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Toward Selection of Trustworthy and Efficient E-Learning Platform

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ABSTRACT The e-learning sector continues to evolve, with a growing number of eLearning resources available to businesses, government agencies, and individual people. With the fastest growth in developing economies attempting to close the educational gap, the scope of eLearning is now stronger than ever. Because of its low cost, comfort, and availability, e-learning is quickly becoming the world's dominant educational force of the twenty-first century. Students, experts, and professors are interacting with the educational setting in new ways due to e-learning platforms. Several academics struggle with deciding which of the numerous available platforms is the most suited for their scenario. Evaluating the benefits and drawbacks of every platform can help learners all over the world in designing personalized learning options that meet their budgets and context. This innovation is resilient and ever-changing in order to suit the needs of learners and educators all over the world. This article gives a brief overview of various popular online learning platforms. The main objective of this article is to shed some light on the effective advancement of e-learning platforms and evaluate them using a hybrid multiple criteria decision making (MCDM) model-oriented analysis amid pandemics and natural calamities, as well as provide recommendations for users about how to interact with the complexities of e-learning platform selection.

INDEX TERMS E-Learning platforms, system quality, e-learning standards, system evaluation, fuzzy logic.

I. INTRODUCTION

Education has undergone significant transformations of technological advancements. The technology has provided the entire training & teaching process into the virtual realm. Without even a question, eLearning has established itself in the educational landscape. Possibilities for multimedia learning have emerged as the pace of broadband internet has increased. Even social networking has had a significant influence on education and continues to evolve. In the business world, e-learning is gaining traction. Firms use it to train their employees, streamline procedures, and extend their scope.

Web-based training programs, blended learning, online learning, undergraduate distance learning, and immersive learning are all examples of e-learning that are used in research and many operational environments. Many reputable educational institutions in Australia and the United States already provide e-learning to international students [1]. E-learning was indeed a different method that was used in the last decade and is still used today. Many concepts of e-learning are being used to describe the use of tools that can be used to provide teaching materials in a digital form for knowledge seekers, with the internet being the most common method [2]. Innovation and technology are used in e-learning to promote, improve, and extend educational materials, access, and practice progress monitoring. E-l earning, which began as an internet-based content distribution system for colleges, is now used by a wide range of organizations, including large corporations, small companies, government, non-profits, as well as trade groups. Healthcare, telecommunications, e-commerce, education, and infrastructure are among the top industries that are using e-learning. Universities and other organizations are turning to e-learning which provides online training for several reasons. Although there have been several advancements in the processes of delivering online training, the requirements for privacy [3] and security [4]–[6] have been generally neglected today.

Today, e-learning encompasses a lot more than just sharing information. E-learning is collaborative, on-demand and it is accessible on a range of digital devices ranging from personal computers to laptops and mobile devices. This greatly improves learning participation and persistence.

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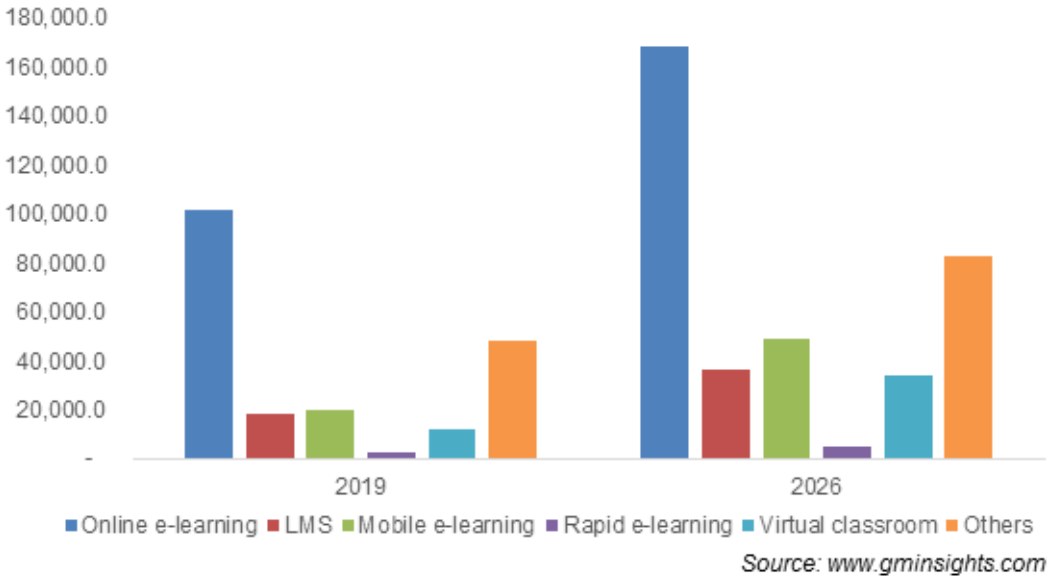

FIGURE 1. Global e-learning market size, by technology, 2019 & 2026 (USD Million).

The e-learning industry is increasing due to the rising demand for innovative education and training. Business players' growing integration of advanced cloud services is fueling the technology's spread. The accessibility of learning content for teaching and preparing students or workers has increased dramatically in recent years. Students and employees are receiving learning opportunities from e-learning industry leaders in collaboration with content makers. The productivity growth is being driven by the versatility of training from remote locations.

To control the transmission of the COVID-19 pandemic, companies and educational institutions have been temporarily closed, public meetings have been limited, and social distance has been maintained. This has had a positive impact on the e-learning industry, with a growing number of institutions opting for digital classrooms. As per a recent research report from Global Market Insights, Inc., the e-learning market will be worth more than USD 375 billion by 2026. The following Fig 1 shows the outcome of the Global Market Insights report.

Modernizing education has allowed dissolving conventional access hurdles, such as exorbitant prices and locations, leading to making well-informed working environments and individuals. Online education is a terrific technique to acquire new qualifications and keep involved with many people because of the guidelines for self-isolation around the new coronavirus. There are distinctive categories of courses and platforms for online education nowadays. One may take many years understanding differences, planning how best to utilize a learning platform, how to learn, and afterward transfer to another medium and do it afresh. This paper aimed at evaluating eight famous online learning platforms such as Pluralsight, Codecademy, Thinkific, Udacity, Udemy, Coursera, LinkedIn Learning, and Skillshare to assist users. This paper uses a hybrid MCDM model-oriented analysis towards the selection of a secure and efficient E-learning platform.

