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Analyzing MAUT, ELECTRE, and SMART Methods in Determining the Best Physics Learning Media Aid

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ABSTRACT

This study, titled " Analyzing MAUT, ELECTRE, and SMART Methods in Determining the Best Physics Learning Media Aid", evaluates three decision analysis methods—Multi-Attribute Utility Theory (MAUT), Elimination Et Choix Traduisant la Realité (ELECTRE), and Simple Multi-Attribute Rating Technique (SMART). Focused on factors like usability, effectiveness, cost, and adaptability, it guides educators in choosing the best learning tools. Using a multi-criteria decision analysis framework, the research systematically assesses MAUT, ELECTRE, and SMART, emphasizing their strengths and limitations in physics education. Beyond immediate decision-making, it prompts discussions on technology integration, encouraging innovative approaches. Findings offer insights for future research at the intersections of technology, pedagogy, and decision science. In conclusion, the study illuminates decision analysis methods for optimal physics learning media tools. PhyWiz's consistent top-ranking performance highlights its potential for enhancing physics education. The research recommends PhyWiz integration, emphasizing regular evaluation and adoption of innovative tools to improve physics education quality. It provides a practical guide for educators, contributing to continuous enhancements in teaching and learning experiences

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INTRODUCTION

In the dynamic field of education, technology integration is vital, especially in physics education. The international journal introduces a study titled "Multi-Criteria Decision Analysis for Selecting Optimal Physics Learning Media Tools." This research compares three decision analysis methods— Multi-Attribute Utility Theory (MAUT), Elimination Et Choix Traduisant la Realité (ELECTRE), and Simple Multi-Attribute Rating Technique (SMART)—to aid educators in choosing the best learning tools based on factors like usability, effectiveness, cost, and adaptability.

The challenge in selecting physics learning tools lies in considering multiple factors. This study aims to offer valuable insights to educators, administrators, and policymakers, guiding them in making informed decisions. It utilizes a multi-criteria decision analysis framework to evaluate MAUT, ELECTRE, and SMART, highlighting their strengths, limitations, and applicability in physics education.

The research extends beyond immediate decision-making concerns, sparking discussions on technology integration in education. It not only explores MAUT, ELECTRE, and SMART but also encourages innovative approaches in educational technology decision analysis. The findings provide a foundation for future research, prompting scholars to explore the intersections of technology, pedagogy, and decision science. Ultimately, the study promotes a holistic understanding for educators to harness technology's full potential, creating immersive and effective physics learning experiences and contributing to ongoing conversations about refining educational practices in the 21st century.

LITERATURE REVIEW

The research compared MAUT, ELECTRE, and SMART methods for selecting optimal physics learning media tools. Criteria like usability, effectiveness, cost-efficiency, and technological adaptability were identified and weighted using these methods. The findings offer insights into the strengths and limitations of each method, aiding informed decision-making in physics education.

There are 6 (six) alternative physics learning media tools listed in Table 1.

Table 1. Alternative Data for Physics Learning Media Tools

Code	Alternative
F1	Physics Question Bank
F2	Easy Physics Learning
F3	Physics Formula
F4	PhyWiz
F5	Pocket Physics
F6	Complete Physics Formulas & Materials

In determining physics learning media tools, criteria that support decision-making are essential. There are 6 (six) criteria, as outlined in Table 2.

Table 2. Criteria Data

Code	Criteria	Weights	Attribute
C1	Storage Capacity	2	Cost
C2	Aplication Features	3.5	Benefit
C3	Number of Materials	1.5	Benefit
C4	Number of Language Options	1	Benefit
C5	Number of Users	1	Benefit
C6	Review Rating	1	Benefit

Data Criteria Descriptions:

1. Strorage Capacity
   Description: The amount of storage space utilized by the application, measured in megabytes (MB). This criterion indicates the space the application occupies on a device.
2. Application Features
   Description: The features available within the application. This criterion outlines the functionalities and characteristics that the application offers to its users.
3. Number of Materials
   Description: The quantity of educational materials or topics available within the application. This criterion reflects the extent of content coverage in terms of different subject areas.
4. Number of Language Options
   Description: The variety of language choices provided by the application. This criterion caters to users with diverse language preferences, enhancing accessibility and usability.
5. Number of Users
   Description: The total count of individuals who have downloaded and installed the application. This criterion indicates the popularity and reach of the application among users.
6. Review Rating
   Description: The overall rating assigned to the application based on user reviews. This qualitative criterion reflects the satisfaction level of users and the perceived effectiveness of the application.

