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Fuzzy AHP-TOPSIS approaches to prioritize teaching solutions for Intellect Errors

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Abstract: The teaching fraternity and intellects play an important role in students' careers as they make students industry-ready. During their teaching, they make different types of errors. One of the neglected aspects during teaching is intellect errors and these directly or indirectly impact students learning capabilities. The scattered literature shows that there are twelve types of intellect errors like 'error of coincidence', 'senses error', 'analogy error', 'subjectivity error', etc. To minimize these errors, six solutions have been identified like 'selection of right instruments', 'development of critical thinking in the students', 'aware about knowledge engineering development' etc. This study aims to identify and prioritize the solutions to overcome the errors of the intellect that has been the ignored aspect of the teaching till now. A hybrid approach of fuzzy AHP (Analytical Hierarchy Process) and Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) has been proposed to rank the solutions that minimize the intellect errors. Fuzzy AHP is used to compute the weights for intellect errors by doing the pairwise comparison and fuzzy TOPSIS is used to rank the identified solutions with the help of generated weights of fuzzy AHP. The results show that "error of proximity" and "senses error" are the highest and least rated intellect errors respectively. The topmost rated solution to handle errors of the intellect is "development of critical thinking in the students".

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1. Introduction

Intellects are working on the students to make them industry-ready. Instead of progression and expansion in education and technology developments, industry experts always complain students lack analytical as well as critical thinking skills. Some of these lacking skills may be the result of errors done by the intellects. Intellect errors can be wrenching out at the wrong interpretations by looking at insufficient as well as incorrect data and then looking at the literature to support these interpretations. This will result in inaccurate deductions and theories. The intellects have to go the other way around i.e. correct interpretations of the data should be taught in the class instead of neglecting the incorrect data (Palanki, 2021). In C programming books, generally, you find a program to calculate Armstrong's number of three-digit numbers. It is calculated by finding out the overall sum of the cube of each digit in the three-digit number. If this sum is equal to the original number, then it is Armstrong's number. This is true for three-digit numbers and intellects generally do the same thing for four-digit, five-digit, etc. numbers but the truth is it is calculated by finding out the overall sum of the power of the "number of digits" of each digit in the number. This wrong concept is also carried by students in the industry work too. One other type of intellect error by the intellects is that when students show programming programs to the teachers, they neglect the proper formatting, comments, and rules that are necessary for proper readability and documentation of the programs. This lack of professional skills is developed in the students unknowingly whereas this is one of the most important skills as industries are too focused-on documentation and rules for writing programs. The important thing is to firstly inculcate skills like analytical, reasoning, critical thinking, and troubleshooting skills in the students before making them industry-ready. If these skills are not given to the students, then it leads to disasters in the projects like manufacturing industries, medical treatment, budget handling, research development and results in high upfront and operational project costs, delayed time, poor usage of resources and infrastructures. Section 2 describes different types of intellects errors whereas section 3 deals with the solutions that minimize the intellect errors. Section 4 discusses the research methodology in which fuzzy AHP and fuzzy TOPSIS have been described with their implementation procedure. Section 5 of the current study targets the conclusions.

2. Intellect Errors

The life of a human consists of seven attributes (Revel Miller, 2019). The attributes are self-aspect, emotional aspect, social aspect, spiritual aspect, physical aspect, behavioral aspect, and mental aspect. These seven aspects are the pillars of human beings' life. These aspects are directly or indirectly related to emotions, drives for eating & sleeping as well as thinking levels and innovations. With these aspects, intellect errors are also associated (Palanki, 2021) and these are mentioned as:

A. Error of coincidence

This is also called 'Post hoc fallacy' or 'Post hoc ergo propter hoc'. This fallacy states that "Event Q" has occurred due to "Event P" or in other words it can be said that event Q has occurred after the occurrence of event P. But, both events P and Q are independent of each other. In this type of error, it is also assumed that one event is a cause and the other event is an effect. It is just a coincidence. Suppose you went out of the house and it rains. It does not mean when you go out, it will rain. In the first stance, it is just a coincidence. Sometimes, intellects do the error of coincidence while giving lectures. They give explicit reasoning for the acts that intellects should not work on, but they tell post hoc stories to justify their acts (Summers, 2017).