The rest of this study is organized as follows: In Section 2, the paper presents the literature review. Section 3 discusses the overview of different e-learning platforms. In Section 4, the evaluation criteria for different e-learning platforms have been discussed. Section 5 presents the adopted hybrid Fuzzy AHP-TOPSIS method. Section 6 demonstrates the results and discussion. Finally, the paper concludes in Section 7.

II. LITERATURE REVIEW

Fard *et al.* [5] presented a study aimed at identifying the key factors that affect e-learning system performance. As a result, they employed two effective strategies from the fields of Multiple Criteria Decision Making (MCDM) as well as Artificial Intelligence. They rated the aspects by using fuzzy TOPSIS and a pair-wise survey. They conducted fuzzy logic to determine the true level of variables. The evaluation results indicated that system efficiency is a crucial factor in operation, knowledge, and learning community performance.

Büyüközkan *et al.* [6] used an axiomatic design-based methodology for fuzzy group decision making to measure the effectiveness of e-learning web pages. They also used the fuzzy TOPSIS approach. They discussed a case study concentrating on Turkish e-learning websites with concluding remarks and suggestions for potential studies regarding the empirical results.

Mohammed *et al.* [7] surveyed a sample of 95 participants who included academic and support staff as well as PG students in Malaysia. They were required to rate the value of five e-learning assessment parameters that would

be analyzed with the AHP technique. They also graded the output of five different e-learning methods against each of the criteria. The TOPSIS method was used to calculate the average output of each e-learning solution. According to the findings, Flipped Classroom is the best e-learning solution, with strategic preparation for e-learning deployment being the most critical criterion.

Fedrizzi and Molinari [8] presented a model aimed at assisting this assessment process in the presence of various characteristics and a board of educationists. Each expert evaluates e-learning route alternatives using the TOPSIS tool, with the expectation that the ratings are linguistically evaluated and interpreted by positive triangular fuzzy numbers. Provided with the independent alternative rankings, a majority modeling module was employed, in which the disagreement among single expert's ratings and group standings were calculated by using the Spearman foot rule distance.

Naveed *et al.* [9] presented a study that used the analytic hierarchy method (AHP) in conjunction with group decision-making (GDM) and fuzzy AHP (FAHP) to investigate a variety of variables from various dimensions of a web-based E-Learning environment.

There are also many other literature works [10]–[13] that used the fuzzy AHP-TOPSIS based MCDM approach to solving this type of decision-making problem. In this paper, we are using fuzzy AHP-TOPSIS to evaluate the different e-learning platforms.

III. DIFFERENT E-LEARNING PLATFORMS

A. PLURALSIGHT

Pluralsight is among the top digital platforms for individuals interested in learning technical skills because it provides full courses created by experts in the field. Pluralsight has a wide range of subjects to select but it is primarily focused on offering programs in the IT/CS field, rendering it close to Codecademy. Students can pursue a career in information security, IT telecommunications, coding, software engineering, web design, and even more by learning on the Pluralsight e-learning platform. The courses are well-organized with useful, high-quality information. Furthermore, upon accomplishment within each program, the student will receive a certificate. Pluralsight is ideal for those involved in the IT/tech market, and in certain situations, it is even superior to Codecademy [14]–[17]. Pluralsight has enhanced their video content and audio quality requirements, although there are still numerous modules that predate these improvements.

B. CODECADEMY

Codecademy is now one of the largest online learning sites for programmers, with over a hundred courses for all computer languages available for free. Codecademy is a website where people can learn to program for free on the web [18]–[23]. It's for students who would like to learn JavaCSS, HTML, Ruby, Python, PHP, Sass, SQL, as well as other programming languages. One may also approach other Codecademy members and teachers for guidance and suggestions. It's great for beginners, and it's also great for more experienced users if you're prepared to pay for the extra functionality. Offline access to Codecademy classes is not accessible. It does not provide classes in any other languages except English.

C. THINKIFIC

Thinkific is a digital learning platform that allows users to quickly build and sell courses, whether you're targeting a few learners or millions [24]–[27]. Thinkific, unlike the majority of the other sites on this list, is geared toward those who want to teach rather than learn. Anyone can use the platform to develop, promote, and offer online courses to millions of students around the world. Small companies and solo business owners who wish to educate others would love Thinkific. The free account is much more than adequate, as it includes a wide variety of functionality. Its most advanced plans, on the other hand, are likely to be more productive for anyone if they want to offer at a top scale or have a larger company. Thinkific offers services to make easy course displays and add extra content including video, quizzes, digital tutorials, assessments, Documents, audio, and even complete reviews. Essentially, users have everything they need to build an effective course. The majority of Thinkfic's services are only accessible with higher-priced subscriptions. The platform's major flaw is its lack of adequate security.

D. UDACITY

Udacity is an online learning network that aims to help people master the knowledge that today's tech businesses are looking for in their workforce [12], [13], [28], [29]. The system's a suggesting ambition, and that's exactly what it needs people to do when they use it. While Udacity does not provide approved courses, it does collaborate with leading technology companies to provide the complete course. They present you with certificates that are highly regarded by most tech companies. Udacity courses are ideal for technology specialists who need specific skills or knowledge to advance their careers into new industries but do not need university credentials. Udacity is pricey and does not issue certificates for free online courses. Although Udacity programs are not certified, they are comparable in price to many recognized courses.

E. UDEMY

Udemy has some of the most diverse range of specific courses. This site is all about making it simple and easy for learners to know valuable skills, that is why the programs are in video format. While many programs are free, the majority of the advanced ones require payment [30], [31]. The cost varies by course, as well as the course designer determines whether the training is free or not. The users rank each program, so other users can see how common and interesting it is. Users earn an Udemy certificate for finishing the program, but it will not be recognized by companies, because the platform, like Skillshare, is all about acquiring practical knowledge. Overall, Udemy is beneficial to a wide range

of individuals, and one can participate in several courses at extremely low prices. It is less expensive than other e-learning platforms. They provide more focused courses than some other platforms. This e-learning platform is simple to use. To ensure a higher quality of the content, Udemy must go through a comprehensive author selection procedure. A few of the courses appear to be written somebody with basic expertise for the sole purpose of making money on Udemy.

