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Research Article

Efficacy Analysis of Different Modes of Learning in Undergraduate Courses During and Post COVID-19 Pandemic

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Abstract. Prior to COVID-19, taking undergraduate courses Online was an added option. Most of the universities in Telangana offered classes in Physical mode prior to COVID-19, Online mode during COVID-19, and have been currently offering classes in Hybrid mode. The current study aims at analyzing a variety of elements from the perspectives of Online education to assess the quality as well as its effectiveness in undergraduate courses that are widely practiced in most of the colleges of Telangana State, India due to the unprecedented challenges posed by the pandemic. The present study would like to focus on the administrators of e-learning platforms, teachers, and learners. To compare the relative weights of various elements while comparing Hybrid learning, Virtual learning, and Physical learning, the *Analytical Hierarchy Process* (AHP) approach was utilized. The results of this study can also serve as the foundation for evaluating hybrid, online, and offline learning in undergraduate courses.

Keywords. Analytical Hierarchy Process, Fuzzy AHP, Triangular Fuzzy AHP, TOPSIS method, Comparison analysis, Sensitivity analysis

Mathematics Subject Classification (2020). 90B50

1. Introduction

The global educational system has gone online due to the COVID-19 epidemic, and the Indian Ministry of Education has taken a number of actions to offer online instruction in response to the crisis. These consist of the *Pragyata* Guidelines on Digital Education, *Bharat Net* internet access and many more. Online learning cannot completely replace the traditional physical teaching-learning process, even though it has helped to keep education alive in these difficult circumstances. Both online and offline classroom settings have benefits and drawbacks. In a virtual learning environment, instructors deliver lectures through video or audio contents over the internet while students follow a digitally based curriculum. Students' learn online at least half the time and in-person classroom settings the other half in a hybrid learning environment.

Although the COVID-19 outbreak brought about temporary adjustments, online learning has persisted for two years. The consensus among researchers in education is that the current trend of remote instruction may not end soon and may even change after COVID-19 (Castro and Zermeno [4]). Making use of Triangular Fuzzy Numbers (TFN) instead of the crisp numbers as mentioned by van Laarhoven and Pedrycz [9]. The TOPSIS approach was used in this paper to determine the weights of the alternatives. The 'Triangular Fuzzy Scale' is described in Table 1.

Table 1. Triangular Fuzzy Scale

Crisp number(s)	Triangular fuzzy number	Definition
1	$(1,1,1)$	Equal significance
3	$(1,3,5)$	Little more significant than the other
5	$(3,5,7)$	Important
7	$(5,7,9)$	Very important
9	$(7,9,11)$	Extremely significant
$2,4,6,8$	$(1,2,3)$, $(3,4,5)$, $(5,6,7)$, $(7,8,9)$	Intermediate values

This study examines the utilization of several learning modalities —Offline, Online, and Hybrid— in undergraduate courses both in Telangana State Universities and Colleges during and after the COVID-19 pandemic.

Three alternatives have been considered in the present study as follows:

Offline Education (A_1)

Prior to the introduction of alternative learning methods such as online learning or hybrid learning, the conventional offline method of teaching-learning had been the widely acknowledged method. No wonder, the offline method paved the scope for regular physical connections with students. Contrary to the online platform of learning, the traditional offline classes are known to be popular for other merits such as better scope to monitor students' behavior and classroom engagement, it widens the scope of more accurate assessment of students' response and creates a conducive environment for constructive communication between a student and a teacher. There is no denying the fact that in spite of being an advanced form of teaching-learning method, online education cannot overshadow the merits of offline education which is believed to be vital to students' overall development.

Online Education (A_2)

The present face of education is highly revolutionized with the introduction of advanced technology. Compared to offline education, online education offers more flexibility in terms of easy access to study materials. The location of the learner or the teacher is no longer considered a constraint. Students are in an advantageous position as they can access the study materials even when they are at home. Another merit of online education is the opportunity it provides to a student who is not able to attend traditional classrooms due to various constraints. Students can learn at their own pace within a space of their convenience, once provided with dependable internet connectivity and necessary resources. Students learn to be more responsible without being physically monitored which in turn helps them to develop self-discipline and better time-management.