B. Error of proximity

This is also called "order-effect". It occurs when a person does the rating on one item and it affects the rating of other items that immediately comes after it (Javidmehr & Ebrahimpour, 2015). Suppose we buy mangoes from a particular shop and every time they are good in quality but maybe sometimes rotten mangoes can be bought from that shop, this is an example of proximity error. Suppose that interviewer knows particular university students are brilliant in programming and every time they are selected and a weak programming student can clear the interview as the interviewer has a perception that these students have high programming skills. This is another example of intellect proximity error.

C. Senses error

The author (Patterson, 2016) stated that sometimes senses deceive and that is the reason why we should not fully believe in the senses. Look when intellects try to differentiate between different micro-organisms with the naked eye, they are failed to do. For differentiating micro-organisms, a microscope is required. This statement states that the important thing is to choose the right instrument for a given problem to minimize the senses' error.

D. Error of ignorance

Intellects do this error as they perceive they know everything but actually, they do not know or in other words, it can be said that decision-makers believe that some outcomes may occur but in the end, these outcomes do not occur, these are ignorance errors committed by the intellects (Wolfson & Carroll, 1976). These types of errors when committed in the industry then the loss is high.

E. Error of habit

When a man sees a small stone on the road, he has the habit of hitting the stone with his foot and when he inadvertently hit a large stone with his foot, he injured his foot. This is an example of an 'error of habit'. Suppose an examiner gives very few marks to a tougher programming question and suddenly a good answer comes his way but he again gives very few marks. This is an example of an 'error of habit'.

F. Generalization error

The experts are examining the intellects of ten persons of a town and they find that all ten people are below average. Here, experts can conclude that all the persons of this town are below average in intellects. This type of generalization error should be avoided when the sample size is very less and a conclusion is made for the whole population. To minimize this type of error, discussions, and sharing of information should be encouraged (Nadeau & Bengio, 2003).

G. Error of the bandwagon

Due to external pressure, a decision is accepted or rejected. This effect is a bandwagon. Suppose you want to buy a bike based on its average and then you do a survey and you find bike "A" has more average as mentioned in its advertisement and all people will also support that too. This feature can be one of the top criteria for selecting a bike but one must list down all the cons of this particular bike before buying the bike. By using this technique, the error of the bandwagon can be minimized.

H. Familiarity Error

This error occurs when the problem was familiar and people just ignore and it becomes a calamity. Let's take a case when a family knows when they switched on the TV, there are small sparks in wires and all family members are ignorant to this and later on, this small spark leads to fire in the house. This type of error is a familiarity error.

I. Subjectivity Error

When an individual makes a decision, there are chances of bias and it leads to subjective error. To minimize the subjective error, group decision-making, brainstorming, or Delphi techniques are preferred. Decision-making improves when group-decision making takes place.

J. Analogy Error

Many experts use an analogy to enhance a better understanding of the concepts but this does not prove the hypothesis. This is just used for understanding. For example, when you reap good things, you will get good things in return.

K. Error of irrelevance

When a certain argument is taking place and the critics talk about the problems that are not associated with that argument. This is an 'error of irrelevance'. Suppose a researcher writes a paper on Rice Hispa disease identification and the reviewer tells to survey rice soil and that is irrelevant to this particular disease as it is not associated with soil at all. This is an 'error of irrelevance'.

L. Error of the machine

The researchers are using machine learning and deep learning models on the collected datasets without understanding why they are using these techniques. This leads to wrong interpretations.

Fig. 1: Types of Intellect Errors

3. Possible Teaching Solutions of Intellect Errors

Several teaching solutions can be used for minimizing the intellect errors and these are listed as:

a) Development of critical thinking skills in the students (Renatovna, 2019), (Rahmawati & Harun, 2019), (Bezanilla, Fernández-Nogueira, Poblete, & Galindo-Domínguez, 2019), (Palanki, 2021).

b) Intellects should be aware of knowledge engineering developments (Palanki, 2021).

c) Intellects should have good communication skills and be team collaborators (Bambaeeroo & Shokpour, 2017), (Palanki, 2021).

d) Follow ethical practices (Sherpa, 2018), (Kusumaningrum, Sumarsono, & Gunawan, 2019), (Palanki, 2021).

e) Teachers should be innovative, flexible, and learners (Kalyani & Rajasekaran, 2018), (Palanki, 2021).

f) Selection of right instruments for teaching (Rahmawati & Harun, 2019), (Palanki, 2021).