F. COURSERA

Coursera is an online learning site that offers free courses. On this site, prominent universities and corporations have all accepted courses [32], [33]. As a result, Coursera is ideal for both students and practitioners, including whole businesses. Coursera is free and registered users can access a large number of courses, however, the better the choices, the more the price. Coursera also offers social quizzes as well as homework assistance from other classmates. Students at smaller colleges may be allowed to supplement their course requirements with top-notch instruction from respected university professors [34]–[37]. Coursera is extremely well-organized. They collaborate with the world's top prestigious academic institutions. There are numerous pricing subscriptions available, which might make the actual cost of the course appear complicated and ambiguous to many people. Because of the structure of the course content, some programs may necessitate prior knowledge. It is not always user-friendly.

G. LinkedIn LEARNING

LinkedIn Learning is the professional networking site's educational portal, with open and premium courses in the industry, engineering, and creative fields. The idea that LinkedIn learning is run by LinkedIn, the world's biggest networking network for professionals, is its primary advantage. LinkedIn Learning, as planned, refers to professional development [38]–[41]. LinkedIn Learning is among the top online training sites for businesses for users who prepared to pay for any of the programs. LinkedIn Learning is good because it helps you to study on your schedule by watching short videos or enrolling in more advanced classes with much more information. Users will get a completion certificate; however, consider the fact that this is not an approved diploma from an Institution or a Partner. The system occasionally hangs up. LinkedIn Learning offers learning paths, but somehow it leaves a lot to be expected. There isn't an adequate explanation of why or formative assessment.

H. SKILLSHARE

Skillshare is ideal for designers and visual artists, but even with a large database of courses, it is also ideal for many people and businesses. Skillshare is excellent because it has such a large group and the latest courses are introduced all the time [42]–[45]. Users pay a single monthly fee and gain access to all that the web has to offer. Skillshare's classes are classified into four main types: business, technology, creative, as well as lifestyle. There are no qualifications to be earned and none of the courses are certified. Even then, Skillshare is about acquiring practical information that you can apply later in your career, not really about certification. Since Skillshare is a group, most of the courses are created by its participants. Users can communicate with other members of the web and get support and advice because it is a group. Once a student completes a course, he/she will not receive any form of official (or non-official) certification. It serves as a platform for personal development. Because anyone can develop their own program on Skillshare, the content quality of the available courses varies.

IV. EVALUATION CRITERIA

A multi-rater analysis, multi-source responses, filled assessment, and report community results were used to evaluate various e-learning platforms. The efficiency evaluation is based on the following two main factors i.e. Content quality and System quality. The following Fig. 2 shows the hierarchy for effectiveness evaluation of different e-learning sites.

A. CONTENT QUALITY

The content presented should cover the entire topic, and also be accurate. The language should be precise and comprehensible. The learning objectives should be well defined so that the teaching and assessment are well aligned to the former. There should be scope for feedback. It should also be able to gauge prior knowledge of a student to master a subsequent concept. The Content quality criterion is denoted as T1. The Content quality criteria further categorize into some sub-criteria such as Reliability, Updated, Understandability, Timeliness, and Accuracy and denoted as T11, T12, T13, T14, and T15.

B. SYSTEM QUALITY

The system quality of an e-learning platform is determined by the technology it runs on. System quality may be assessed from two angles: developers and end-users. The level of visual representation and accessibility are emphasized by programmers. End-users, on the other hand, are more concerned with responsiveness, loading speed, and other factors. The System quality criterion is denoted as T2. The System quality criteria further categorize into some sub-criteria such as Visual representation, Security, Loading speed, and Accessibility and denoted as T21, T22, T23, and T24.

V. HYBRID FUZZY AHP-TOPSIS METHOD

Many MCDM strategies have been presented to assist decision-makers in handling difficult circumstances by making better decision options. Indeed, the Fuzzy AHP technique was chosen for this conceptual methodology because of its capacity to structure and break down a fuzzy decision-making challenge into sub-problems and after that estimate the weight of each piece to categorize it as per its relative relevance. In terms of the rating alternatives, we selected the fuzzy TOPSIS method because of its potential to handle with collective decision-making challenges in

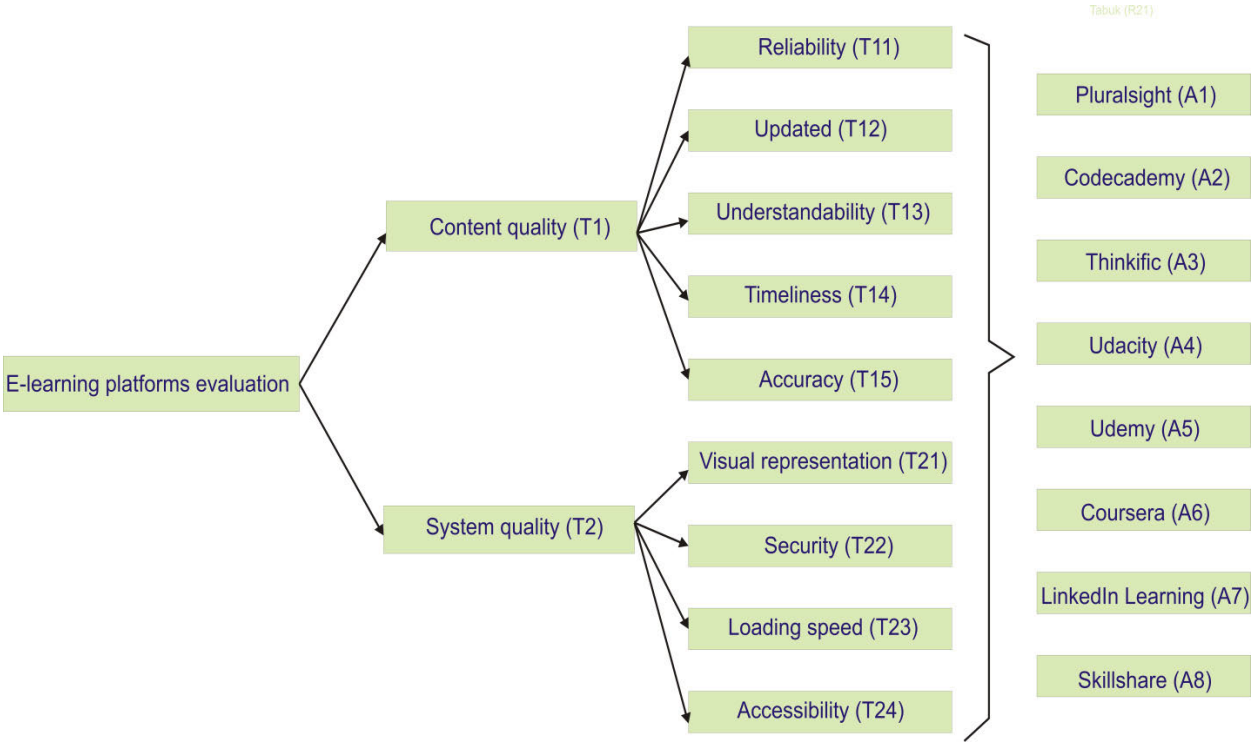

FIGURE 2. Hierarchy for effectiveness evaluation of different e-learning sites.