Hybrid Mode of Education (A_3)

The simplest definition of hybrid learning is when instructors instruct students simultaneously online and in conventional classroom settings. While some students participate digitally, others attend classes in person. The goal is to combine offline and Online modes of instruction effectively to improve the caliber and experience of learning for the students.

Six criteria have been considered in the present study as follows:

- Influence of Teaching methodology (C_1)
- Influence of Communication (C_2)
- Influence of Classrooms (C_3)
- Influence of Flexibility (C_4)
- Influence of Student-Teacher interaction (C_5)
- Influence of Practical learning (C_6)

2. Literature Review

2.1 Online Education in Under Graduate Institutes During the Pandemic

Online education, commonly known as e-learning, refers to educational delivery methods made possible by the internet. These include coaching, teaching, and studying educational content that has been digitally preserved (Fallon and Brown [7], Lee and Kim [10]). As a result of the pandemic, online lessons were implemented against the will of those who were immediately affected by them, creating a version of a live experiment in which teachers, students, and administrators discovered the shortcomings of this teaching style.

Throughout the entire course, students have to guide their own learning. Students often received less clear explanations from their teachers than in-person classes, and the lack of prompt response decreased their desire to study. Students reported feeling distant from both their lecturers and fellow classmates (Karkar-Esperat [8], Yim [16], Yoon and Woo [17]).

When classes moved Online, administrators in charge of overseeing online education were also unprepared, leading to problems with system connections, copyright, and privacy. They also encountered a brand-new reality, distinct from the one they had been used to, in which Online classes made up a relatively small percentage of all classes (Mahender *et al*. [11]). Since the present LMS (*Learning Management System*) for online classes served as the basis for virtual learning, there is a great need for systems that are specifically made for the virtual learning environment. This endeavor requires the expansion of human resources for training and administration. Previous research on the topic has focused a lot of attention on student satisfaction with online learning (Naseer and Rafique [13]).

The following papers were thought to present the findings of the current investigation more effectively: [11] *A computational method for normalization of Trapezoidal Fuzzy Numbers*, [5] *Selection of student for annual excellence award: An application of Trapezoidal Fuzzy AHP*, and [6] *Application of analytic hierarchy process in engineering education*.

2.2 Hybrid Course Delivery in Post-COVID-19 Adaptations

Numerous institutions have previously put procedures into place to modify and make their educational delivery accessible to the needs of their students. While blended learning includes some aspects of online course delivery, other approaches employ the hybrid model, which blends online and in-person sessions. All students must, however, take part in every delivery modality (Meydanlioglu and Arikan [12]). Furthermore, the hybrid-flexible paradigm combines online and face-to-face training. Each lesson and learning activity is offered in-person, synchronously online, and asynchronously online, giving students the flexibility to select how they engage with it (Beatty [2]). Although students have more alternatives because to the hybrid-flexible method, their feeling of community may be disrupted and experience gaps may increase.

3. Results

The following two methods explains the AHP Method and Fuzzy AHP Methods. In comparison analysis, these two methods are applied.

3.1 Analytical Hierarchy Process Method

The AHP method involves the following steps.

- Build Hierarchy and define goal at the top of the hierarchy.
- Establish Priorities.
- Calculate the Ratings.
- Compare the Alternatives.

3.2 Fuzzy AHP Method

Let $X = \{x_1, x_2, x_3, \dots, x_m\}$ be an object set and $Y = \{y_1, y_2, y_3, \dots, y_n\}$ be a predetermined objective. With this method, every object undergoes a matching extent analysis for every objective. Thus, for every object, m extent analysis values can be obtained,

$$M_{y_i}^1, M_{y_i}^2, \dots, M_{y_i}^m, \quad i = 1,2,3,\dots,n,$$

where $M_{y_i}^j$, $j = 1,2,3,\dots,m$.