4. Research Methodology

The literature shows that the researchers have not explored much about intellect errors and their solutions. Thus, there is a need to identify, analyze and prioritize intellect errors. At the same time, different solutions have been proposed by the researchers to overcome these intellect errors but these solutions are very much scattered in the literature. There is a need to collect, organize and analyze these solutions that will help the Intellects and students to minimize the mistakes in their decision-making process. Hybrid fuzzy AHP and fuzzy TOPSIS have been used in the current study to prioritize the solutions for minimizing intellect errors. The intellect errors and the solutions are described in Section 2 and Section 3 respectively. Fuzzy AHP is applied to acquire the weights of the intellect errors and these weights are used by fuzzy TOPSIS for ranking the solutions that will be best suited to minimize the intellect errors. The choice of current methodology that uses hybrid fuzzy AHP-TOPSIS approach is supported by several motives and these are listed as:

- Ranking of Intellect errors and their solutions comes under the category of multi-criteria decision making. This involves human judgments that are mostly subjective and unclear. It becomes problematic to represent these judgments in numerical values, so to handle the imprecision, ambiguity, and vagueness in the judgments appropriately fuzzy-based methods are used.

- This hybrid approach improves a significant amount of time in computations when compared with other decision-making approaches like elimination & choice expressing reality (ELECTRE), interpretive structural modeling (ISM), and analytic network process (ANP).

- Both these approaches are quite simple in understanding, conception, and application.

- The main reason for electing this hybrid approach is due to its suitability to handle the complex multi-decision environment.

4.1 Fuzzy AHP

The fuzzy AHP procedure consists of many strides and these are taken from the study (Chang, 1996). The strides are described as:

Stride 1: Initially, a pairwise matrix is prepared using triangular fuzzy numbers (TFNs). The expert opinions are taken into account along with equation (1) to make this pairwise matrix.

$$\tilde{E} = \begin{bmatrix} 1,1,1 & \tilde{e}_{12} & \tilde{e}_{13} & \tilde{e}_{14} & \cdots & \tilde{e}_{1n} \\ \tilde{e}_{21} & 1,1,1 & \tilde{e}_{23} & \tilde{e}_{24} & \cdots & \tilde{e}_{2n} \\ \tilde{e}_{31} & \tilde{e}_{32} & 1,1,1 & \tilde{e}_{34} & \cdots & \tilde{e}_{3n} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \tilde{e}_{n1} & \tilde{e}_{n2} & \tilde{e}_{n3} & \tilde{e}_{n4} & \cdots & 1,1,1 \end{bmatrix} \quad (1)$$

where $\tilde{e} = (a_{xy}, b_{xy}, c_{xy})$ and x ,y= 1,2,3,……n are triangular fuzzy numbers.

Stride 2: Fuzzy synthetic extent values (FVs) are reckoned with the help of equation number 2.

$$FV_x = \left(\sum_{y=1}^{n} a_y \;, \sum_{y=1}^{n} b_y \;, \sum_{y=1}^{n} c_y\right) * \left(\frac{1}{\sum_{x=1}^{n} c_x}, \frac{1}{\sum_{x=1}^{n} b_x}, \frac{1}{\sum_{x=1}^{n} a_x}\right) \quad (2)$$

Stride 3: Here, the Degree of possibility (DPos) is computed.

Stride 4: Calculation of fuzzy weight (FuzW) and non-fuzzy weight (NFuzW) for all intellect errors is done.

4.2 Fuzzy AHP Implementation

The abbreviations for all Intellect errors have been mentioned in Annexure A. Firstly in fuzzy AHP, the experts' linguistic assessment method is described for rating all the

Table 1 : Fuzzy Linguistic Scale used for pairwise decision

Linguistic Term	TFNs (a,b,c)	Linguistic Term	TFNs (a,b,c)
Equal	$\tilde{1}$ = (1,1,1)	Moderate	$\tilde{3}$ = (2,3,4)
Strong	$\tilde{5}$ = (4,5,6)	Very Strong	$\tilde{7}$ = (6,7,8)
Tremendous	$\tilde{9}$ = (9,9,9)	Intermediate value between Equal and Moderate	$\tilde{2}$ = (1,2,3)
Intermediate value between Moderate and Strong	$\tilde{4}$ = (3,4,5)	Intermediate value between Strong and Very Strong	$\tilde{6}$ = (5,6,7)
Intermediate value between Very Strong and Tremendous	$\tilde{8}$ = (7,8,9)		

intellect errors as shown in table 1. Table 1 consists of nine linguistic terms along with an associated TFN that will be used by the decision-makers for pairwise comparison of intellect errors. 15 experts have given their opinions for making a pairwise decision comparison matrix using equation 1. Table 2 shows the aggregated values of the decision matrix values mentioned by the different experts.