unpredictable contexts. The major benefits of the Hybrid Fuzzy AHP-TOPSIS approach can be highlighted by evaluating the selected alternatives as well as criteria. Furthermore, the criteria evaluation phase (FAHP procedure) is fundamentally distinct from the alternatives (fuzzy TOPSIS).

A. FUZZY AHP

fuzzy set concept and the extension rule can be used in the Fuzzy Analytic Hierarchy Process (FAHP). Whenever it comes to eliminating inaccuracy in evaluation, FAHP is particularly needed. Manual judgment is important in several decision-making situations. However, when making a human judgment, there is always the risk of making a mistake. The DM's decision-making can become skewed. The fuzzy technique is often used in decision-making to minimize such uncertainty [46]–[49]. Fuzzy set concepts and expansion concepts are useful in making correct decisions.

B. FUZZY TOPSIS

The fundamental principle of TOPSIS, as suggested by Chen and Hwang [25], is that even the optimization process should be the quickest route from the positive ideal solution as well as the farthest distance from the negative ideal solution. All data are believed to be understood specifically in traditional MCDM approaches, like classical TOPSIS. Crisp data, on the other hand, are insufficient to model real-life circumstances in many cases because human decisions, including desires, are always ambiguous and cannot be calculated with an absolute numerical value [26]–[29], [50]–[53]. Fuzzy set theory helps in dealing with skewed or inaccurate evaluations by using linguistic terminology to offer a more objective measurement of subjective decisions.

The following Fig. 3 shows the flow chart of the hybrid fuzzy AHP-TOPSIS method for the evaluation of different popular e-learning platforms.

VI. RESULTS AND DISCUSSION

This segment discusses a variety of data analysis findings from the hybrid fuzzy AHP-TOPSIS model's integration. Experts also conduct behavioral tests to evaluate the efficacy of various important e-learning sites based on predetermined parameters. To this end, the troublesome behavior of large groups of integration indicators must be identified and characterized. Scholars and researchers in this field face a difficult challenge in quantifying the effects of various e-learning sites mathematically. To reach the aim of our research study, we adopted hybrid fuzzy AHP-TOPSIS, a well-developed and established decision-maker strategy. This technique is quite well for ranking different e-learning sites according to their content and system quality. We gathered opinions from 85 experts from various tech organizations and academic institutions in order to produce a more comprehensive outcome The knowledge gathered from these specialists was used to compile the findings of our investigations. The different factors for the performance evaluation at the implementation phase i.e. Content quality and System quality are represented by T1, T2 respectively.

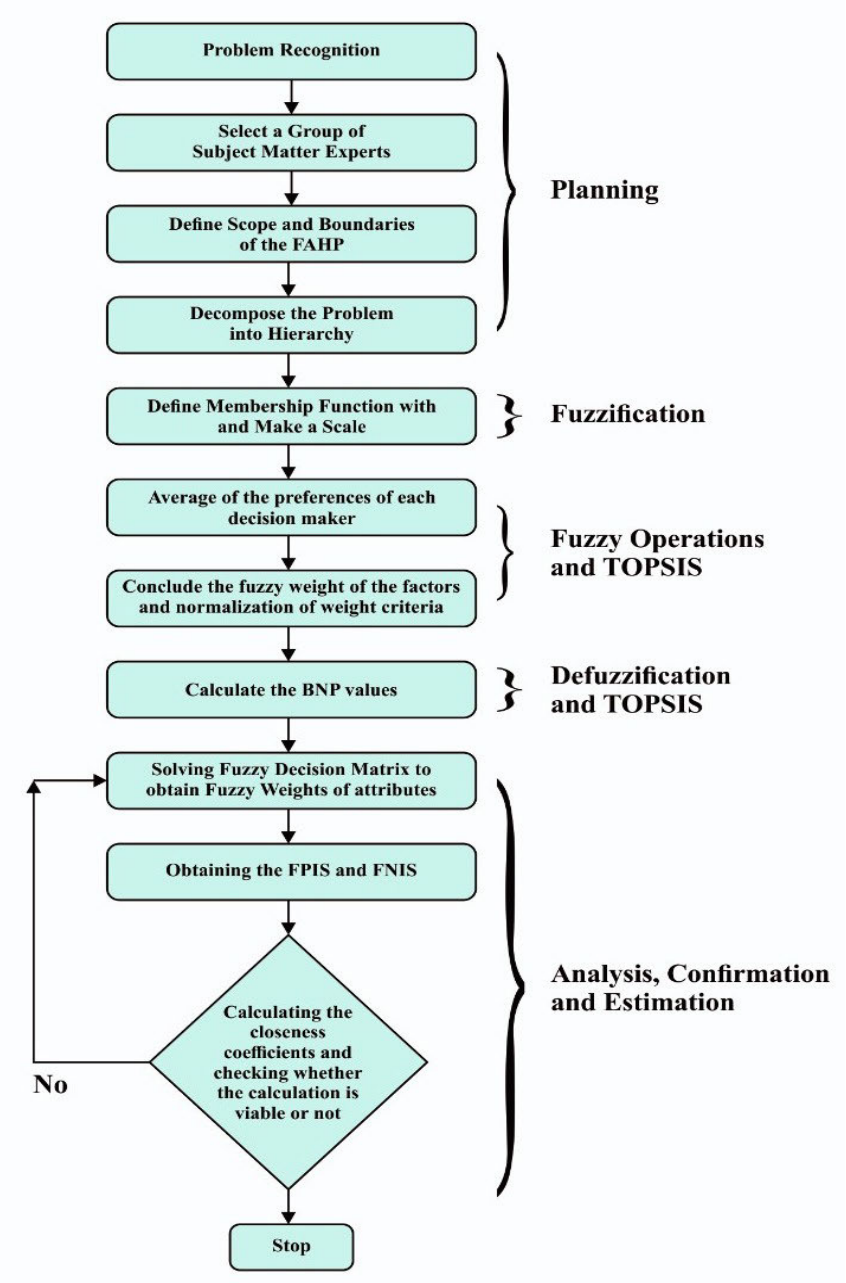

FIGURE 3. Flow chart of fuzzy AHP-TOPSIS method.