Step 1: In relation to the ith object, the fuzzy synthetic extent's value is defined as

$$S_i = \sum_{j=1}^{m} M_{y_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{y_i}^j\right]^{-1}. \tag{1}$$

To find $\sum_{j=1}^{m} M_{y_i}^j$, for a specific matrix, applying *fuzzy addition* on m extent values so that

$$\sum_{j=1}^{m} M_{y_i}^j = \left[\sum_{j=1}^{m} p_j, \sum_{j=1}^{m} q_j, \sum_{j=1}^{m} r_j\right] \tag{2}$$

and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{y_i}^j\right]^{-1}$, carry out the *fuzzy addition process* of $M_{y_i}^j$, $j = 1,2,3,\dots,m$, so that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{y_i}^j = \left[\sum_{i=1}^{n} p_i, \sum_{i=1}^{n} q_i, \sum_{i=1}^{n} r_i\right]. \tag{3}$$

Then,

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{y_i}^j\right]^{-1} = \left[\frac{1}{\sum_{i=1}^{n} r_i}, \frac{1}{\sum_{i=1}^{n} q_i}, \frac{1}{\sum_{i=1}^{n} p_i}\right]. \tag{4}$$

Step 2: If $\widetilde{M}_1 = (p_1, q_1, r_1)$ and $\widetilde{M}_2 = (p_2, q_2, r_2) \geq \widetilde{M}_1 = (p_1, q_1, r_1)$, then,

$$V(\widetilde{M}_2 \geq \widetilde{M}_1) = \sup_{y \geq x}[\min(\mu_{\widetilde{M}_1}(x), \mu_{\widetilde{M}_2}(y))]. \tag{5}$$

Another way to put this is as:

$$\begin{aligned} V(\widetilde{M}_2 \geq \widetilde{M}_1) &= hgt(\widetilde{M}_2 \cap \widetilde{M}_1) \\ &= \mu_{\widetilde{M}_2}(d) \\ &= \begin{cases} 1, & \text{if } q_2 \geq q_1, \\ 0, & \text{if } p_1 \geq r_2, \\ \frac{p_1 - r_2}{(q_2 - r_2) - (q_1 - p_1)}, & \text{otherwise.} \end{cases} \end{aligned}$$

Step 3: A *convex fuzzy number* can be represented as

$$\begin{aligned} V(M \geq M_1, M_2, M_3, \dots\dots, M_k) &= V\begin{bmatrix} (M \geq M_1) \text{ and } (M \geq M_2) \\ \text{and } \dots \text{ and } (M \geq M_k) \end{bmatrix} \\ &= \min V(M \geq M_i), \quad i = 1,2,3,\dots,k. \end{aligned} \tag{6}$$

Suppose that, $d'(A_i) = \min V(T_i \geq T_k)$ for $k = 1,2,3,\dots,n$; $k \neq i$. Then, the *weight vector* is

$$W' = (d'(A_1), d'(A_2), d'(A_3) \dots, d'(A_n))^T, \tag{7}$$

where A_i, $i = 1,2,3,\dots,n$ are n components.

Step 4: After normalization, the *normalized vectors* are

$$W = (d(A_1), d(A_2), d(A_3), \dots, d(A_n))^T, \tag{8}$$

where W is *non-fuzzy number*.

3.3 TOPSIS Method

The TOPSIS method is used to find the weights of the alternatives verses criteria. AHP offers a decision hierarchy and calls for pair-wise criterion comparison. Consequently, thorough understanding of the decision hierarchy's criteria is necessary in order to use AHP and make informed decisions (Tzeng and Huang [14], Xu [15]) made the initial demonstration of the TOPSIS approach. By this method, the option that is most distant from the negative ideal solution and most similar to the positive ideal solution would be the best one, see Benítez *et al*. [3].

The ideal solution is one that minimizes the benefit criteria while increasing the cost criteria. As a result, the positive ideal solution consists of the best possible results for every criterion, whereas the negative ideal solution consists of the worst possible results for every criterion. To ascertain the ultimate ranking of the various teaching strategies utilized in undergraduate courses in the state of Telangana, the TOPSIS technique is utilized in this study.