Presented below is Table 3, which serves as an alternative listing of several applications to be considered for selection as the most suitable physics learning media tools.

Table 3. Alternative Physics Learning Media Tool

Alternative	C1	C2	C3	C4	C5	C6
Physics Question Bank	3.8	Question Bank	0	1	50000	4.6
Easy Physics Learning	11	Materials, Videos, Question Bank	11	1	10000	4.6
Physics Formula	7.1	Materials	48	1	1000000	5.0
PhyWiz	6.4	Materials, Question Bank	35	10	1000000	4.5
Pocket Physics	10	Materials	27	3	1000000	4.7
Complete Physics Formulas & Materials	12	Materials	55	1	50000	4.6

In Criterion 2, various features of the offered applications are observed, and these features represent linguistic data that needs to be straightforwardly weighted. The weighting model can be seen in the following Table 4.

Table 4. Application Feature Weighting (Criterion 2)

Description	Weight
Materials	1
Videos	1
Question Bank	1

From Table 4, the weighting of criteria can generate compatibility rating data as shown in the following Table 5.

Table 5. Compatibility Rating Data

Alternative	C1	C2	C3	C4	C5	C6
F1	3.8	1	0	1	50000	4.6
F2	11	3	11	1	10000	4.6
F3	7.1	1	48	1	1000000	5.0
F4	6.4	2	35	10	1000000	4.5
F5	10	1	27	3	1000000	4.7
F6	12	1	55	1	50000	4.6

METHODOLOGY

This research aims to conduct a systematic analysis and selection of the best physics learning media tools through the application of three multi-criteria decision-making methods: Multi-Attribute Utility Theory (MAUT), Elimination Et Choix Traduisant la Realité (ELECTRE), and Simple Multi-Attribute Rating Technique (SMART).

Multi-Attribute Utility Theory (MAUT) Method

Multi-Attribute Utility Theory (MAUT) is a decision-making method used to compare and identify the best option by combining various criteria such as risk, cost, and benefits. The goal is to ensure unbiased and fair decisions based on a rational assessment of all relevant factors. Positive values contribute to higher evaluations, while negative values or risks lower the overall assessment. The steps for implementing the MAUT method are as follows:

a. Creating the decision matrix to outline the alternatives and their corresponding criteria.

$$X_{ij} = \begin{bmatrix} r_{11} & \cdots & r_{1j} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{i1} & \cdots & r_{ij} & \cdots & r_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mj} & \cdots & r_{mn} \end{bmatrix}; i = 1, \dots, m, j = 1, \dots, n$$

b. Normalizing the initial matrix to ensure fair comparison between different criteria.

Determining normalization values for Benefit criteria

$$\left(r_{ij}^{*}\right) = \frac{r_{ij} - \min\left(r_{ij}\right)}{\max\left(r_{ij}\right) - \min\left(r_{ij}\right)}$$

Determining normalization values for Cost criteria

$$r_{ij}^{*} = 1 + \left(\frac{\min\left(r_{ij}\right) - r_{ij}}{\max\left(r_{ij}\right) - \min\left(r_{ij}\right)}\right)$$

c. Calculating Marginal Utility Values

$$u_{ij} = \frac{e\left(r_{ij}^{*}\right)^{2} - 1}{1{,}71}$$

d. Calculating Final Utility Values

$$U_i = \sum_{j}^{n} = 1 u_{ij} . w_j$$

Elimination Et Choix Traduisant la Realité (ELECTRE) Method

The Electre method, with its focus on outranking and concordance-discordance principles, offered a unique perspective on the compatibility of physics learning media tools with the identified criteria. The results showcased a nuanced ranking of tools based on their overall performance, enabling educators to make informed choices aligned with their specific needs.