Table 2: Calculated Intellect Errors fuzzy aggregated decision matrix

	EC	EP	---------	-------	---------	EIr	EM
EC	(1,1,1)	(0.23,0.31,0.44)				(2.00,3.00,4.00)	(1.89,2.33. 3.00)
EP	(2.33,3.33,4.33)	(1,1,1)				(5.00,6.00,7.00)	(1.78,2.13,2.50)
SE	(1.08,1.78,2.50)	(2.08,2.78,3.50)				(0.20,0.25,0.33)	(1.80,2.17,2.56)
EIg	(2.71,3.38,4.06)	(2.08,2.78,3.50)				(2.00,3.00,4.00)	(0.33,0.50,1.00)
EH	(0.23,0.31,0.44)	(1.71,2.39,3.07)				(2.00,3.00,4.00)	(3.44,4.17,5.00)
GE	(0.73,1.42,2.11)	(2.71,3.39,4.07)	---------	-------	---------	(0.25,0.33,0.50)	(2.00,3.00,4.00)
EB	(1.42,2.11,2.83)	(3.67,4.67,5.67)				(0.33,0.50,1.00)	(1.89,2.29,3.05)
FE	(0.25,0.33,0.50)	(0.14,0.17,0.20)				(2.00,3.00,4.00)	(1.89,2.33,3.00)
SubE	(1.00,2.00,3.00)	(2.75,3.44,4.17)				(2.00,3.00,4.00)	(1.89,2.33,3.00)
AE	(1.38,2.06,2.73)	(1.10,1.44,1.80)				(2.00,3.00,4.00)	(2.00,3.00,4.00)
EIr	(0.25,0.33,0.50)	(0.14,0.17,0.20)				(1,1,1)	(2.00,3.00,4.00)
EM	(0.71,1.39,2.07)	(2.71,3.39,4.07)				(0.25,0.33,0.50)	(1,1,1)

Table 3 have FVs for all intellect errors and it is calculated by the use of extent analysis method and for the computation, equation 2 is used.

Table 3: Fuzzy Synthetic extent values of all criteria

Fuzzy Synthetic Criteria (FC)	**Fuzzy Synthetic Extent Values (FVs)**
FC1 (EC)	a1=0.05, b1=0.08, c1=0.15
FC2 (EP)	a2=0.07, b2=0.12, c2=0.19
FC3 (SE)	a3=0.03, b3=0.06, c3=0.10
FC4 (EIg)	a4=0.05, b4=0.08, c4=0.14
FC5 (EH)	a5=0.04, b5=0.07, c5=0.13
FC6 (GE)	a6=0.05, b6=0.09, c6=0.16
FC7 (EB)	a7=0.06, b7=0.10, c7=0.17
FC8 (FE)	a8=0.05, b8=0.08, c8=0.15
FC9 (SubE)	a9=0.05, b9=0.10, c9=0.18
FC10 (AE)	a10=0.05, b10=0.10, c10=0.19
FC11 (EIr)	a11=0.03, b11=0.06, c11=0.10
FC12 (EM)	a12=0.03, b12=0.06, c12=0.12

After performing this stride, the minimum degree of possibility (DPos) is computed as shown in table 4. This step is used to find the greatest fuzzy value among several fuzzy numbers. It is calculated using equations 3, 4, and 5.

V(FC1 >= FC2) = 1 iff b1 >= b2 (3)

V(FC1 >=FC2) = 0 iff a1 >= c2 (4)

$$V(FC_2 \geq FC_1) = \frac{a_{1-}c_2}{(b_{2-}c_2)-(b_{1-}a_1)} \quad (5)$$

Now, the next step is to calculate the Fuzzy weight (FuzW), non-fuzzy weight/normalized weight (NFuzW) using equation 6 and equation 7.