A decision matrix that has been normalized as

$$u_{ij} = \frac{w_{ij}}{\sqrt{\sum_{j=1}^{m} w_{ij}^2}}\ , \ j = 1,2,3,\dots,m; i = 1,2,3,\dots,n \tag{9}$$

The *weighted normalized decision matrix* is $v_{ij} = w_{ij} * u_{ij}$, $j = 1,2,3,\dots,m$; $i = 1,2,3,\dots,n$.

The *Positive and Negative Ideal Solutions* are:

$V^* = \{v_1^*, v_2^*, \dots, v_n^*\}$ Maximum values and $V^- = \{v_1^-, v_2^-, \dots, v_n^-\}$ Minimum values

Each alternative's distance from PIS and NIS is:

$$d_{ij}^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \quad j = 1,2,3,\dots,m, \tag{10}$$

$$d_{ij}^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \quad i = 1,2,3,\dots,m. \tag{11}$$

Each alternative's closeness coefficient is:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \quad i = 1,2,3,\dots\dots,m, \tag{12}$$

CC_i values are compared to determine the ranking of alternatives.

Notations

Matrix size $= n$, Consistency Index $= CI = \frac{\lambda_{\max - n}}{n-1}$, $\lambda_{\max}$ is the greatest eigen value, Random Index $= RI = 0.52$ for 3×3 matrix, Consistency Ratio $= CR = \frac{CI}{RI}$.

Table 2 to Table 7 explains Fuzzy options displaying the relative weights of each choice for Criteria 1 through Criteria 6.

Table 2. Normalized weight vector with respect to C_1

C_1	A_1	A_2	A_3	Normalized weight vector
A_1	(1,1,1)	(5,7,9)	(3,5,7)	0.970
A_2	(1/9,1/7,1/5)	(1,1,1)	(1/5,1/3,1)	0.000
A_3	(1/7,1/5,1/3)	(1,3,5)	(1,1,1)	0.243
$\lambda_{\max} = 3.0648$, $CI = 0.0324$, $CR = 0.0623$				

Table 3. Normalized weight vector with respect to C_2

C_2	A_1	A_2	A_3	Normalized weight vector
A_1	(1,1,1)	(3,5,7)	(5,6,7)	0.977
A_2	(1/7,1/5,1/3)	(1,1,1)	(1,3,5)	0.215
A_3	(1/7,1/6,1/5)	(1/5,1/3,1)	(1,1,1)	0.000
$\lambda_{\max} = 3.094$, $CI = 0.047$, $CR = 0.0903$				

Table 4. Normalized weight vector with respect to C_3

C_3	A_1	A_2	A_3	Normalized weight vector
A_1	(1,1,1)	(5,7,9)	(1,3,5)	0.899
A_2	(1/9,1/7,1/5)	(1,1,1)	(1/5,1/3,1)	0.000
A_3	(1/5,1/3,1)	(1,3,5)	(1,1,1)	0.438
$\lambda_{\max} = 3.0070$, $CI = 0.0035$, $CR = 0.0067$				

Table 5. Normalized weight vector with respect to C_4

C_4	A_1	A_2	A_3	Normalized weight vector
A_1	(1,1,1)	(3,4,5)	(3,5,7)	0.918
A_2	(1/5,1/4,1/3)	(1,1,1)	(1,3,5)	0.397
A_3	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)	0.000
$\lambda_{\max} = 3.08576$, $CI = 0.04288$, $CR = 0.08246$				

Table 6. Normalized weight vector with respect to C_5

C_5	A_1	A_2	A_3	Normalized weight vector
A_1	(1,1,1)	(7,9,11)	(1,3,5)	0.902
A_2	(1/11,1/9,1/7)	(1,1,1)	(1/7,1/5,1/3)	0.000
A_3	(1/5,1/3,1)	(3,5,7)	(1,1,1)	0.431
$\lambda_{\max} = 3.0290$, $CI = 0.0145$, $CR = 0.0278$				

Table 7. Normalized weight vector with respect to C_6

C_6	A_1	A_2	A_3	Normalized weight vector
A_1	(1,1,1)	(3,5,7)	(1,3,5)	0.834
A_2	(1/7,1/5,1/3)	(1,1,1)	(1/5,1/3,1)	0.074
A_3	(1/5,1/3,1)	(1,3,5)	(1,1,1)	0.546
$\lambda_{\max} = 3.0385$, $CI = 0.01925$, $CR = 0.0370$				

Table 8 describes Fuzzy options showing weights of Criteria to Criteria as given below.

