EFFECTIVE LEARNER ENGAGEMENT THROUGH GAME-BASED APPS: AN EVAMIX DECISION-MAKING FRAMEWORK

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ABSTRACT

The metamorphosis in the existing educational system is demanding a paradigm shift from conventional learning methods to more interactive, game-based approaches. Acquisition and retention of learners' engagement are the primary purposes of this learning transition. The teaching community of this digital era is circumscribed by the challenges of effective learner engagement. The academicians of this age are exploring the effects of employing game-based apps in sustaining learners' engagement. This has resulted in the bloom of diverse game-based apps, which has further constrained the teachers in choice-making of apps. This research work addresses the hurdles in determining the optimal alternative of game-based apps, considering the critical criteria such as adaptability, scalability, flexibility and others. The multi-criteria decision-making method of EVAMIX (EVAluation of MIXed data) is applied to evolve a decision-making model. The results obtained are compared with those of other decision-making methods. Sensitivity analysis is performed by modifying the criterion weights to determine the influence of criterion significance over the ranking results. The choice of the experts and the subjectivity of their opinions may contribute to the limitations of the proposed model.

Keywords: Game-based learning, EVAMIX, learner engagement

INTRODUCTION

The educational landscape is undergoing massive transformation with the integration of AI enabled technology in this digital era. The advanced technology has made learning more self-paced, however the engagement of the learners in this digital era is more challenging. The teachers are encountering several challenges in maximizing the attention span of the learners. As traditional instructive or lecture approaches do not engage the

learners effectively, it is essential to switch to a more engaging and interactive pedagogy. This has grounded the roots of interactive pedagogies and one such is game based learning. The evolution of pedagogies primarily depends on the needs of the learners. The origin of game-based learning takes back to few decades. This learning pedagogy integrates game mechanics to the educational contents to enrich learner motivation, interaction and retention. This learning pedagogy is built on the idea that play induces active learning, problem-solving and collaboration. The conventional or the classical pedagogy shall be transformed to a more interactive, engaging and learner-centered with game mechanics.

The digital market is developing different game-based apps suiting to diverse learners. These learning apps are also customized suiting to specific subjects. Moreover, the blooming of these apps is escalating at recent times. This has made the selection of optimal game-based apps more complex. The conflicting and interacting criteria such as adaptability, scalability, flexibility, cost effectiveness, compatibility and other factors further constraints the decision process. On other hand the criteria are also classified as quantitative and qualitative. The criteria set in general are a composition of both the nature of criteria. The decision-makers must choose a ranking method to handle both subjective judgements and objective measures. There are different multi criteria decision making methods existing in literature used to rank the alternatives. However, handling both quantitative and qualitative criteria simultaneously is essential in formulating optimal ranking results.

In this context, the method of EVAMIX is chosen to handle the intricate decision process of ranking the alternatives of game-based learning apps. The decision making model developed in this research work is discussed with diverse criterion weights. The remaining contents of the paper are structured into the following sections. The review of literature is presented in section 2. The methodology is explained in section 3. Theranking problem of game based learning apps is discoursed in section 4. The ranking results are discussed in section 5 and the last section concludes the work.

REVIEW OF WORKS

This section presents a brief review of literature of the applications of EVAMIX MCDM method in diverse areas. Researchers have applied the method of EVAMIX in various contexts of decision making. To mention a few, Asgharizadeh et al [3] to asses safety

performance, Sohrabi & Nemati [20] to rank anti-corruption approaches. Chojnacka & Górecka [11] to evaluate public benefit organizations. Mokwena [18] to examine investment strategies in education and transport. Cengiz [9] to determine optimal laptop selection. Basar [7] to compare global airline rankings. Denis and Kalkan [12] to assess the rankings of higher educational institutions. Heinz et al [13] to evaluate business simulation activities. Furthermore, EVAMIX method is also discussed with fuzzy and neutrosophic representations. Yazir et al [26] applied fuzzy EVAMIX to select new design gas carriers to energize maritime logistics. Wang [25] discoursed neutrosophic based decision framework to analyse the performances in construction projects.