NFuzW = (d`(Q1), d`(Q2), d`(Q3), d`(Q4)…….d`(Qn))$^T$ where d`(Qi)=min V(FCa >= FC_b) & a,b =1,2,3…n and a≠b (6)

FuzW=(d(Q1), d(Q2),d(Q3),d(Q4)…….d(Qn))^T (7)

After the computation of weights, they are ranked according to their weights. The highest weight incurred is ranked highest and the lowest weight incurred is ranked lowest among all intellect errors as mentioned in Table 5.

Table 4: Calculated Degree of possibility for all criteria

	V(FC1)	**V(FC2)**	**V(FC3)**	**V(FC4)**	**V(FC5)**	**V(FC6)**	**V(FC7)**	**V(FC8)**	**V(FC9)**	**V(FC10)**	**V(FC11)**	**V(FC12)**
	0.72	1.00	0.66	0.95	0.88	1.00	1.00	0.99	1.00	1.00	0.67	0.75
	1.00	1.00	0.33	0.64	0.57	0.79	0.85	0.71	0.84	0.91	0.36	0.45
	1.00	1.00	0.71	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00
	1.00	1.00	0.78	1.00	0.93	1.00	1.00	1.00	1.00	1.00	0.72	0.80
	0.93	1.00	0.59	0.88	0.81	1.00	1.00	1.00	1.00	1.00	0.79	0.86
DPos	0.88	1.00	0.53	0.81	0.74	0.94	1.00	0.93	1.00	1.00	0.61	0.69
	1.00	1.00	0.67	0.95	0.89	1.00	1.00	0.87	0.99	1.00	0.54	0.62
	0.90	1.00	0.57	0.84	0.77	0.96	1.00	0.89	1.00	1.00	0.69	0.76
	0.83	1.00	0.49	0.77	0.70	0.89	0.95	0.82	0.94	1.00	0.58	0.66
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.51	0.59
	1.00	1.00	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	1.00
Min DPos	0.72	1.00	0.33	0.64	0.57	0.79	0.85	0.71	0.84	0.91	0.36	0.45

Table 5: Ranking of Intellect Errors

Criteria	Normalized Weights	Ranking of Criteria
EC	0.088	6
EP	0.122	1
SE	0.040	12
EIg	0.079	8
EH	0.070	9
GE	0.097	5
EB	0.104	3
FE	0.087	7
SubE	0.103	4
AE	0.112	2
EIr	0.044	11
EM	0.055	10

4.3 Fuzzy TOPSIS

TOPSIS is defined as the compensatory accumulation method that found the best alternative by calculating the geometric distance that is shortest towards the positive ideal solution (PIS) and farthest from the negative ideal solution (NIS) after identifying weights and normalizing each criterion score. The experts find it very difficult to assign a crisp number rating to the alternatives for the attributes. Fuzzy TOPSIS is used in this to handle experts uncertain judgments vagueness and linguistic judgments by providing relative importance to the attributes by using fuzzy numbers (Patil & Kant, 2014), (Sirisawat & Kiatcharoenpol, 2018), (Singh & Sarkar, 2019), (Rampasso et al., 2019). The authors (Huang & Yoon, 1981) have introduced this concept and is one of the prevalent approaches of multi-criteria.

The steps involved in this approach are described below:

Step 1: Create fuzzy matric using linguistic assessment as mentioned in table 1 and rate each teaching solution of intellect errors. In the current study, 15 experts rated six solutions for 12 intellect errors. The abbreviations for all solutions have been mentioned in Annexure B.

Step 2: Compute the aggregate fuzzy matrix (see table 6) for taking inputs from 15 experts.

The aggregate function is used to aggregate the opinions of all experts is shown in equation 8.

$$F = \min\left(\sum_{q=1}^{q} d_{ijq}\right), e = 1/q \sum_{q=1}^{q} e_{ijq}, f = \max\left(\sum_{q=1}^{q} f_{ijq}\right) \quad (8)$$

Step 3: Now, do the normalization of aggregated function which is shown in table 7.