Table 8. Normalized weight vector with respect to Criteria to Criteria

	C_1	C_2	C_3	C_4	C_5	C_6	Normalized weight vector
C_1	1	1	1/3	5	3	1/5	0.423
C_2	1	1	3	3	1/3	5	0.472
C_3	3	1/3	1	1/3	3	1/3	0.379
C_4	1/5	1/3	3	1	1	3	0.382
C_5	1/3	3	1/3	1	1	1/3	0.311
C_6	5	1/5	3	1/3	3	1	0.460

The ranking of every alternative obtained by Fuzzy AHP and TOPSIS methods is shown in Table 9.

Table 9. Ranking of Alternatives (by Fuzzy AHP and TOPSIS methods)

	C_1	C_2	C_3	C_4	C_5	C_6	Weights	Ranks
A_1	0.97	0.97	0.89	0.91	0.90	0.83	1.00	1
A_2	0.00	0.21	0.00	0.39	0.00	0.07	0.18	3
A_3	0.24	0.00	0.43	0.00	0.43	0.54	0.31	2

The ranking of every alternative obtained by Analytical Hierarchy Process and TOPSIS methods is shown in Table 10.

Table 10. Ranking of Alternatives (by AHP and TOPSIS methods)

	0.17	0.24	0.13	0.14	0.12	0.2	Weights	Ranks
	C_1	C_2	C_3	C_4	C_5	C_6		
A_1	0.73	0.72	0.67	0.67	0.67	0.64	1	1
A_2	0.08	0.19	0.09	0.23	0.06	0.10	0.11	3
A_3	0.19	0.09	0.24	0.10	0.27	0.26	0.19	2

It is observed that the rankings are same in both the cases, that is in AHP-TOPSIS and Fuzzy AHP-TOPSIS methods. In Figure 1 the comparison analysis is displayed.

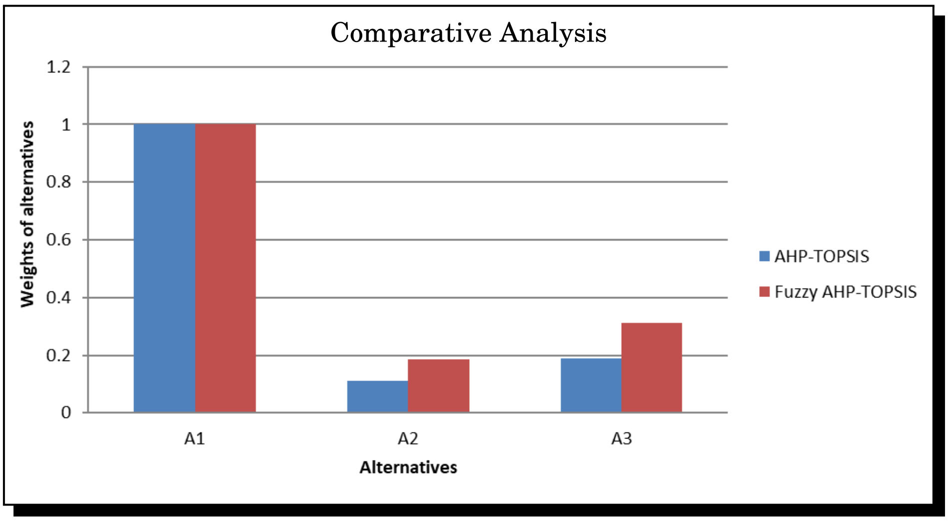

Figure 1. Ranking of the alternatives compared by two methods

4. Sensitivity Analysis

It is crucial to ascertain whether this selection is steady and sturdy after determining the ranks of the alternatives. The effect of a particular criterion on the priority of the alternatives can be ascertained using the sensitivity analysis. Alinezhad and Abbas [1] presented an examination of the impact of altering the weight of one attribute on the ultimate ranking of alternatives.