The steps for implementing the ELECTRE method are as follows:

a. Forming a pairwise comparison matrix for each alternative in each criterion.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}$$

b. Normalize the matrix to obtain the normalized result matrix R.

$$R = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix}$$

n is the number of alternatives, and m is the number of criteria. The ELECTRE method employs the normalization formula as follows:

$$= \frac{x_{ij}}{\sum_i^m x_{ij}} \; dengan \; i = (1, 2, \dots, m) \; dan \; j = (1, 2, \dots, n)$$

c. Next is assigning weights to each criterion indicating their relative importance (Wj).

$$W = \begin{bmatrix} w_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & w_n \end{bmatrix}$$

Using the formula: $W = W_1, W_2, \dots, Wn$; dengan $\sum_{j=1}^{m} Wj = 1$

d. Determining the weighted normalized matrix by multiplying the weights with the pairwise comparison matrix to form matrix V.

$$\begin{bmatrix} v_{11} & \cdots & v_{1n} \\ \vdots & \ddots & \vdots \\ v_{m1} & \cdots & v_{mn} \end{bmatrix} = \begin{bmatrix} w_1 r_{11} & \cdots & w_n r_{1n} \\ \vdots & \ddots & \vdots \\ w_1 r_{m1} & \cdots & w_n r_{mn} \end{bmatrix}$$

e. Determining the concordance index and discordance index.

1) The equation used to determine the concordance index is:

$$C_{kl} = \{j \; V_{kj} \geq V_{ij}\} \text{ untuk } j = 1, 2, \dots, n$$

The concordance index set indicates the summation of criterion weights.

2) The discordance index set (D_{kl}) is defined as:

$$C_{kl} = \{j \; V_{kj} \geq V_{ij}\} \text{ untuk } j = 1, 2, \dots, n$$

3) Forming the concordance matrix (C) is achieved using the equation:

$$C_{kl} = \sum j \in c_{kl} W_j$$

4) Constructing the discordance matrix (D) is done using the equation:

$$d_{kl} = \frac{max\{|v_{kj} - v_{ij}|\} j \in D_{kl}}{max\{|v_{kj} - v_{ij}|\} \forall j}$$

5) Building the dominant concordance matrix F involves determining a threshold value (c) using the equation:

$$\underline{C} = \frac{\sum_{k}^{m}=1 \sum_{j}^{m}=1 \ c_{kl}}{m(m-1)}$$

Alternative Ak may have the opportunity to dominate Al if the concordance index C_{kl} exceeds the threshold c, where $C_{kl} \geq= C$. The elements of the dominant concordance matrix F are determined as:

$$F_{kl} = \begin{Bmatrix} 1, jika \ c_{kl} \geq C \\ 0, jika \ c_{kl} < C \end{Bmatrix}$$

6) Constructing the dominant discordance matrix G involves using a threshold value (d) obtained from the equation:

$$\underline{d} = \frac{\sum_{k}^{m}=1 \sum_{j}^{m}=1 \, c_{kl}}{m(m-1)}$$

The elements of the dominant discordance matrix G are determined as:

$$G_{kl} = \begin{Bmatrix} 1, jika \ c_{kl} \geq C \\ 0, jika \ c_{kl} < C \end{Bmatrix}$$

7) Performing the aggression of the dominant matrix (E), which indicates the partial preference order of alternatives, is obtained using the equation:

$$e_{kl} = F_{kl} \times G_{kl}$$

Simple Multi-Attribute Rating Technique (SMART) Method

The SMART (Simple Multi-Attribute Rating Technique) method is utilized in this research. It aids in formulating and evaluating alternative physics learning media tools based on various relevant criteria. These criteria are Specific, Measurable, Achievable, Relevant, and Time-bound. SMART is a decision-making method designed to gather information about all data related to multiple attributes and criteria.

The steps for implementing the SMART method are as follows:

a. Determining Criteria
b. Determining the weight of each criterion using the interval 1-100 for each criterion with the highest priority.
c. Calculating the normalization weight for each criterion by comparing the criterion weight value with the total weight of all criteria, using the equation:

$$Normalization = \frac{W_j}{\sum W_j}$$

Where:

W_j is the weight of a criterion,
$\sum W_j$ is the total weight of all criteria.

d. Assigning criterion values for each alternative.
e. Calculating the utility value for each criterion.
For the Cost criterion, using this formula:

$$u_i\,(a_i) = \frac{(C_{max} - C_{out})}{(C_{max} - C_{min})} \times 100\%$$

For the Benefit criterion, using this formula:

$$u_i\,(a_i) = \frac{(C_{out} - C_{min})}{(C_{max} - C_{min})} \times 100\%$$

Descriptions:
$u_i\,(a_i)$: Utility value of criterion i for alternative a_i
C_{max} : Maximum criterion value
C_{min} : Minimum criterion value
C_{out} : Criterion value for alternative a_i

f. Calculate the final value for each criterion.