Step 4: Compute the weighted fuzzy evaluation matrix using equation 9 for all six solutions. The results are shown in Table 8.

$$\tilde{N} = \text{Normalized fuzzy matrix} * Wj$$
$$\tilde{N} = [\tilde{N}_{ij}]_{s*t} \quad i = 1,2,\ldots\ldots s, \quad j=1,2,\ldots\ldots\ldots t \quad \text{where}$$
$$\tilde{N}_{ij} = \tilde{r}_{ij}\,(.)W_j \quad (9)$$

Step 5: Calculate the fuzzy positive ideal solution (A*) and fuzzy negative ideal solution (A^-) for each solution using equation 10 and equation 11 respectively.

$$A^* = (\tilde{N}_1^*, \tilde{N}_2^* \ldots\ldots \tilde{N}_n^*) \quad \text{where } N_j^* = (\tilde{C}_j^*, \tilde{C}_j^*, \tilde{C}_j^*) \text{ and}$$
$$\tilde{C}_j^* = \max_i\{\tilde{C}_{ij}\} \quad (10)$$
$$A^- = (\tilde{N}_1^-, \tilde{N}_2^- \ldots\ldots \tilde{N}_n^-) \quad \text{where } \tilde{N}_j^- = (\tilde{C}_j^-, \tilde{C}_j^-, \tilde{C}_j^-) \text{ and}$$
$$\tilde{a}_j^- = \min_i\{\tilde{a}_{ij}\} \quad (11)$$

Step 6: The distance of each solution from A^* and A^- is calculated using equations 12 and 13.

$$F_i^+ = \sum_{j=1}^{n} dv(\tilde{N}_{ij}, \tilde{N}_j^*) \quad i = 1,2\ldots\ldots m \quad (12)$$
$$F_i^- = \sum_{j=1}^{n} dv(\tilde{N}_{ij}, \tilde{N}_j^-) \quad i = 1,2\ldots\ldots m \quad (13)$$

Step 7: Determine the closeness of coefficient (CCi) using equation 14 and rank the solutions based on the values of CCi. The results are mentioned in table 9.

Table 6: Calculated Fuzzy aggregated Evaluation Matrix for Intellect Solutions

	EC	EP	SE	EIg	EH	GE	EB	FE	SubE	AE	EIr	EM
IFL	(1,4,7)	(5,6,7)	(5,6,7)	(2,4,7)	(3,5.33,7)	(1,5.33,9)	(5,6,7)	(5,6,7)	(5,6,7)	(3,5.33,7)	(3,5.33,7)	(5,6,7)
CTS	(3,4.33,6)	(3,4,5)	(3,4,5)	(3,4.33,6)	(3,4,5)	(3,4,5)	(3,4,5)	(3,5.33,9)	(3,6,9)	(3,5.33,9)	(3,5.33,9)	(3,5.33,9)
CSTC	(1,5,9)	(2,6.33,9)	(1,6,9)	(7,8,9)	(7,8,9)	(7,8,9)	(7,8,9)	(2,6.33,9)	(2,5,9)	(2,6.33,9)	(2,6.33,9)	(2,6.33,9)
KED	(1,3.67,7)	(2,3,4)	(2,3,4)	(2,3,4)	(2,3,4)	(2,3,4)	(2,3,4)	(2,5,9)	(2,5,9)	(2,5,9)	(3,6,9)	(2,5,9)
FEP	(2,3.67,5)	(3,4,5)	(3,4,5)	(3,5,8)	(3,4,5)	(3,4,5)	(3,4,5)	(2,3.67,5)	(2,3.67,5)	(2,3.67,5)	(2,3.67,5)	(2,3.67,5)
RI	(2,5.33,9)	(3,5.33,9)	(3,5.33,9)	(3,5.33,9)	(3,5.33,9)	(3,5.33,9)	(3,5.33,9)	(3,4,5)	(3,4.67,7)	(3,4,5)	(3,4,5)	(3,4,5)

Table 6 consists of six rows and twelve columns where columns are intellect errors and the rows consist of solutions for these twelve mentioned intellect errors. The aggregated fuzzy matrix is the result of 15 experts who have rated six solutions concerning twelve intellect errors using linguistic scale. Aggregated fuzzy matrix is calculated using equation 8.

