EMPIRICAL ASSESSMENT OF THE INFLUENCE OF VIRTUAL AND AUGMENTED REALITY TECHNOLOGIES ON LEARNING DYNAMICS

Huseynzada G.
PhD Candidate in Economics
Employee on educational technologies
Azerbaijan State Oil and İndustrial University
Baku, Azerbaijan
https://doi.org/10.5281/zenodo.17352699

Abstract

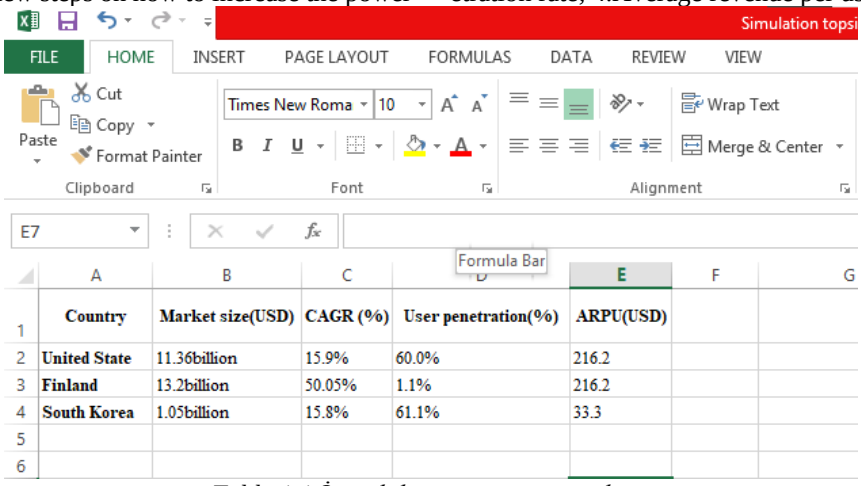
This study explores the impact of Augmented Reality (AR) and Virtual Reality (VR) technologies on the educational process. With the continuous development of technology, teaching methods are evolving toward more interactive and immersive approaches. By analyzing experiences from the United States, Finland, and South Korea, the research compares the implementation strategies and objectives of AR and VR in different educational systems. The study aims to determine the areas of education most affected by these technologies and assess their influence on learning outcomes. Findings indicate that the use of AR and VR enhances students' motivation, supports inclusive learning environments—especially for learners with disabilities—and improves practical skill acquisition. Overall, the integration of immersive technologies demonstrates significant potential for advancing digital transformation in education and shaping future pedagogical frameworks.

Keywords: Digital transformation, augmented reality, virtual reality, simulation, interactivity, visualization

The recent growth of technological innovations has significantly changed the education system. Among them, Virtual Reality and Augmented Reality have brought together the power of living beings to engage with them.[1] Complexity has become increasingly important in the education sector for clarification and simulations. Despite the growing global momentum in VR and AR education, limited research is still available. The aim of the study is to clarify the technological differences between the past and the present, highlight the importance of digital transformation, and show applications and their use in three different countries. Numerous comparisons are made, and key factors are highlighted. The digitalization of education has been of great denotation in strategically enhancing the learning operation neighboring the world. [2] Many countries are developing modernistic plans to advance this strategy and taking new steps on how to increase the power of their education arrangement, and they have now better understood what digitalization means.

In order to compare the systems of Virtual Reality (VR) and Augmented Reality (AR) in education in the three countries I have gathered information, the USA, Finland and South Korea, we will conduct the TOPSIS solution using the exact sources we have obtained. [3][4] Using this method, we will bring to mind the most ideal and anti-ideal solutions. Solving the processes clearly divided into stages helps to understand the results more deeply. As a result of objective solutions, more balanced results can be obtained. Now, the following table provides an accurate baseline based on the available information gathered:

4 criteria for TOPSIS analysis – 2025 data in education sector: 1.Market size in education sector ; 2.Compound annual growth rate (CAGR); 3.User penetration rate; 4.Average revenue per user (ARPU)



	A	B	C	D	E	F	G
1	**Country**	**Market size(USD)**	**CAGR (%)**	**User penetration(%)**	**ARPU(USD)**		
2	**United State**	11.36billion	15.9%	60.0%	216.2		
3	**Finland**	13.2billion	50.05%	1.1%	216.2		
4	**South Korea**	1.05billion	15.8%	61.1%	33.3		
5							
6							