The weights of the criteria that were obtained and the significance of the weight of a criterion whose sensitivity was assessed were considered in the current study. The weights of criteria changed with minimum values of '0' in steps of 0.1. The importance of other criteria in the same hierarchy is changed in proportion to their original weights such that the sum of weights of all criteria in that level approximately is equal to one.

Figures 2 to 7 explains preferential weights of alternatives when weights of criteria 1 to 6 respectively changed.

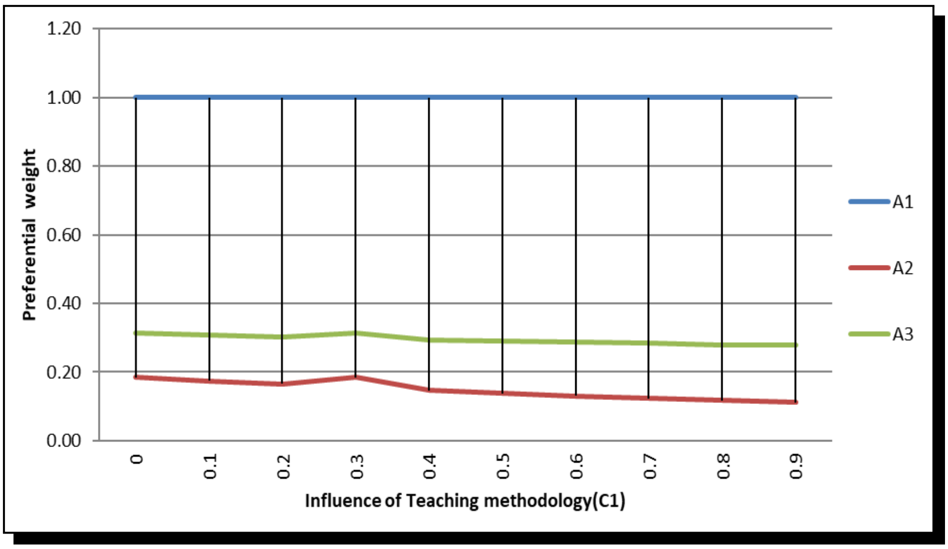

Figure 2. Preferential weights of alternatives when weights of the criteria 1 has been changed

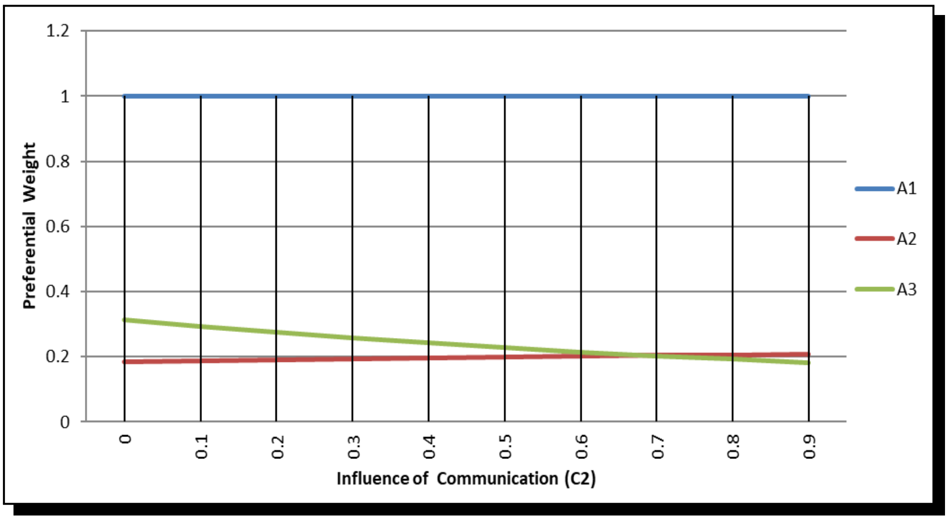

Figure 3. Preferential weights of alternatives when weights of the criteria 2 has been changed