The method of EVAMIX is applied in combination with other MCDM methods to enhance the efficacy of the ranking results. Veera and Ravipudi [23] employed the combination of AHP-EVAMIX in industrial environments to handle intricate operational settings. Adali [1] and Aytac [4] integrated TODIM to enhance recruitment decisions in health sector. Tsiko [21] combined GIS, simulated annealing with fuzzy representations to make optimal landfill site selection. Ulutas and Cengiz [22] employed CRITIC-EVAMIX to evaluate the quality of technological product. Merkepçi & Baransel [16] developed neutrosophic based CRITIC-EVAMIX for drone selection. Bakır & Çakır [5] used the similar combination to assess macroeconomic potential. Waguaf et al [24] developed a hybrid model combining AHP, TOPSIS and EVAMIX for risk control. Liu et al [15] integrated regret theory in cloud service provider selection.

From the afore mentioned literature, it is observed that the method of EVAMIX is primarily applied in ranking of the alternatives, however to increase decision efficiency, it is applied in combination with other methods. Also, it is found that the method of EVAMIX is not applied to rank the game based apps, adding to it, comparison of EVAMIX results based on different criterion weights is also not explored to the best of our knowledge. This is one of shortcomings identified pertinent to application of EVAMIX. The educationalists have explored the impacts of game based apps in learning. As the learners are digital savvy, the educators of this era chose different pedagogies to foster effective engagement of the learners. Schiele [19] studied the effectiveness of game-learning literacy app in preschool children from different backgrounds. Benzon et al [8] explored the effects of game-based learning over the student's self-regulation, efficiency and comprehension. Bang et al [6] evaluated the

effectiveness of personalized game learning app in enhancing the reading skills of younger children. Michael et al [17] developed and evaluated the learning app for teaching basic programming. The selected review of game-based learning demonstrates the need of customizing the game-based learning apps suiting the learner needs. However, study focussing on the attributes of game-based learning apps does not exist in the literature. This is another shortcoming identified subjected to game-based learning apps. This has motivated the authors to develop a decision-making model to rank the game-based apps used to effectively engage the learners.

METHODOLOGY

The method of EVAMIX is explained in this section. The following steps form the algorithmic framework of the proposed model.

Step 1: Formation of Decision Making matrix

The problem is well-defined taking into the account of the alternatives and criteria. The decision-making matrix considering alternatives and the criteria is constructed.

$$X = \begin{bmatrix} r_{11} & \cdots & r_{1j} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{i1} & \cdots & r_{ij} & \cdots & r_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mj} & \cdots & r_{mn} \end{bmatrix}_{m \times n} ; \quad i = 1,\ldots,m, \; j = 1,\ldots,n$$

Here r_{ij} represents the measure of alternative i satisfying the criteria j. The weights of the criteria are assumed to be $W = [w_1, w_2,\ldots,w_n]$

Step 2: Determining the Superior rate of the Alternatives

The criteria are classified into qualitative and quantitative denoted as O and C respectively based on ordinal and cardinal representations. The alternatives are compared with one another with respect to the significant criteria.

$$\alpha_{ii'} = \left[\sum_{j \in O} \{w_j \times \mathrm{sgn}(e_{ij} - e_{i'j})\}^c \right]^{1/c} ; \quad i, i' \in \{1,\ldots,m\}, \; j = 1,\ldots,n$$

where e_{ij} specifies the evaluation of the alternative A_i based on the attribute C_j and e'_{ij} denotes the evaluation of the alternative A'_i based on the attribute C_j as shown in

$$sgn(e_{ij} - e_{i'j}) = \begin{cases} -1 & if \quad e_{ij} < e_{i'j} \\ 0 & if \quad e_{ij} = e_{i'j}; \quad i, i' \in \{1,\ldots,m\}, j = 1,\ldots,n \\ +1 & if \quad e_{ij} > e_{i'j} \end{cases}$$

Step 3 : Determination of Differential matrix in the ordinal Attributes

The differential values considering ordinal attributes are considered. The α^+ and α^- values denoting the most and least dominant criteria considering each of the alternatives are determined.

$$\delta_{ii'} = \frac{(\alpha_{ii'} - \alpha^-)}{(\alpha^+ - \alpha^-)}; \quad i, i' \in \{1,\ldots,m\}$$

Step 4 : Determination of Differential matrix in the cardinal Attributes

The differential values considering cardinal attributes are considered. The α^+ and α^- values denoting the most and least dominant criteria considering each of the alternatives are determined.