$$u\,(a_i) = \sum_{j=1}^{m} w_j \times u_j\,(a_j)$$

Descriptions:
$u_i\,(a_i)$: Total value for alternative a_i
w_j : Normalized weight value for criterion j
$u_j\,(a_j)$: Utility value for criterion j for alternative a_j

RESULTS

The calculation for each alternative to generate the ranking of the best physics learning media tools by implementing the MAUT, ELECTRE, and SMART methods is as follows:

Multi-Attribute Utility Theory (MAUT) Method

a. Creating the decision matrix to outline the alternatives and their corresponding criteria.

b. Normalizing the initial matrix to ensure fair comparison between different criteria.

C1 Criteria (Cost)

$$r_{11} = 1 + \frac{3.8 - 3.8}{12 - 3.8} = 1$$

$$r_{21} = 1 + \frac{3.8 - 11}{12 - 3.8} = 0.1219$$

$$r_{31} = 1 + \frac{3.8 - 7.1}{12 - 3.8} = 0.5975$$

$$r_{41} = 1 + \frac{3.8 - 6.4}{12 - 3.8} = 0.6829$$

$$r_{51} = 1 + \frac{3.8 - 10}{12 - 3.8} = 0.2439$$

$$r_{61} = 1 + \frac{3.8 - 12}{12 - 3.8} = 0$$

C2 Criteria (Benefit)

$$r_{12} = \frac{1 - 1}{3 - 1} = 0$$

$$r_{22} = \frac{3 - 1}{3 - 1} = 1$$

$$r_{32} = \frac{1 - 1}{3 - 1} = 0$$

$$r_{42} = \frac{2 - 1}{3 - 1} = 0.5$$

$$r_{52} = \frac{1 - 1}{3 - 1} = 0$$

$$r_{62} = \frac{1 - 1}{3 - 1} = 0$$

For **C3** to **C6 Criteria**, perform the same calculations as they are considered benefit criteria. Therefore, with the aforementioned calculations, the resulting table of normalized matrix is as follows:

$$X_{ij} = \begin{bmatrix} 3.8 & 1 & 0 & 1 & 50000 & 4.6 \\ 11 & 3 & 11 & 1 & 10000 & 4.6 \\ 7.1 & 1 & 48 & 1 & 1000000 & 5.0 \\ 6.4 & 2 & 35 & 10 & 1000000 & 4.5 \\ 10 & 1 & 27 & 3 & 1000000 & 4.7 \\ 12 & 1 & 55 & 1 & 50000 & 4.6 \end{bmatrix}$$

Table 6. The Results of the Marginal Utility Value Calculations

Alternative	C1	C2	C3	C4	C5	C6
F1	1.0048	0	0	0	0.0009	0.0238
F2	0.0087	1.0048	0.0238	0	0	0.0238
F3	0.2509	0	0.6676	0	1.0048	1.0048
F4	0.3474	0.1660	0.2918	1.0048	1.0048	0
F5	0.0358	0	0.1593	0.0295	1.0048	0.1735
F6	0	0	1.0048	0	0.0009	0.0238

b. Calculating Final Utility Values

$U_1 = (2 \times 1.0048) + (3.5 \times 0) + (1.5 \times 0) + (1 \times 0) + (1 \times 0.0009) + (1 \times 0.0238) = 2.0343$

$U_2 = (2 \times 0.0087) + (3.5 \times 1.0048) + (1.5 \times 0.0238) + (1 \times 0) + (1 \times 0) + (1 \times 0.0238) = 3.5937$

$U_3 = (2 \times 0.2509) + (3.5 \times 0) + (1.5 \times 0.6676) + (1 \times 0) + (1 \times 1.0048) + (1 \times 1.0048) = 3.5128$

$U_4 = (2 \times 0.3474) + (3.5 \times 0.1660) + (1.5 \times 0.2918) + (1 \times 1.0048) + (1 \times 1.0048) + (1 \times 0) = 3.7231$