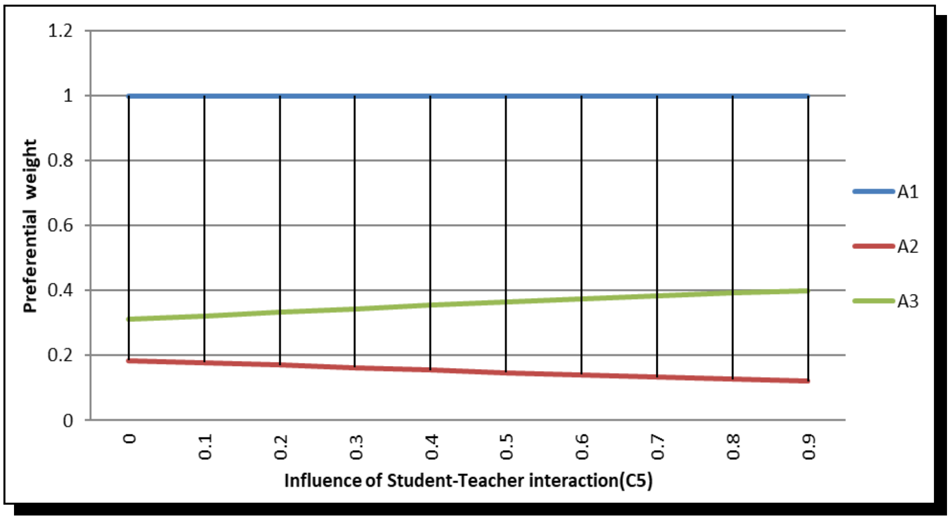

Figure 4. Preferential weights of alternatives when weights of the criteria 3 has been changed

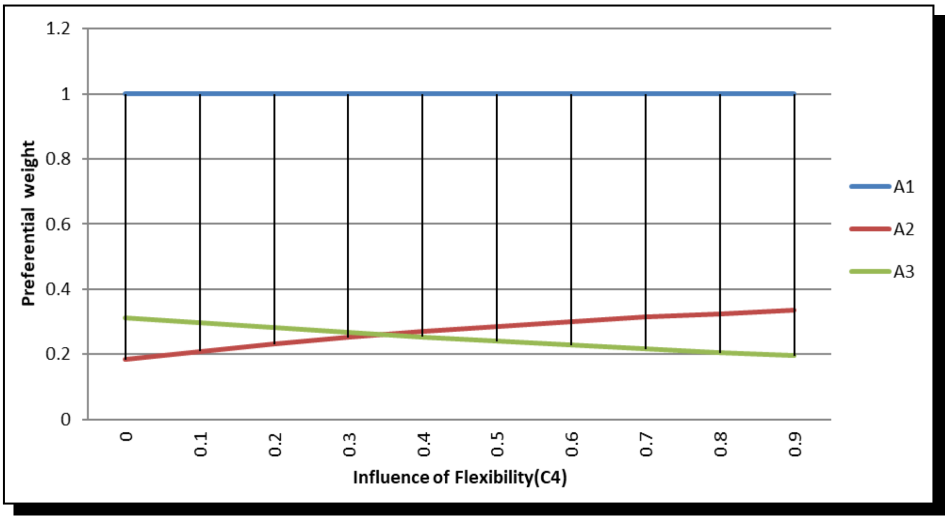

Figure 5. Preferential weights of alternatives when weights of the criteria 4 has been changed