Table 1.1 İnitial decision matrix analysis

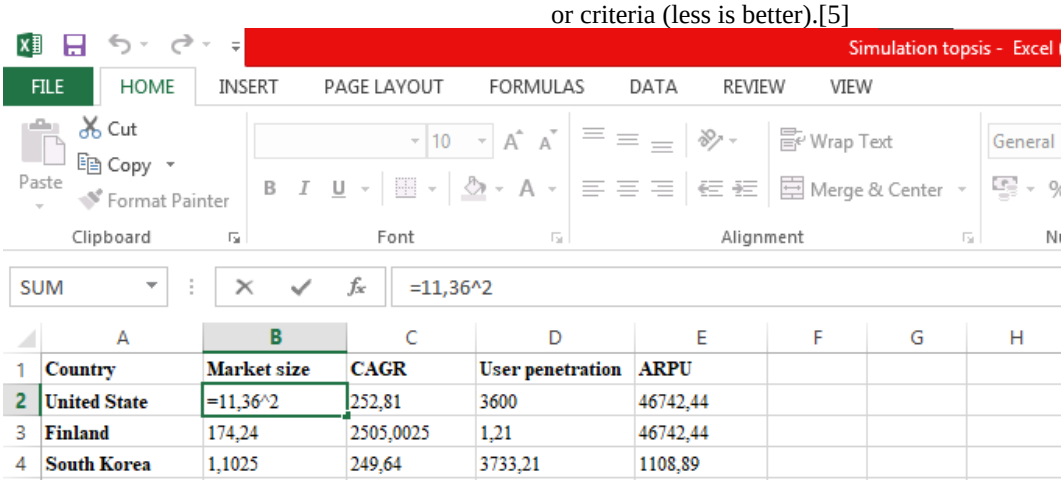
We normalize the given data. The purpose of normalization is to reduce criteria given in different dimensions to the same dimension, making them dimensionless and facilitating comparison. The formula I will use to apply normalization is this:

for i = 1, …, m; j = 1, …, n

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Figure 1.5 Formula for normalization

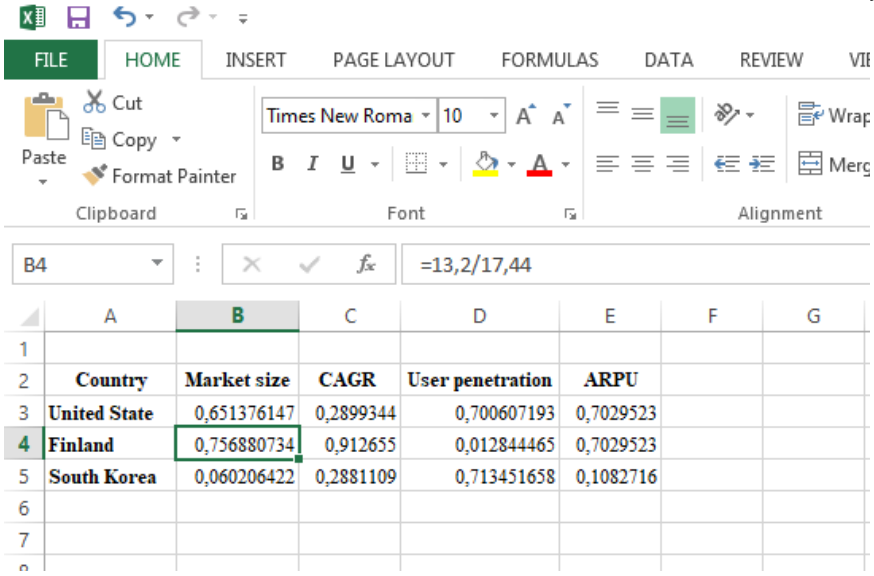
In TOPSIS method we have m alternatives and n criteria and we have the score of each option with respect to each criterion. Let xij score of option i with respect to criterion j. We have a matrix X = (xij) and m×n matrix. Here is J the set of benefit attributes or criteria (more is better) and J' be the set of negative attributes or criteria (less is better).[5]



	A	B	C	D	E	F	G	H
1	**Country**	**Market size**	**CAGR**	**User penetration**	**ARPU**			
2	**United State**	=11,36^2	252,81	3600	46742,44			
3	**Finland**	174,24	2505,0025	1,21	46742,44			
4	**South Korea**	1,1025	249,64	3733,21	1108,89			

Table 1.2 Normalization of these process

We have recorded the results we obtained for all the criteria of the alternatives given in this table by applying the same method. I have shown. I have squared all the criteria accordingly and recorded them in the table. Then, I have to calculate (Σx2ij)1/2 for each column. We squared each one in the correct order, added them up, and took the square root. For the next step we need to get rij so divide each column by (Σx2ij)1/2.