$$d_{ii'} = \frac{(\alpha_{ii'} - \alpha^-)}{(\alpha^+ - \alpha^-)}; \quad i, i' \in \{1,\ldots,m\}$$

Step 5: Computation of Total Dominance

The total dominance values of each of the alternatives are determined using

$$D_{ii'} = w_o\delta_{ii'} + w_c d_{ii'}; \quad i, i' \in \{1,\ldots,m\}$$

Where, $w_o = \sum_{j \in O} w_j$ and $w_c = \sum_{j \in C} w_j.$

The score of each alternative is determined using

$$S_i = \left[\sum_{i'} \frac{D_{i'i}}{D_{ii'}} \right]^{-1}; \quad i, i' \in \{1, \ldots, m\}$$

EVAMIX RANKING OF GAME-BASED APPS

Let us consider a decision-making problem of ranking game based apps for effective engagement of the learners f digital natives. The criteria considered for ranking are listed as follows:

C1 : Adaptability

C2 : Scalability

C3: Flexibility

C4 : Compatibility

C5 : Cost-Effective

C6 : Performance Efficiency

Let us consider the alternatives as G1, G2,G3, G4 and G5. A hypothetical decision-making matrix is constructed based on the opinion of the experts.

The criteria C1-C4 are assumed to be qualitative and C5-C6 to be quantitative.

Alternatives	C1	C2	C3	C4	C5	C6
G1	High	Medium	High	High	75	85
G2	Medium	High	Medium	Medium	65	78
G3	Low	Medium	Medium	Low	55	70
G4	High	High	High	Medium	80	90
G5	Medium	Low	High	High	70	82

The cost index values are presented in the fifth column. Also, the linguistic variables are defined as High, Medium and Low assuming the following values;

- High → 8–10

- Medium → 5–7

- Low → 1–4

The modified matrix is

Alternatives	C1	C2	C3	C4	C5	C6
G1	9	6	8	9	75	85
G2	6	8	6	6	65	78
G3	3	5	5	4	55	70
G4	8	9	9	7	80	90
G5	6	4	8	8	70	82

The attribute C1-C4,C6 are considered to be benefit and the criterion C5 is of cost category.

The decision-making problem is discussed under different cases based on the criterion weights.

Case (i) Equal Criterion Weights

C1	C2	C3	C4	C5	C6
0.16	0.16	0.16	0.16	0.16	0.16

With respect to all the qualitative attributes, which are benefit in nature, the value HIGH is considered to be more dominant and the value LOW is considered to be less dominant. In the

quantitative attribute C5, the dominant value is 55 and the least value is 80. In C6, 90 is dominant and 70 is least dominant.

The qualitative attributes of the decision matrix $\alpha_{ii'}$ is

$$\alpha_{ii'} = \begin{pmatrix} 0 & 0.32 & 0.48 & 0 & 0.32 \\ 0.32 & 0 & 0.48 & 0 & -0.16 \\ 0.48 & 0.48 & 0 & -0.64 & -0.32 \\ 0 & 0 & -0.64 & 0 & 0.16 \\ 0.32 & -0.16 & -0.32 & 0.16 & 0 \end{pmatrix}$$

The qualitative attributes of the decision matrix α_{ii} is

$$\alpha_{ii'} = \begin{pmatrix} 0 & -0.48 & -0.32 & -1.6 & 1.28 \\ -0.48 & 0 & 2.88 & -4.32 & -1.44 \\ -0.32 & 2.88 & 0 & -0.32 & -4.32 \\ -1.6 & -4.32 & -0.32 & 0 & -0.32 \\ 1.28 & -1.44 & -4.32 & -0.32 & 0 \end{pmatrix}$$

The differential matrix in the ordinal attributes $\delta_{ii'}$ is

$$\begin{bmatrix} 0.57 & 0.86 & 1 & 0.57 & 0.86 \\ 0.86 & 0.57 & 1 & 0.57 & 0.43 \\ 1 & 1 & 0.57 & 0 & 0.29 \\ 0.57 & 0.57 & 0 & 0.57 & 0.71 \\ 0.86 & 0.43 & 0.29 & 0.71 & 0.57 \end{bmatrix}$$