The Content quality factor is further divided into sub-factors i.e. Reliability, Updated, Understandability, Timeliness, and Accuracy denoted by T11, T12, T13, T14, and T15 respectively. Similarly, the System quality factor is further divided into sub-factors i.e. Visual representation, Security, Loading speed, and Accessibility denoted by T21, T22, T23, and T24 respectively. The systematic approach of hybrid fuzzy-AHP TOPSIS is used according to the functional structure shown in Fig. 3 to determine the effectiveness of different e-learning sites such as Pluralsight, Codecademy, Thinkific, Udacity, Udemy, Coursera, LinkedIn Learning, and Skillshare represented by A1, A2, A3, A4, A5, A6, A7 and A8 respectively. The following Tab. 1 to Tab. 11 demonstrates the statistical findings of the present study.

TABLE 1. Fuzzy pair-wise comparison matrix at level 1.

	T1	T2
T1	1.00000, 1.00000, 1.00000	0.30005, 0.38009, 0.56100
T2	-	1.00000, 1.00000, 1.00000

TABLE 2. Fuzzy aggregated pair-wise comparison matrix at level 2 for content quality.

	T11	T12	T13	T14	T15
T11	1.00000, 1.00000, 1.00000	0.69000, 0.88600, 1.10000	0.22600, 0.27600, 0.35700	1.00000, 1.51006, 1.90033	0.49000, 0.63007, 1.00000
T12	-	1.00000, 1.00000, 1.00000	0.69005, 0.90050, 1.34006	0.26800, 0.30052, 0.51008	0.16006, 0.10097, 0.20053
T13	-	-	1.00000, 1.00000, 1.00000	1.00000, 1.30020, 1.55002	0.30001, 0.43005, 0.80003
T14	-	-	-	1.00000, 1.00000, 1.00000	0.22002, 0.28007, 0.41005
T15	-	-	-	-	1.00000, 1.00000, 1.00000

TABLE 3. Fuzzy aggregated pair-wise comparison matrix at level 2 for system quality.

	T21	T22	T23	T24
T21	1.00000, 1.00000, 1.00000	0.65008, 1.16005, 1.68800	1.14009, 1.43900, 1.69700	0.26800, 0.35002, 0.50018
T22	-	1.00000, 1.00000, 1.00000	1.19300, 1.58003, 2.15000	1.00000, 1.51006, 1.93003
T23	-	-	1.00000, 1.00000, 1.00000	1.00000, 1.32000, 1.55002
T24	-	-	-	1.00000, 1.00000, 1.00000

TABLE 4. Defuzzified pair-wise comparison matrix.

	T1	T2	Weights
T1	1.00000	0.41112	0.29300
T2	2.43312	1.00000	0.70700
			C.R.=0.001000

In this scope, the integration of Fuzzy AHP with Fuzzy TOPSIS, i.e., two prominent MCDM approaches, for the evaluation of various wireless network alternatives as described. While the relative importance of each factor to the others may be explicitly stated, fuzzy numbers have been used to account for the complexities of subjective decisions in the problems' description. The proposed method was finally verified using a computational model that demonstrated how the most efficient approach; in this case, the most efficient e-learning platform was chosen. The satisfaction degree (CC-i) of different alternatives is estimated as 0.4945457, 0.4243457, 0.3243457, 0.5575487, 0.5546794, 0.5445754, 0.4256580 and 0.5000124 for A1, A2, A3, A4, A5, A6, A7 and A8 respectively. As per the findings shown in Fig. 4 the fourth alternative (A4) Udacity is highly effective and proficient among several other e-learning platforms. Alternatives A5 and A6 are Udemy and Coursera respectively. These are very much close to the top alternatives in the findings shown in Figure 4.

A. SENSITIVITY ANALYSIS

Sensitivity analysis as a technique or tool has a significant role in correlational studies. It is practiced where we have to find the impact or effect of the independent variable on the dependent variable when we make some changes in the independent variable values. So, it can help researchers to validate the results [12], [13], [30], [31]. The weights generated by TOPSIS under fuzzy environment have been considered as variables and, in every experiment, the selected attribute's weight is changed while others remain constant. There is nine evaluation of different e-learning platforms selected for this

TABLE 5. Aggregated pair-wise comparison matrix at level 2 for content quality.

	T11	T12	T13	T14	T15	Weights
T11	1.00000	0.89200	1.17300	1.49100	0.69100	0.18300
T12	1.12100	1.00000	0.99400	0.37200	0.20300	0.11500
T13	0.85300	1.00600	1.00000	1.29800	0.49400	0.15600
T14	0.67100	2.68800	0.77000	1.00000	0.30300	0.15700
T15	1.44700	4.92600	2.02400	3.30000	1.00000	0.38900
						CR=0.0733549

TABLE 6. Aggregated pair-wise comparison matrix at level 2 for system quality.

	T21	T22	T23	T24	Weights
T21	1.00000	1.17200	1.36300	0.37200	0.21900
T22	0.85300	1.00000	1.63300	1.49100	0.28700
T23	0.73400	0.61300	1.00000	1.29800	0.21100
T24	2.68800	0.67100	0.77000	1.00000	0.28300
					C.R.= 0.010000

TABLE 7. Overall weights and ranking of methods.

First Level Attributes	Local Weights of First Level	Second Level Attributes	Local Weights of Second Level	Overall Weights
T1	0.29300	T11	0.18300	0.05400
		T12	0.11500	0.03400
		T13	0.15600	0.04500
		T14	0.15700	0.04600
		T15	0.38900	0.11400
T2	0.70700	T21	0.21900	0.15500
		T22	0.28700	0.20300
		T23	0.21100	0.14900
		T24	0.28300	0.20000

TABLE 8. Subjective cognition results of evaluators in linguistic terms.