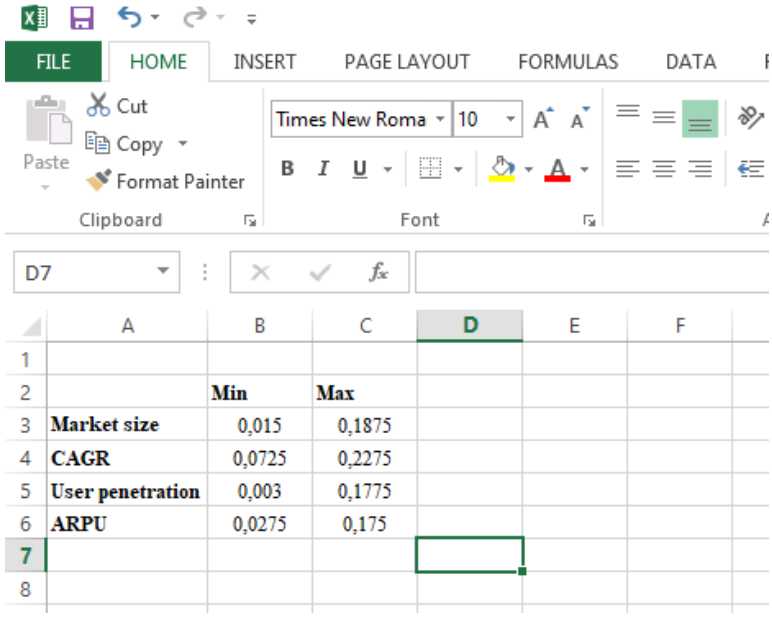
	A	B	C	D	E	F	G
1							
2	**Country**	**Market size**	**CAGR**	**User penetration**	**ARPU**		
3	**United State**	0,651376147	0,2899344	0,700607193	0,7029523		
4	**Finland**	0,756880734	0,912655	0,012844465	0,7029523		
5	**South Korea**	0,060206422	0,2881109	0,713451658	0,1082716		
6							
7							

Table 1.3 Dividing the starting form by the number derived from the square root

To solve the table above, we obtained the data for all the criteria given in order by dividing them by the numbers we took the square root of. As you can see in the problem, to get 0.75, it is solved as 13.2/17.44. In the next step, the same procedure is applied to all of them.

2nd Step:The weight we need to solve the next stage is 0.25. In general, the sum of the weights of all criteria should always be 1, that is, 100%. Therefore, in this case, the weight for each criterion will be 0.25, since it shows how important it is. we complete this process by multiplying by 0.25.

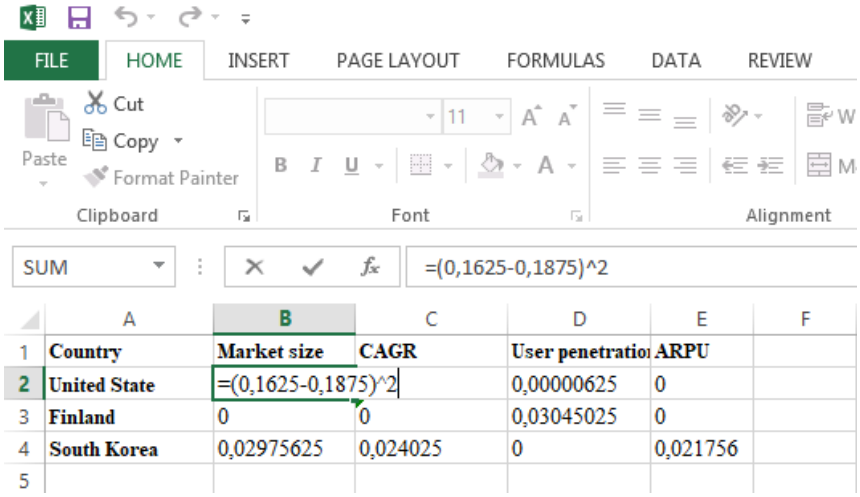
3rd Step: Now we will define ideal and negative ideal solutions. For Ideal solution - A* = { v1* , …, vn*}, where vj* ={ max (vij) if j ∈ J ; min (vij) if j ∈ J' } For Negative ideal solution - A' = { v1' , …, vn' }, where v' = { min (vij) if j ∈ J ; max (vij) if j ∈ J' }



