methods to evaluate operation efficiency of daycare centers. *Mathematics*, *11*(8), 1793. https://doi.org/10.3390/math11081793