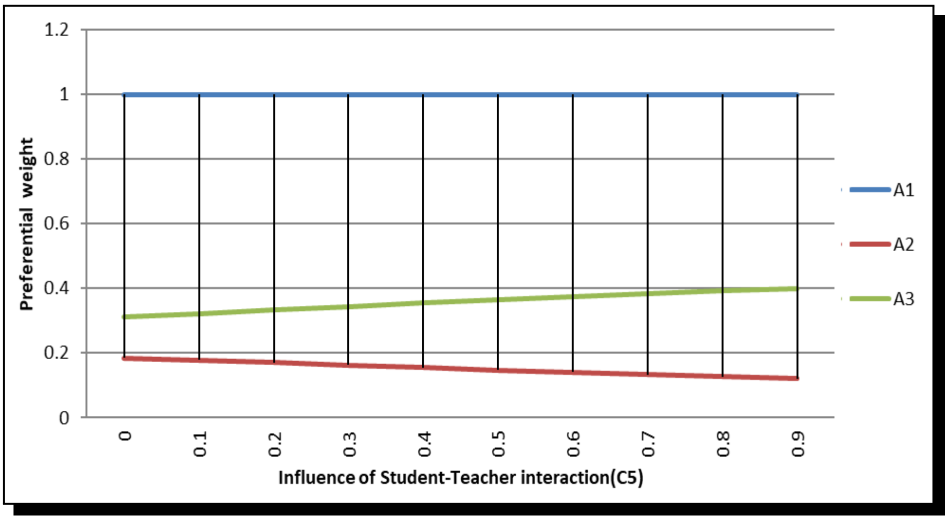

Figure 6. Preferential weights of alternatives when weights of the criteria 5 has been changed

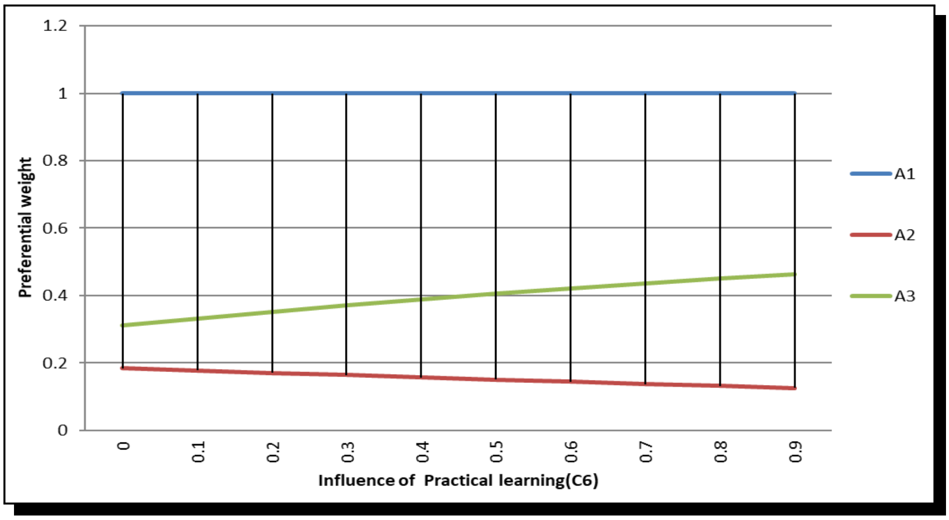

Figure 7. Preferential weights of alternatives when weights of the criteria 6 has been changed

Figures 2, 4, 6, and 7 show that modifications to criteria C_1, C_3, C_5, and C_6 have no effect on the ranking order of the options. The alternatives available in First, Second, and Third are A_1, A_2, and A_3, respectively. The alternative A_1 was ranked highest for the other criteria C_2 and C_4, as shown in Figures 3 and 5. The rankings of alternatives A_2 and A_3 are varied for higher values.

5. Conclusion

Comparing the three alternatives in perspective of six criteria, it is observed that Offline education (1.000) came out on top, followed by Hybrid mode education (0.312). Online education (0.184) was ranked third at the end. Offline education maximizes the possibility of face-to-face interaction, verbal and nonverbal feedback, evaluation and shapes a student's career. Online and Hybrid mode of education with their virtues to some extent fail to exert similar impact upon students since motivation of being engaged in the class may be hampered by various distractions; there might be unwillingness for active participation since teachers have less control over them and most importantly without the very physical environment that makes learning more effective, online mode may not fetch the best results. It would remain only an option to facilitate learning where students would miss the human touch of a teacher.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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