	A	B	C	D	E	F
1						
2		**Min**	**Max**			
3	**Market size**	0,015	0,1875			
4	**CAGR**	0,0725	0,2275			
5	**User penetration**	0,003	0,1775			
6	**ARPU**	0,0275	0,175			
7						
8						

Table 1.4 Clarifying ideal and negative ideal solutions

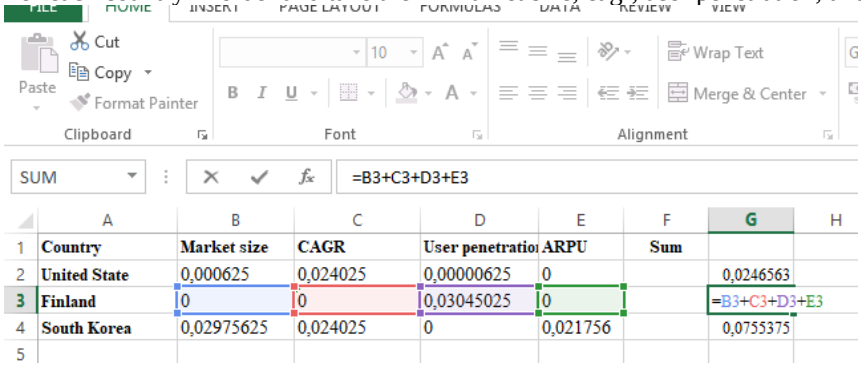
4th Step: I calculate the separation dimensions for each alternative. The formula is: Si * = [Σ (vj*– vij)2] ½ . The solution for ideal alternatives:



	A	B	C	D	E	F
1	**Country**	**Market size**	**CAGR**	**User penetratio**	**ARPU**	
2	**United State**	=(0,1625-0,1875)^2		0,00000625	0	
3	**Finland**	0	0	0,03045025	0	
4	**South Korea**	0,02975625	0,024025	0	0,021756	
5						

Table 1.5 Determine ideal solution

Now we need to collect the answers with row which I received for each country in order and take the root. This part shows the max ideal for each country's market size, cagr, user penetration, and arpu.

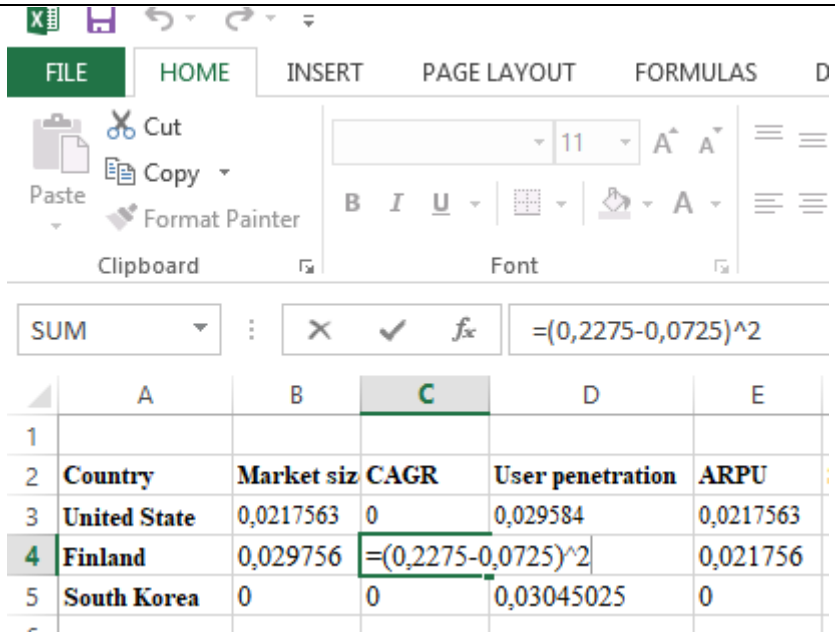


	A	B	C	D	E	F	G	H
1	**Country**	**Market size**	**CAGR**	**User penetratio**	**ARPU**	**Sum**		
2	**United State**	0,000625	0,024025	0,00000625	0		0,0246563	
3	**Finland**	0	0	0,03045025	0		=B3+C3+D3+E3	
4	**South Korea**	0,02975625	0,024025	0	0,021756		0,0755375	
5								

Table 1.6 Summary process for ideal

This calculation part explain that which has the best level for all attributes. Now, I will focus on negative sides to find out worst value for each attribute. The formula is: S'i = [Σ (vj' – vij)2] ½