Properties/ Alternatives	A1	A2	A3	A4	A5	A6	A7	A8
T11	0.910, 2.450, 4.450	2.450, 4.270, 6.270	3.180, 5.180, 7.100	1.450, 3.070, 4.910	0.820, 2.270, 4.270	3.000, 4.820, 6.820	0.910, 2.450, 4.450	2.450, 4.270, 6.270
T12	2.450, 4.450, 6.450	2.910, 4.640, 6.550	2.450, 4.450, 6.450	0.910, 2.450, 4.450	2.450, 4.270, 6.270	3.910, 5.910, 7.820	2.450, 4.450, 6.450	2.910, 4.640, 6.550
T13	2.820, 4.820, 6.820	3.180, 5.180, 7.100	2.180, 4.090, 6.140	2.820, 4.640, 6.640	1.910, 3.730, 5.730	2.550, 4.450, 6.450	2.820, 4.820, 6.820	3.180, 5.180, 7.100
T14	4.280, 6.370, 8.370	2.450, 4.450, 6.450	0.910, 2.450, 4.450	2.450, 4.270, 6.270	3.910, 5.910, 7.820	3.910, 5.910, 7.910	4.280, 6.370, 8.370	2.450, 4.450, 6.450
T15	4.270, 6.270, 8.140	2.820, 4.820, 6.820	2.450, 4.450, 6.450	2.910, 4.640, 6.550	1.450, 3.000, 4.910	3.180, 5.180, 7.090	4.270, 6.270, 8.140	2.820, 4.820, 6.820
T21	5.360, 7.360, 9.120	3.730, 5.730, 7.550	2.820, 4.820, 6.820	3.180, 5.180, 7.100	1.450, 3.070, 4.910	2.090, 3.730, 5.730	5.360, 7.360, 9.120	3.730, 5.730, 7.550
T22	4.640, 6.640, 8.550	3.000, 5.000, 7.140	2.180, 4.090, 6.140	2.820, 4.640, 6.640	1.910, 3.730, 5.730	2.550, 4.450, 6.450	4.640, 6.640, 8.550	3.000, 5.000, 7.140
T23	0.910, 2.450, 4.450	2.450, 4.270, 6.270	3.910, 5.910, 7.820	2.450, 4.450, 6.450	2.910, 4.640, 6.550	3.910, 5.910, 7.910	4.280, 6.370, 8.370	2.450, 4.450, 6.450
T24	3.180, 5.180, 7.100	1.450, 3.070, 4.910	0.820, 2.270, 4.270	3.000, 4.820, 6.820	0.910, 2.450, 4.450	2.910, 4.640, 6.550	2.450, 4.450, 6.450	0.910, 2.450, 4.450

study. Hence nine experiments have been carried out, one for each independently, and the calculated results are enlisted in Tab.12. The weight of each attribute is represented as the original weight in the same table. Nine experiments have been carried out from Exper.1 to Exper.9. Each represents one attribute as an independent variable, and the other as dependent variables from T11 to T24, respectively. After calculating the satisfaction degree (CC-i) of each attribute (experiment), the final results are depicted in Tab. 12. Results of the analysis conclude that the alternative A4 has attained the highest degree of satisfaction. Further, the result variation shows that the alternative rating is sensitive to the weights. The graphical representation of sensitivity experiments is depicted in Fig.5.

TABLE 9. Normalized fuzzy-decision matrix.

Properties/ Alternatives	A1	A2	A3	A4	A5	A6	A7	A8
T11	0.580, 0.800, 1.000	0.370, 0.630, 0.900	0.420, 0.690, 0.950	0.320, 0.580, 0.850	0.470, 0.740, 1.000	0.370, 0.630, 0.900	0.420, 0.690, 0.950	0.320, 0.580, 0.850
T12	0.500, 0.720, 0.930	0.490, 0.750, 1.000	0.320, 0.590, 0.860	0.340, 0.610, 0.870	0.380, 0.640, 0.890	0.490, 0.750, 1.000	0.320, 0.590, 0.860	0.340, 0.610, 0.870
T13	0.320, 0.580, 0.850	0.470, 0.740, 1.000	0.270, 0.560, 0.860	0.370, 0.630, 0.900	0.420, 0.690, 0.950	0.470, 0.740, 1.000	0.270, 0.560, 0.860	0.370, 0.630, 0.900
T14	0.340, 0.610, 0.870	0.380, 0.640, 0.890	0.420, 0.690, 1.000	0.490, 0.750, 1.000	0.320, 0.590, 0.860	0.380, 0.640, 0.890	0.420, 0.690, 1.000	0.490, 0.750, 1.000
T15	0.370, 0.630, 0.900	0.420, 0.690, 0.950	0.210, 0.460, 0.730	0.120, 0.350, 0.660	0.370, 0.600, 0.860	0.420, 0.690, 0.950	0.210, 0.460, 0.730	0.120, 0.350, 0.660
T21	0.490, 0.750, 1.000	0.320, 0.590, 0.860	0.130, 0.360, 0.670	0.370, 0.660, 0.970	0.490, 0.740, 0.980	0.320, 0.590, 0.860	0.130, 0.360, 0.670	0.370, 0.660, 0.970
T22	0.500, 0.720, 0.930	0.390, 0.660, 0.940	0.290, 0.540, 0.820	0.420, 0.690, 1.000	0.290, 0.570, 0.880	0.390, 0.660, 0.940	0.290, 0.540, 0.820	0.420, 0.690, 1.000
T23	0.380, 0.640, 0.890	0.420, 0.690, 1.000	0.490, 0.750, 1.000	0.320, 0.590, 0.860	0.130, 0.360, 0.670	0.420, 0.690, 1.000	0.490, 0.750, 1.000	0.320, 0.590, 0.860
T24	0.210, 0.460, 0.730	0.120, 0.350, 0.660	0.370, 0.600, 0.860	0.370, 0.600, 0.860	0.370, 0.660, 0.970	0.120, 0.350, 0.660	0.370, 0.600, 0.860	0.370, 0.600, 0.860

TABLE 10. Weighted normalized fuzzy-decision matrix.