$U_5 = (2 \times 0.0358) + (3.5 \times 0) + (1.5 \times 0.1593) + (1 \times 0.0295) + (1 \times 1.0048) + (1 \times 0.1735) = 1.5814$

$U_6 = (2 \times 0) + (3.5 \times 0) + (1.5 \times 1.0048) + (1 \times 0) + (1 \times 0.0009) + (1 \times 0.0238) = 1.5319$

After obtaining the final utility values, which will later be used as the final ranking values, they can be observed in the table below:

Table 7. Ranking Data

Code	Alternative	Value	Ranking
F4	PhyWiz	3.7231	1
F2	Easy Physics Learning	3.5937	2
F3	Physics Formula	3.5128	3
F1	Physics Question Bank	2.0343	4
F6	Complete Physics Formulas & Materials	1.5319	5
F5	Pocket Physics	1.5184	6

Elimination Et Choix Traduisant la Realité (ELECTRE) Method

Before proceeding with the calculations to finalize the implementation of the ELECTRE method, we will standardize each individual criterion by assigning it a value within the range of 1 to 5.

Table 8. Standardization Table for K1 Criteria

Strorage Capacity (K1)	Standard Value
<2	1
3 - 5	2
6 - 8	3
9 - 11	4
>12	5

Table 9. Standardization Table for K2 Criteria

Application Features (K2)	Standard Value
<1	1
2	2
3	3
4	4
>5	5

Table 10. Standardization Table for K3 Criteria

Number of Materials (K3)	Standard Value
<10	1
11 - 20	2
21 - 30	3
31 - 40	4
>41	5

Table 12. Standardization Table for K4 Criteria

Number of Language Options (K4)	Standard Value
<1	1
2	2
3	3
4	4
>5	5

Table 13. Standardization Table for K5 Criteria

Number of Users (K5)	Standard Value
<10000	1
10001 - 50000	2
50001 - 100000	3
100001 - 500000	4
>500001	5

Table 14. Standardization Table for K6 Criteria

Review Rating (K6)	Standard Value
1 - 1,9	1
2 - 2,9	2
3 - 3,9	3
4 - 4,9	4
5	5

Standardization table for the criteria of selecting Physics Learning Applications used in this research can be seen in the following table:

Table 15. Conversion of Criteria Values

Alternative Code	Alternative Name	Criteria Value					
		K1	K2	K3	K4	K5	K6
A_1	Physics Question Bank	2	1	1	1	2	4
A_2	Easy Physics Learning	4	3	2	1	1	4
A_3	Physics Formula	3	1	5	1	5	5
A_4	PhyWiz	3	2	4	5	5	4
A_5	Pocket Physics	4	1	3	3	5	4
A_6	Complete Physics Formulas & Materials	5	1	5	1	2	4

Now, we will proceed to the calculations.

a. Forming a pairwise comparison matrix for each alternative in each criterion.

$$X = \begin{bmatrix} 2 & 1 & 1 & 1 & 2 & 4 \\ 4 & 3 & 2 & 1 & 1 & 4 \\ 3 & 1 & 5 & 1 & 5 & 5 \\ 3 & 2 & 4 & 5 & 5 & 4 \\ 4 & 1 & 3 & 3 & 5 & 4 \\ 5 & 1 & 5 & 1 & 2 & 4 \end{bmatrix}$$

b. Normalize the matrix to obtain the normalized result matrix R.

1) Normalize K1 Criteria (Cost)

Value $|x_1| = \sqrt{2^2 + 4^2 + 3^2 + 3^2 + 4^2 + 5^2} = 8.888$

$A_{11} = \frac{2}{8.888} = 0{,}225$ $\qquad$ $A_{41} = \frac{3}{8.888} = 0{,}337$

$A_{21} = \frac{4}{8.888} = 0{,}450$ $\qquad$ $A_{51} = \frac{4}{8.888} = 0{,}450$

$A_{31} = \frac{3}{8.888} = 0{,}337$ $\qquad$ $A_{61} = \frac{5}{8.888} = 0{,}562$

2) Normalize K2 Criteria (Benefit)

Value $|x_2| = \sqrt{1^2 + 3^2 + 1^2 + 2^2 + 1^2 + 1^2} = 4.123$

$A_{12} = \frac{1}{4.123} = 0{,}242$ $\qquad$ $A_{42} = \frac{2}{4.123} = 0{,}485$