The solution for non-ideal alternatives:



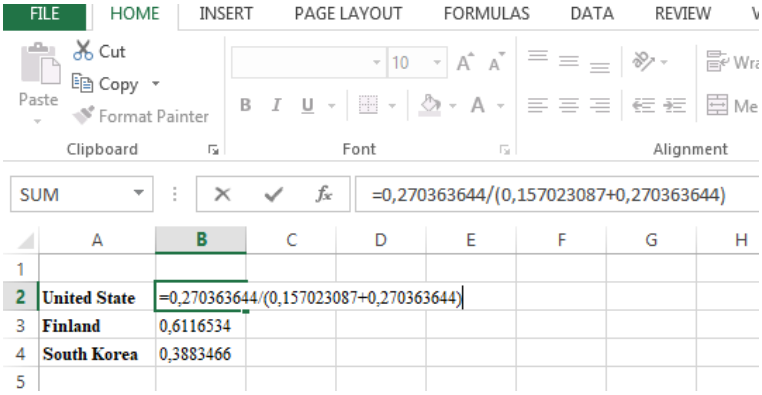
	A	B	C	D	E
1					
2	**Country**	**Market siz**	**CAGR**	**User penetration**	**ARPU**
3	**United State**	0,0217563	0	0,029584	0,0217563
4	**Finland**	0,029756	=(0,2275-0,0725)^2		0,021756
5	**South Korea**	0	0	0,03045025	0

Table 1.7 Determine non-ideal solution

In this phase of TOPSİS, we examined the ideal and non-ideal parts of the AR and VR phases. It is quite obvious that the evaluation of this area in 3 countries is in a very ideal state. The solution of non-ideal does not mean that it is bad. The main purpose of solving this is that even in the most ideal situations, we can encounter non-ideal situations. By applying and showing all the values, we have seen how the technology is progressing in these countries, both by users and by seeing its power in the market.

5th Step: Now, at this stage, we will calculate and show the relative proximity to the Ideal solution. This stage should be written to determine the best alternative. For this, relative proximity is taken as a basis. In the TOPSIS method, the values should always be between 0 and 1. Therefore, at the end of this stage that I will solve, I will take the value that will be closest to 1.

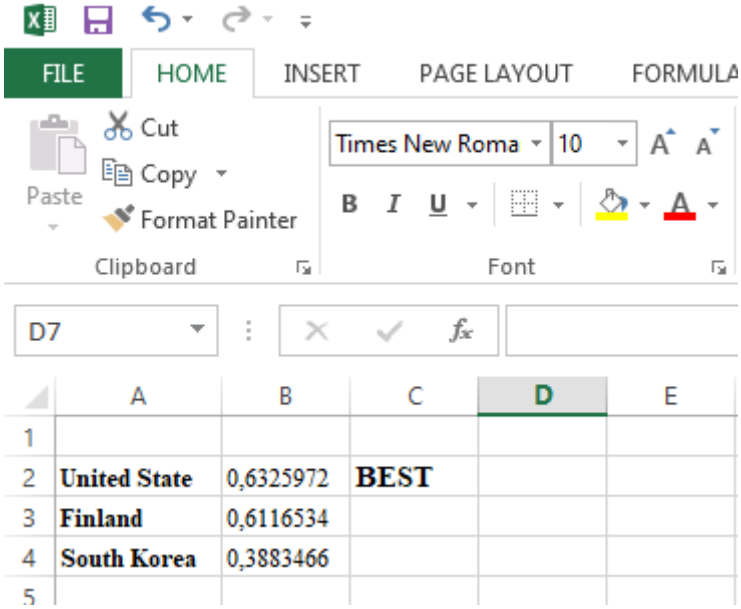
Formula is: Ci* = S'i / (Si* +S'i). Here is the S'j is non ideal, S*I is ideal.



	A	B	C	D	E	F	G	H
1								
2	**United State**	=0,270363644/(0,157023087+0,270363644)						
3	**Finland**	0,6116534						
4	**South Korea**	0,3883466						
5								

Table 1.8 Clarification of the relative proximity to the ideal solution Ci These shows that, how was calculation.*

Final ranking step Ci:*



	A	B	C	D	E
1					
2	**United State**	0,6325972	**BEST**		
3	**Finland**	0,6116534			
4	**South Korea**	0,3883466			
5					

Table 1.9 Select the option with Ci closest to 1.*

The answers wesolved and received were as follows. It is clear that the one closest to 1 will be the best solution for us. Therefore, among these solutions, Ci*=0.63 is noted as the best. Based on the TOPSIS method I have solved, it seems that the US holds the highest position in the education system due to its technological power, namely Virtual Reality and Augmented Reality. Following it is Finland, and then South Korea. All this shows that America is maintaining its leading position in the world with its technological power.