Properties/ Alternatives	A1	A2	A3	A4	A5	A6	A7	A8
T11	0.059, 0.118, 0.240	0.047, 0.109, 0.243	0.029, 0.067, 0.158	0.036, 0.072, 0.162	0.019, 0.052, 0.135	0.016, 0.050, 0.137	0.029, 0.067, 0.158	0.036, 0.072, 0.162
T12	0.054, 0.116, 0.278	0.041, 0.095, 0.242	0.059, 0.121, 0.296	0.054, 0.116, 0.278	0.041, 0.095, 0.242	0.059, 0.121, 0.296	0.059, 0.121, 0.296	0.054, 0.116, 0.278
T13	0.041, 0.095, 0.198	0.061, 0.121, 0.233	0.034, 0.091, 0.200	0.041, 0.095, 0.198	0.061, 0.121, 0.233	0.034, 0.091, 0.200	0.034, 0.091, 0.200	0.041, 0.095, 0.198
T14	0.102, 0.137, 0.299	0.114, 0.144, 0.306	0.125, 0.155, 0.344	0.102, 0.137, 0.299	0.114, 0.144, 0.306	0.125, 0.155, 0.344	0.125, 0.155, 0.344	0.102, 0.137, 0.299
T15	0.029, 0.067, 0.158	0.036, 0.072, 0.162	0.019, 0.052, 0.135	0.029, 0.067, 0.158	0.036, 0.072, 0.162	0.019, 0.052, 0.135	0.019, 0.052, 0.135	0.029, 0.067, 0.158
T21	0.077, 0.131, 0.230	0.065, 0.123, 0.228	0.043, 0.096, 0.196	0.017, 0.059, 0.152	0.049, 0.108, 0.221	0.065, 0.121, 0.223	0.043, 0.096, 0.196	0.017, 0.059, 0.152
T22	0.054, 0.116, 0.278	0.041, 0.095, 0.242	0.059, 0.121, 0.296	0.041, 0.100, 0.260	0.045, 0.098, 0.239	0.045, 0.098, 0.239	0.059, 0.121, 0.296	0.041, 0.100, 0.260
T23	0.041, 0.095, 0.242	0.059, 0.121, 0.296	0.059, 0.121, 0.296	0.054, 0.116, 0.278	0.024, 0.055, 0.133	0.041, 0.095, 0.198	0.019, 0.052, 0.135	0.016, 0.050, 0.137
T24	0.061, 0.121, 0.233	0.034, 0.091, 0.200	0.034, 0.091, 0.200	0.041, 0.095, 0.198	0.059, 0.121, 0.296	0.041, 0.100, 0.260	0.114, 0.144, 0.306	0.125, 0.155, 0.344

TABLE 11. Closeness coefficients to the aspired level among the different alternatives.

Alternatives		d+i	d-i	Gap Degree of CC+i	Satisfaction Degree of CC-i
Pluralsight	A1	1.245770	1.345125	0.5245754	0.4945457
Codecademy	A2	0.685467	0.867548	0.5945764	0.4243457
Thinkific	A3	0.784457	1.457845	0.6645731	0.3243457
Udacity	A4	2.045754	1.475487	0.3945764	0.5575487
Udemy	A5	2.231245	1.544576	0.4245454	0.5546794
Coursera	A6	0.424578	0.415754	0.4245764	0.5445754
LinkedIn Learning	A7	0.465847	0.395487	0.4125645	0.4256580
Skillshare	A8	0.584574	0.502524	0.5265487	0.5000124

B. COMPARATIVE ANALYSIS OF THE STUDY

The problems where we are not able to decide the solution of the specified problem is completely true or completely false come under the domain of MCDM problems. Trying to obtain precise solutions for these problems without considering their imprecision will produce inefficient results. To find efficient and effective results for these problems, fuzzy logic has significant importance. It has a great ability to address the uncertainty that is present in the problem information [32]–[35] and can generate solutions to the problem in more than two possibilities. That can be in the form of 0, 0.1, 0.2…, 0.9, 1, or can be completely true, completely false, partially true,

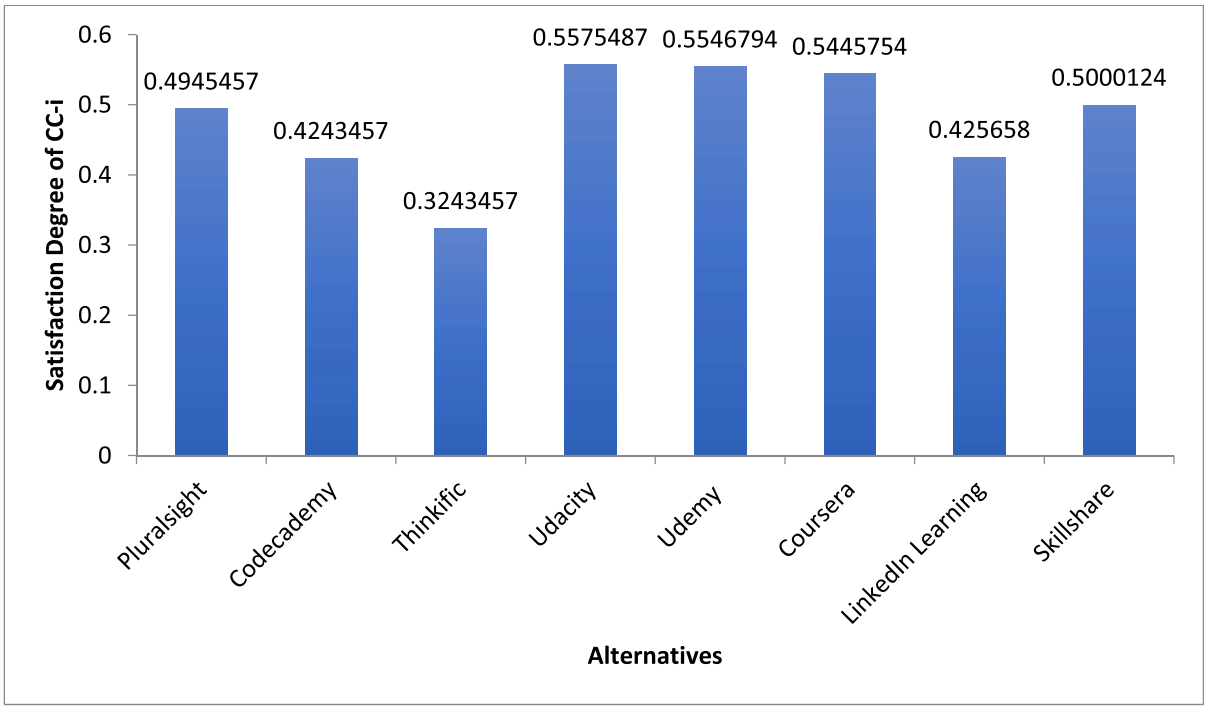

FIGURE 4. Graphical representation of satisfaction degree of different alternatives.