Table 7: Normalized Fuzzy Evaluation Matrix for Intellect Solutions

	EC	EP	SE	EIg	EH	GE	EB	FE	SubE	AE	EIr	EM
IFL	(0.14,0.25,1.00)	(0.14,0.17,0.20)	(0.14,0.17,0.20)	(0.14,0.25,0.50)	(0.14,0.19,0.33)	(0.11,0.19,1.00)	(0.14,0.17,0.20)	(0.14,0.17,0.20)	(0.14,0.17,0.20)	(0.14,0.19,0.33)	(0.14,0.19,0.33)	(0.14,0.17,0.20)
CTS	(0.17,0.23,0.33)	(0.20,0.25,0.33)	(0.20,0.25,0.33)	(0.17,0.23,0.33)	(0.20,0.25,0.33)	(0.20,0.25,0.33)	(0.20,0.25,0.33)	(0.11,0.19,0.33)	(0.11,0.17,0.33)	(0.11,0.19,0.33)	(0.11,0.19,0.33)	(0.11,0.19,0.33)
CSTC	(0.11,0.20,1.00)	(0.11,0.16,0.50)	(0.11,0.17,1.00)	(0.11,0.13,0.14)	(0.11,0.13,0.14)	(0.11,0.13,0.14)	(0.11,0.13,0.14)	(0.11,0.16,0.50)	(0.11,0.20,0.50)	(0.11,0.16,0.50)	(0.11,0.16,0.50)	(0.11,0.16,0.50)
KED	(0.14,0.27,1.00)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.25,0.33,0.50)	(0.11,0.20,0.50)	(0.11,0.20,0.50)	(0.11,0.20,0.50)	(0.11,0.17,0.33)	(0.11,0.20,0.50)
FEP	(0.20,0.27,0.50)	(0.20,0.25,0.33)	(0.20,0.25,0.33)	(0.13,0.20,0.33)	(0.20,0.25,0.33)	(0.20,0.25,0.33)	(0.20,0.25,0.33)	(0.20,0.27,0.50)	(0.20,0.27,0.50)	(0.20,0.27,0.50)	(0.20,0.27,0.50)	(0.20,0.27,0.50)
RI	(0.11,0.19,0.50)	(0.11,0.19,0.33)	(0.11,0.19,0.33)	(0.11,0.19,0.33)	(0.11,0.19,0.33)	(0.11,0.19,0.33)	(0.11,0.19,0.33)	(0.20,0.25,0.33)	(0.14,0.21,0.33)	(0.20,0.25,0.33)	(0.20,0.25,0.33)	(0.20,0.25,0.33)

For comparing all the criteria, linear transformation of all the raw data is necessary so that data is normalized. Equation 15 will be used to generate the normalized data of Table 7.

$R = [\tilde{r}_{ij}]_{s*t}$ i = 1,2,……s , j=1,2,……….t (15) where

$\tilde{r}_{ij} = (\frac{d_{ij}}{f_j^*}, \frac{e_{ij}}{f_j^*}, \frac{f_{ij}}{f_j^*})$ where $f_j^* = {}^{max}_{i}\{f_{ij}\}$ (Benefit Criteria)

$\tilde{r}_{ij} = (\frac{f_j^-}{d_{ij}}, \frac{f_j^-}{e_{ij}}, \frac{f_j^-}{f_{ij}})$ where $d_j^- = {}^{min}_{i}\{d_{ij}\}$ (Cost Criteria)

Table 8: Weighted Fuzzy Evaluation Matrix for Intellect Solutions

	EC	EP	SE	EIg	EH	GE	EB	FE	SubE	AE	EIr	EM
IFL	(0.01,0.02,0.09)	(0.02,0.02,0.02)	(0.01,0.01,0.01)	(0.01,0.02,0.04)	(0.01,0.01,0.02)	(0.01,0.02,0.10)	(0.01,0.02,0.02)	(0.01,0.01,0.02)	(0.01,0.02,0.02)	(0.02,0.02,0.04)	(0.01,0.01,0.01)	(0.01,0.01,0.01)
CTS	(0.01,0.02,0.03)	(0.02,0.03,0.04)	(0.01,0.01,0.01)	(0.01,0.02,0.03)	(0.01,0.02,0.02)	(0.02,0.02,0.03)	(0.02,0.03,0.03)	(0.01,0.02,0.03)	(0.01,0.02,0.03)	(0.01,0.02,0.04)	(0.01,0.01,0.01)	(0.01,0.01,0.02)
CSTC	(0.01,0.02,0.09)	(0.01,0.02,0.06)	(0.00,0.01,0.04)	(0.01,0.01,0.01)	(0.01,0.01,0.01)	(0.01,0.01,0.01)	(0.01,0.01,0.01)	(0.01,0.01,0.04)	(0.01,0.02,0.05)	(0.01,0.02,0.06)	(0.01,0.01,0.02)	(0.01,0.01,0.03)
KED	(0.02,0.02,0.04)	(0.02,0.03,0.04)	(0.01,0.01,0.01)	(0.02,0.03,0.04)	(0.02,0.02,0.03)	(0.02,0.03,0.05)	(0.03,0.03,0.05)	(0.01,0.02,0.04)	(0.01,0.02,0.05)	(0.01,0.02,0.06)	(0.01,0.01,0.01)	(0.01,0.01,0.03)
FEP	(0.01,0.02,0.04)	(0.01,0.02,0.04)	(0.00,0.01,0.01)	(0.01,0.02,0.03)	(0.01,0.02,0.02)	(0.02,0.02,0.03)	(0.02,0.03,0.03)	(0.02,0.02,0.04)	(0.02,0.03,0.05)	(0.02,0.03,0.06)	(0.01,0.01,0.02)	(0.01,0.01,0.03)
RI	(0.01,0.02,0.04)	(0.01,0.02,0.04)	(0.00,0.01,0.01)	(0.01,0.02,0.03)	(0.01,0.01,0.02)	(0.01,0.02,0.03)	(0.01,0.02,0.03)	(0.02,0.02,0.03)	(0.01,0.02,0.03)	(0.02,0.03,0.04)	(0.01,0.01,0.01)	(0.01,0.01,0.02)