Based on these 4 criteria, it was better to clarify the analysis of market size, users, annual growth and revenue with TOPSIS analysis. All this analysis shows that the United States is the country that effectively stands out in the digital field in terms of educational strength among the United States, Finland and South Korea.

The United States has demonstrated its digital ecosystem better in this field. All this emphasizes the country's strong infrastructure and the strength of its adaptive education policy. [6]

Finland, which stands out with its model and stands out with its high user power of technology. Even though it is in 2nd place, its strategic impact in the digital field is very strong. [7]

South Korea, although it is strong in the digital and technological fields, takes the last place in the analysis. [8] But this country stands out from other countries in the world due to its digital strength. It is constantly developing as a result of the innovations it makes and the technological tools it produces.

Politically, it is not just about countries having technological tools, but also about ensuring their accessibility. While the US provides a high-income market, Finland is striving to gain a high reputation, while South Korea is struggling to maximize its potential for growth by resorting to strategic means. Educational institutions in all these countries are moving towards their goals to maximize their results. As a result, the study highlights that it is necessary to combine political support in order to increase the strength of the country's education sector and stand at the forefront.

Conclusion

This study examines the transformation that Virtual Reality (VR) and Augmented Reality (AR) have brought to education from past to present, alongside the political and institutional challenges that have emerged. The analysis reveals that while transforming learning is complex, the perceived impact of these technologies may differ across individuals and societies. The adoption of digital innovations is influenced by socio-cultural factors and strategic approaches aimed at optimizing education systems. Long-term research is needed to understand their effect on critical thinking, as well as the role of educators in developing immersive learning skills and implementing effective curricula. The comparative analysis of three countries highlights their distinct digital strategies and technological capacities. The United States leads globally with high student engagement and motivation through VR and AR applications. Finland emphasizes pedagogical innovation and creativity supported by immersive technologies, fostering collaboration worldwide. South Korea, despite internal political challenges, continues to pursue progress in digital education through national projects aimed at stress reduction and learning enhancement. Overall, the study demonstrates how AR and VR have evolved, the innovations they have introduced, and their growing importance in modern education. The findings underline the significance of digital transformation and encourage all countries, including developing ones, to take strategic steps toward advancing accessibility and effectiveness in education.

References:

1. Sathya T., Sharmila K., Sufina K., Revolutionizing Education Through Augmented Reality (AR) and Virtual Reality (VR): Innovations, Challenges and Future Prospects. Asian Journal of Interdisciplinary Research. DOI: 10.54392/ajir2511/ (2025)

2. Olatunbosun B.J., Obianuju C.O., Kazeem S., Digital transformation in education: Strategies for effective implementation. World Journal of Advanced Research and Reviews., DOI: 10.30574/wjarr.2024.23.2.2668, (2024)

3. Madanchian M, Taherdoost H. A comprehensive guide to the TOPSIS method for multi-criteria decision making. Sustainable Social Development; 1(1): 2220. doi: 10.54517/ssd.v1i1.2220, (2023)

4. Mitra M.,Hamed T., A comprehensive guide to the TOPSIS method for multi-criteria decision making. DOI: 10.54517/ssd.v1i1.2220 (2023)

5. E.Manokaran, S.Subhashini, S.Senthilvel, Dr.R.Muruganandham, Dr.K.Ravichandran, Application of Multi Criteria Decision Making Tools and Validation with Optimization Technique-Case Study using TOPSIS, ANN & SAW, IJMBS Vol. 1, Issue 3, (2011)

6. Wadim S., Veronika G., Alexander L.,Guzalbegim R.,Tatiana V., AI-driven adaptive learning for sustainableeducational transformation. DOI: 10.1002/sd.3221, (2024)

7. Nunziata M., Sustainable Development: A Comparison between the Finnish and the Italian Education Systems. 15(10), 8077; https://doi.org/10.3390/su15108077, (2023)

8. İrfan Ayhan., South Korea's Educational Leap Forward: Fostering Reforms in Pedagogy and Curriculum Through Digitalization and Innovation., In book: Global Agendas and Education Reforms. DOI: 10.1007/978-981-97-3068-1_8, (2024)