The differential matrix in the cardinal attributes $\delta_{ii'}$ is

$$\begin{pmatrix} 0.6 & 0.53 & 0.56 & 0.38 & 0.78 \\ 0.53 & 0.6 & 1 & 0 & 0.4 \\ 0.56 & 1 & 0.6 & 0.56 & 0 \\ 0.38 & 0 & 0.56 & 0.6 & 0.56 \\ 0.78 & 0.4 & 0 & 0.56 & 0.6 \end{pmatrix}$$

The total dominance

$$\begin{pmatrix} 0.5568 & 0.72 & 0.8192 & 0.4864 & 0.8 \\ 0.72 & 0.5568 & 0.96 & 0.3648 & 0.4032 \\ 0.8192 & 0.96 & 0.5568 & 0.1792 & 0.1856 \\ 0.4864 & 0.3648 & 0.1792 & 0.5568 & 0.6336 \\ 0.8 & 0.4032 & 0.1856 & 0.6336 & 0.5568 \end{pmatrix}$$

The final score value of each alternative is tabulated in Table 1

Table 1 Ranking of the Alternatives

G1	G2	G3	G4	G5	
0.25	0.42	0.21	0.32	0.34	
4	1	5	3	2	

RESULTS AND DISCUSSIONS

From the ranking results it is found thatthe score values of the alternatives are different. However, the differences in the score values are negligible and this hurdles in deciding the optimal ranking solution to the problem. The consideration of equal criterion weightage may be the primary reason for obtaining these results. Hence, the same problem is addressed using different criterion weights under four different cases. The results obtained are presented in Table 2.

Table 2 Ranking of Alternatives using Different Criterion Weights

Case (i)						
Criterion Weights	C1	C2	C3	C4	C5	C6
	0.10	0.15	0.20	0.18	0.22	0.15
Score Values	G1	G2	G3	G4	G5	
	0.26	0.40	0.23	0.33	0.30	

Ranking Results	4	1	5	2	3	
Case (ii)						
Criterion Weights	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
	0.12	0.18	0.14	0.16	0.20	0.20
Score Values	**G1**	**G2**	**G3**	**G4**	**G5**	
	0.32	0.29	0.34	0.27	0.31	
Ranking Results	2	4	1	5	3	
Case (iii)						
Criterion Weights	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
	0.20	0.12	0.15	0.18	0.15	0.20
Score Values	**G1**	**G2**	**G3**	**G4**	**G5**	
	0.28	0.35	0.30	0.33	0.26	
Ranking Results	4	1	3	2	5	
Case (iv)						
Criterion Weights	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
	0.14	0.16	0.17	0.15	0.21	0.17
Score Values	**G1**	**G2**	**G3**	**G4**	**G5**	
	0.24	0.38	0.29	0.35	0.28	
Ranking Results	5	1	3	2	4	

For better visualization, the graphical representation of the ranking results is presented in Fig. 1.
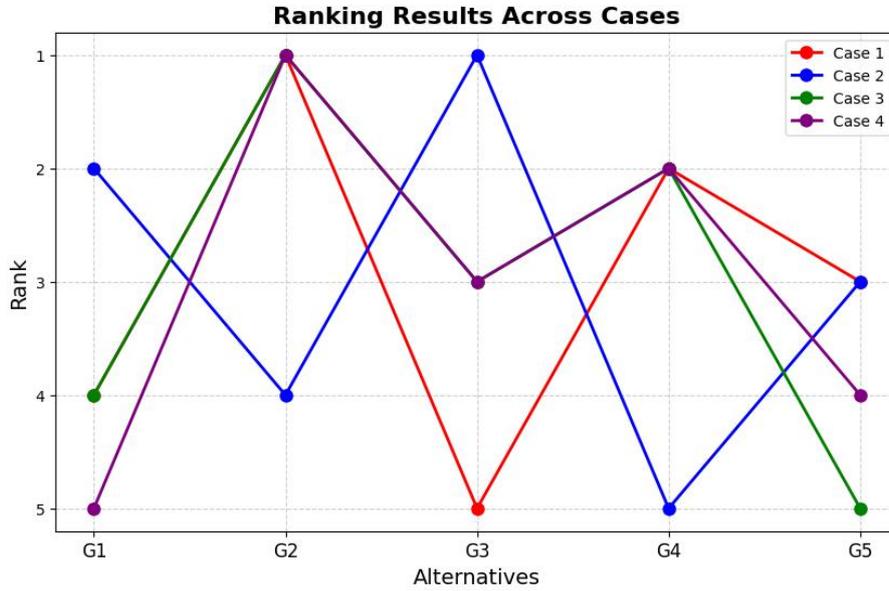