Table 9: Ranking of Intellect Solutions

Solutions	Fi+	Fi-	CCi	Rank
IFL	0.277075	11.758629	0.976978931	3
CTS	0.249336	11.762863	0.979243071	1
CSTC	0.282709	>11.766406	0.976536975	4
KED	0.368640	11.669540	0.969377437	6
FEP	0.304394	11.711677	0.974667741	5
RI	0.249853	11.767752	0.979209389	2

Table 8 is required to calculate the weights of solutions by using equation 9. It is a pre-step before evaluating the ranking of solutions. This is one of the steps for the integration of fuzzy AHP and fuzzy TOPSIS. Table 9 is constructed using equation 14 and it is calculated after figuring out the rank order simultaneously for the fuzzy positive ideal solution and fuzzy negative ideal solution.

5. Conclusion

This study proposes a structured multi-criteria decision-making hybrid approach for evaluating and selecting the best teaching solution to minimize intellect errors. The strength of the proposed hybrid approach is to manage the experts' judgments precisely and carefully. Firstly, intellect errors and their solutions are identified from the literature. This is the neglected aspect of teaching and their literature is not explored vastly in the past. A total of twelve intellect errors and six solutions have been identified. Secondly, fuzzy AHP is applied to intellect errors to compute the weights. The intellect errors are ranked using fuzzy AHP as EP > AE > EB > SubE > GE > EC > FE > EIg > EH > EM > EIr > SE. The most committed error by the intellects is 'error of proximity' (EP) followed by analogy error (AE). The least committed error is 'senses error' (SE). Thirdly, these computed weights of fuzzy AHP are used in fuzzy TOPSIS to rank the teaching solutions that help in minimizing the intellect errors so that the learning capabilities of students are enhanced. Then, fuzzy TOPSIS ranked the solutions as CTS> RI > IFL > CSTC> FEP > KED. The topmost solution is 'development of critical thinking in the students' and the least one is 'knowledge engineering developments'. This study reports that only curriculum updating is not the way to make students ready for industry. The students can be made industry-ready with the student-teacher attributes. These ranked solutions can act as a guideline for teachers to make students industry-ready. In the future, different multi-criteria techniques can be used like fuzzy ANP, fuzzy ISM, and fuzzy ELECTRE to rank teaching solutions and the results will be compared with the current methodology.

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Annexure A: Intellect Errors with Abbreviations

Intellect Errors	Abbreviations
Error of coincidence	EC
Error of proximity	EP
Senses error	SE
Error of ignorance	EIg
Error of habit	EH
Generalization error	GE
Error of the bandwagon	EB
Familiarity Error	FE
Subjectivity Error	SubE
Analogy Error	AE
Error of irrelevance	EIr
Error of the machine	EM

Annexure B: Intellect Errors Solutions with Abbreviations

Solutions	Abbreviations
Teachers should be innovative, flexible and learners	IFL
Development of critical thinking skills in the students	CTS
Intellects should have good communication skills and team collaborators	CSTC
Intellects should be aware of knowledge engineering developments	KED
Follow ethical practices	FEP
Selection of right instruments for teaching	RI