$A_{22} = \frac{3}{4.123} = 0{,}727$ $\qquad$ $A_{52} = \frac{1}{4.123} = 0{,}242$

$A_{32} = \frac{1}{4.123} = 0{,}242$ $\qquad$ $A_{62} = \frac{1}{4.123} = 0{,}242$

Continue the calculations for normalize criteria **K3** to **K6** using the same method. Based on the calculations above, the resulting matrix R is as follows:

$$R = \begin{bmatrix} 0{,}225 & 0{,}242 & 0{,}111 & 0{,}162 & 0{,}218 & 0{,}390 \\ 0{,}450 & 0{,}727 & 0{,}223 & 0{,}162 & 0{,}109 & 0{,}390 \\ 0{,}337 & 0{,}242 & 0{,}559 & 0{,}162 & 0{,}545 & 0{,}487 \\ 0{,}337 & 0{,}485 & 0{,}447 & 0{,}811 & 0{,}545 & 0{,}390 \\ 0{,}450 & 0{,}242 & 0{,}335 & 0{,}486 & 0{,}545 & 0{,}390 \\ 0{,}562 & 0{,}242 & 0{,}559 & 0{,}162 & 0{,}218 & 0{,}390 \end{bmatrix}$$

e. Determine the concordance index and discordance index.

1) Determine the concordance set.

$\boldsymbol{C_{11}} = -$

$\boldsymbol{C_{12}}$
$= \{0.450 \geq 0.900\}$ ×
$= \{0.847 \geq 2.544\}$ ×
$= \{0.166 \geq 0.334\}$ ×
$= \{0.162 \geq 0.162\}$ ✓
$= \{0{,}218 \geq 0.109\}$ ✓
$= \{0.390 \geq 0.390\}$ ✓
$\boldsymbol{C_{12}} = \{4, 5, 6\}$
$\boldsymbol{C_{12}} = W_4 + W_5 + W_6$
$= 1 + 1 + 1 = 3$

$\boldsymbol{C_{13}}$
$= \{0.450 \geq 0.674\}$ ×
$= \{0.847 \geq 0.847\}$ ✓
$= \{0.166 \geq 0.838\}$ ×
$= \{0.162 \geq 0.162\}$ ✓
$= \{0.218 \geq 0.545\}$ ×
$= \{0.390 \geq 0.390\}$ ✓
$\boldsymbol{C_{13}} = \{2, 4, 6\}$
$\boldsymbol{C_{13}} = W_2 + W_4 + W_6$
$= 3.5 + 1 + 1 = 5.5$

Continue the calculations and the results of concordance matrix is as follows:

$$C = \begin{bmatrix} - & 3 & 5.5 & 0 & 4.5 & 6.5 \\ 9 & - & 6.5 & 5.5 & 6.5 & 5.5 \\ 10 & 4.5 & - & 4.5 & 7 & 8 \\ 10 & 4.5 & 8.5 & - & 8 & 6.5 \\ 10 & 6.5 & 8.5 & 3 & - & 6.5 \\ 10 & 6.5 & 9 & 3.5 & 8 & - \end{bmatrix}$$

2) Determine the discordance set.

$\boldsymbol{D_{11}} = -$
$\boldsymbol{D_{12}}$
$= \{0.450 \geq 0.900\}$ ✓
$= \{0.847 \geq 2.544\}$ ✓
$= \{0.166 \geq 0.334\}$ ✓
$= \{0.162 \geq 0.162\}$ ×
$= \{0.218 \geq 0.109\}$ ×
$= \{0.390 \geq 0.390\}$ ×
$\boldsymbol{D_{12}} = \{1, 2, 3\}$

$$= \frac{\max\{|0{,}450 - 0{,}900|; |0{,}847 - 2{,}544|; |0{,}166 - 0{,}334|\}}{\max\{|0{,}450 - 0{,}900|; |0{,}847 - 2{,}544|; |0{,}166 - 0{,}334|; |0{,}162 - 0{,}162|; |0{,}218 - 0{,}109|; |0{,}390 - 0{,}390|\}}$$

$$= \frac{\max\{|0{,}450|; |1{,}697|; |0{,}178|\}}{\max\{|0{,}450|; |1{,}697|; |0{,}178|; |0|; |0{,}109|; |0|\}}$$

$$= \frac{1.697}{1.697} = 1$$

Continue the calculations and the results of discordance matrix is as follows:

$$D = \begin{bmatrix} - & 1 & 1 & 1 & 1 & 1 \\ 0.064 & - & 0.296 & 0.766 & 0.261 & 0.301 \\ 0 & 1 & - & 1 & 0.964 & 1 \\ 0 & 1 & 1.976 & - & 0.265 & 0.529 \\ 0 & 1 & 1 & 1 & - & 1 \\ 0 & 1 & 0.726 & 1 & 0.956 & - \end{bmatrix}$$