Fig. 1 Ranking Results Across Cases

Furthermore, the correlation ranking results are also represented in Fig.2
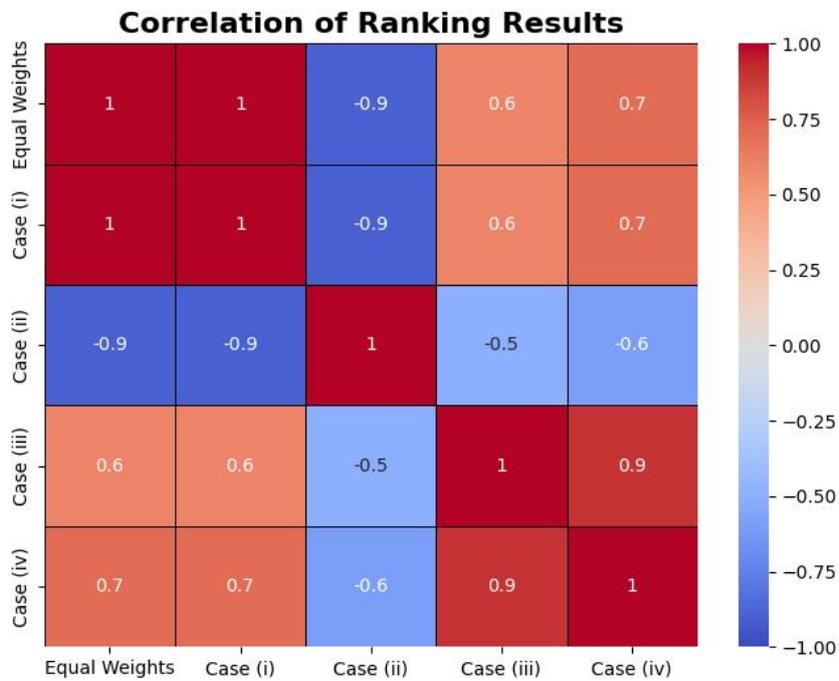

Fig. 2 Correlation of Ranking Results

The dendrogramis used in general to visually cluster the ranking cases based on similarity. In this case, the **hierarchical clustering**is used with the correlation matrix as the similarity measure. The graphical representation is presented in Fig.3.
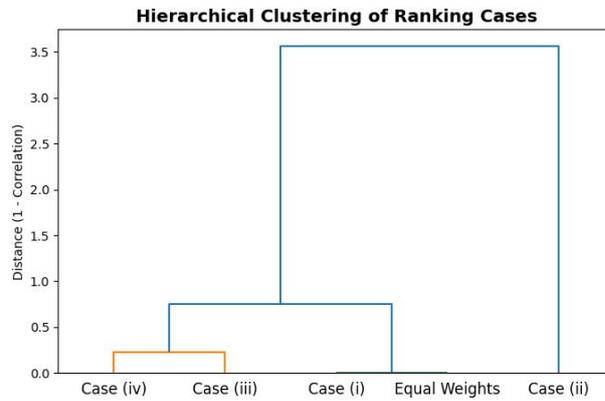

Fig. 3 Hierarchical clustering of the Ranking

The key inferences are presented as follows:

Case (i) = Equal Weights (identical).

Case (ii) is the most divergent (almost the reverse order).

Case (iii) and Case (iv) are highly consistent with each other (0.9).

Equal Weights aligns more with Case (iv) (0.7) than with Case (iii) (0.6).

CONCLUSION

This study explores the application of EVAMIX in the context of ranking optimal Game based learning apps. The ranking is based on equal and different weights and the results are analysed using correlation measures and hierarchical clustering. The proposed decision model shall be applied to several other decision-makingcircumstances to evolve a more comprehensive and optimal results. This method shall be integrated with other MCDM methods of determining the criterion weights. Also, using comparative analysis, the results shall be validated. This method shall also be discussed using various representations of fuzzy and its extended versions.

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