3) Determine the concordance matrix obtained by calculating the threshold value. The results is as follows:

$$F = \begin{bmatrix} - & 0 & 0 & 0 & 0 & 0 \\ 1 & - & 0 & 0 & 0 & 0 \\ 1 & 0 & - & 0 & 1 & 1 \\ 1 & 0 & 1 & - & 1 & 1 \\ 1 & 0 & 1 & 0 & - & 0 \\ 1 & 0 & 1 & 0 & 1 & - \end{bmatrix}$$

4) Determine the discordance matrix obtained by calculating the threshold value. The results is as follows:

$$G = \begin{bmatrix} - & 1 & 1 & 1 & 1 & 1 \\ 0 & - & 0 & 1 & 0 & 0 \\ 0 & 1 & - & 1 & 1 & 1 \\ 0 & 1 & 1 & - & 0 & 0 \\ 0 & 1 & 1 & 1 & - & 1 \\ 0 & 1 & 0 & 1 & 1 & - \end{bmatrix}$$

5) Determining the aggregate dominance matrix. The following are the obtained results:

$$\begin{bmatrix} - & 0 & 0 & 0 & 0 & 0 \\ 0 & - & 0 & 0 & 0 & 0 \\ 0 & 0 & - & 0 & 1 & 1 \\ 0 & 0 & 1 & - & 0 & 0 \\ 0 & 0 & 1 & 0 & - & 0 \\ 0 & 0 & 0 & 0 & 1 & - \end{bmatrix}$$

The final step involves eliminating alternatives with the fewest 1 values. The elimination result represents alternatives with the highest number of 1 values based on calculations in the aggregate dominance matrix, which signifies the top-ranking recommendation.

Table 16. Ranking Data

Code	Alternative	E	Ranking
F4	PhyWiz	33.73	1
F6	Complete Physics Formulas & Materials	33.318	2
F2	Easy Physics Learning	31.312	3
F5	Pocket Physics	30.5	4
F3	Physics Formula	30.036	5
F1	Physics Question Bank	14.5	6

Simple Multi-Attribute Rating Technique (SMART) Method

a. Normalizing weights

$N_1 = \frac{2}{10} = 0.2$

$N_2 = \frac{3.5}{10} = 0.35$

$N_3 = \frac{1.5}{10} = 0.15$

$N_4 = \frac{1}{10} = 0.1$

$N_5 = \frac{1}{10} = 0.1$

$N_6 = \frac{1}{10} = 0.1$

b. Calculating the utility value for each criterion.

C1 Criteria (Cost)

$u_1(a_1) = 100\frac{(12-3.8)}{(12-3.8)}\% = 1$

$u_1(a_2) = 100\frac{(12-11)}{(12-3.8)}\% = 0.263$

$u_1(a_3) = 100\frac{(12-7.1)}{(12-3.8)}\% = 0.597$

$u_1(a_4) = 100\frac{(12-6.4)}{(12-3.8)}\% = 0.683$

$u_1(a_5) = 100\frac{(12-10)}{(12-3.8)}\% = 0.244$

$u_1(a_6) = 100\frac{(12-12)}{(12-3.8)}\% = 0$

C2 Criteria (Benefit)

$u_2(a_1) = 100\frac{(1-1)}{(3-1)}\% = 0$

$u_2(a_2) = 100\frac{(3-1)}{(3-1)}\% = 1$

$u_2(a_3) = 100\frac{(1-1)}{(3-1)}\% = 0$

$u_2(a_4) = 100\frac{(2-1)}{(3-1)}\% = 0.5$

$u_2(a_5) = 100\frac{(1-1)}{(3-1)}\% = 0$

$u_2(a_6) = 100\frac{(1-1)}{(3-1)}\% = 0$

Continue the calculations for C3 – C6 Criteria with the same method above. The results of calculating the utility value is as follows:

Table 17. The Result of Calculating the Utility Values

Alternative	C1	C2	C3	C4	C5	C6
F1	1	0	0	0	0.040	0.2
F2	0.263	1	0.2	0	0	0.2
F3	0.597	0	0.872	0	1	1
F4	0.683	0.5	0.636	1	1	0
F5	0.244	0	0.50	0.222	1	0.4
F6	0	0	1	0	0.040	0.2

a. Calculate the final value for each criterion.

F1 = (0.2*1) + (0.35*0) + (0.15*0) + (0.1*0) + (0.1*0.040) + (0.1*0.2)
= 0.224

F2 = (0.2*0.263) + (0.35*1) + (0.15*0.2) + (0.1*0) + (0.1*0) + (0.1*0.2)
= 0.4256

F3 = (0.2*0.597) + (0.35*0) + (0.15*0.872) + (0.1*0) + (0.1*1) + (0.1*1)
= 0.4502

F4 = (0.2*0.683) + (0.35*0.5) + (0.15*0.636) + (0.1*1) + (0.1*1) + (0.1*0)
= 0.607

F5 = (0.2*0.244) + (0.35*0) + (0.15*0.50) + (0.1*0.222) + (0.1*1) + (0.1*0.4)

= 0.286
F6 = (0.2*0) + (0.35*0) + (0.15*1) + (0.1*0) + (0.1*0.040) + (0.1*0.2)
= 0.174

After completing the calculation process of the Overall Utility Values $u(a_i)$, the obtained results for the overall utility values for each alternative are as follows:

Table 18. Ranking Data

Code	Alternative	Final Result	Ranking
F4	PhyWiz	0.607	1
F3	Physics Formula	0.4502	2
F2	Easy Physics Learning	0.4256	3
F5	Pocket Physics	0.286	4
F1	Physics Question Bank	0.224	5
F6	Complete Physics Formulas & Materials	0.174	6

DISCUSSION

After analyzing and calculating using three decision support system methods, namely MAUT, ELECTRE, and SMART, to find an effective tool for physics learning media, the results consistently show that PhyWiz always ranks 1 or holds the first position among the six other alternatives. In the MAUT method, PhyWiz has a value of 3.7231. In the ELECTRE method, PhyWiz has a value of 33.73. Finally, in the SMART method, it obtains a value of 0.607. This proves that the PhyWiz alternative is the best recommendation as an effective tool for physics learning media.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In conclusion, the study's exploration of Multi-Attribute Utility Theory (MAUT), Elimination Et Choix Traduisant la Realité (ELECTRE), and Simple Multi-Attribute Rating Technique (SMART) has provided a comprehensive understanding of decision analysis methods in the context of selecting optimal physics learning media tools. The complexities involved in decision-making, considering factors such as usability, effectiveness, cost-efficiency, and technological adaptability, have been illuminated.

The consistent top-ranking performance of PhyWiz across all three methods—MAUT, ELECTRE, and SMART—underscores its potential as a preferred tool for enhancing physics education. The robustness and versatility of PhyWiz make it a compelling choice for educators and institutions seeking to integrate effective learning media tools.

Recommendations

The research strongly recommends integrating PhyWiz into physics education as the primary learning media tool. Given its consistent top rankings across various decision analysis methods, educators, administrators, and policymakers are urged to include PhyWiz in the curriculum to ensure students' access to this effective resource.

Moreover, the success of PhyWiz underscores the significance of regularly evaluating and adopting innovative tools in educational practices. The findings highlight the need for ongoing assessments of learning media tools to continually enhance the quality of physics education. Ultimately, the research outcomes provide a practical guide for educators and institutions to make informed decisions, contributing to the continuous improvement of teaching and learning experiences in physics education.

FURTHER STUDY

Future studies on determining the best physics learning media aid should consider expanding beyond MAUT, ELECTRE, and SMART methods to enhance methodological diversity. Additionally, exploring additional variables, such as technology readiness in schools, teacher preferences, and specific student characteristics, would contribute to a more comprehensive understanding. This broader exploration would enrich decision-making processes in physics education and provide a more nuanced perspective on optimal learning media aid selection.

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