TABLE 12. Sensitivity analysis.

Alternatives	Original Weights	Exper.1 T11	Exper.2 T12	Exper.3 T13	Exper.4 T14	Exper.5 T15	Exper.6 T21	Exper.7 T22	Exper.8 T23	Exper.9 T24
Pluralsight	0.4945457	0.4944584	0.4948549	0.4948745	0.4988565	0.4988547	0.4999658	0.4988965	0.4988574	0.4988965
Codecademy	0.4243457	0.4287457	0.4288547	0.4248859	0.4248874	0.4296658	0.4277458	0.4288965	0.4288974	0.4299658
Thinkific	0.3243457	0.3299658	0.3299657	0.3299657	0.3296547	0.3263524	0.3299657	0.3299657	0.3299685	0.3288749
Udacity	0.5575487	0.5588698	0.5585958	0.5596578	0.5596597	0.5596597	0.5596597	0.5596597	0.5596857	0.5599685
Udemy	0.5546794	0.5545569	0.5548754	0.5549968	0.5588748	0.5599665	0.5588974	0.5549968	0.5546638	0.5589657
Coursera	0.5448748	0.5485478	0.5449967	0.5448854	0.5448855	0.5478475	0.5499687	0.5488978	0.5448897	0.5499635
LinkedIn Learning	0.4256580	0.4258854	0.4265478	0.4258856	0.4259625	0.4288574	0.4259659	0.4258658	0.4256895	0.4278954
Skillshare	0.5000124	0.5087454	0.5096541	0.5000000	0.5115414	0.5022321	0.5022365	0.4955874	0.5021354	0.5022324

TABLE 13. Comparison through classical TOPSIS technique.

Alternatives		Fuzzy TOPSIS	Classical TOPSIS
Pluralsight	A1	0.4945457	0.4945241
Codecademy	A2	0.4243457	0.4248547
Thinkific	A3	0.3243457	0.3248567
Udacity	A4	0.5575487	0.5633524
Udemy	A5	0.5546794	0.5854715
Coursera	A6	0.5445754	0.5496578
LinkedIn Learning	A7	0.4256580	0.4232564
Skillshare	A8	0.5000124	0.5110212

or partially false. Therefore, to make Classical TOPSIS more efficient and powerful while addressing MCDM problems, we have to integrate fuzzy logic with it. Furthermore, our study has also done a comparative study of both the classical and fuzzy-based approaches. From the analysis of different research studies, it has been found that applying different methods to the same data shows variations in the final results. This implies that a comparative study will be beneficial to achieve more reliable results [36], [37]. So, the accuracy of results has been checked by researchers through the implementation of different techniques to check [38], [39]. The authors of this work also checked the result's accuracy by applying TOPSIS under a fuzzy environment. Fuzzification and defuzzification of fuzzy logic change the accuracy of results in fuzzy TOPSIS while comparing with classical TOPSIS. Thus, a fuzzy-based approach needs conversion from numeric to TFN values. The comparative results of this work are presented in Tab. 13 and Fig. 6 with comparative values corresponding to each alternative (A1 to A8) under the Classical and fuzzy-based approach of TOPSIS. Further, TOPSIS generated result has got significant correlation (Pearson correlation coefficient is 0.919253) with the results

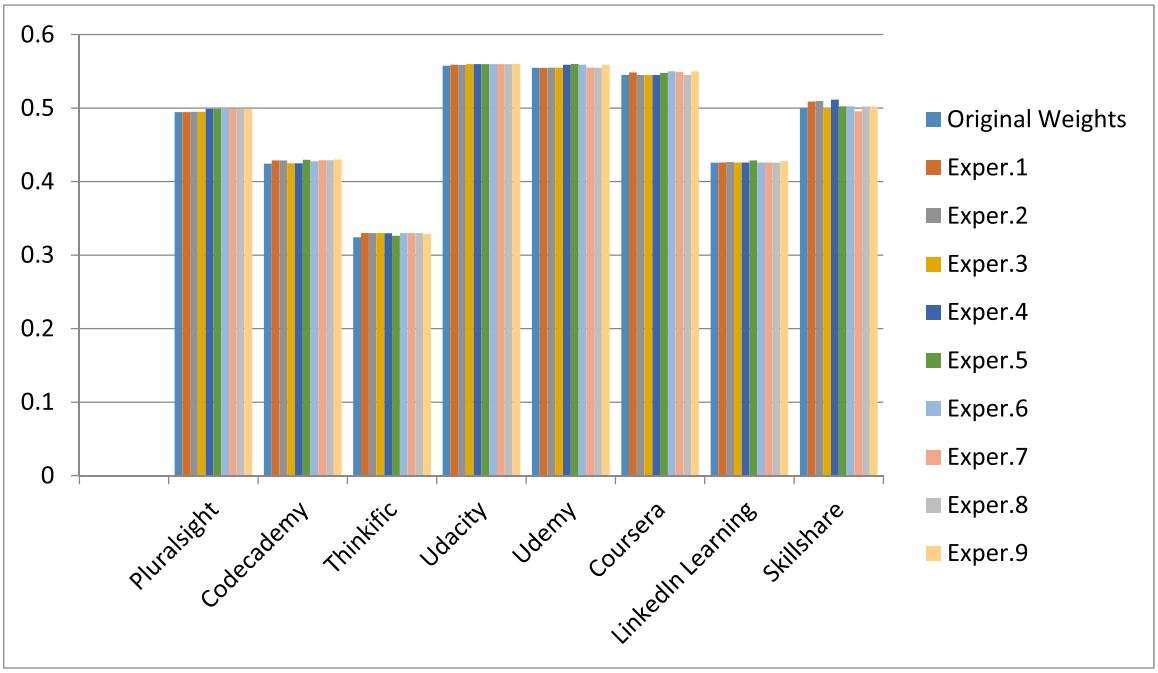

FIGURE 5. Graphical representation of sensitive analysis result.

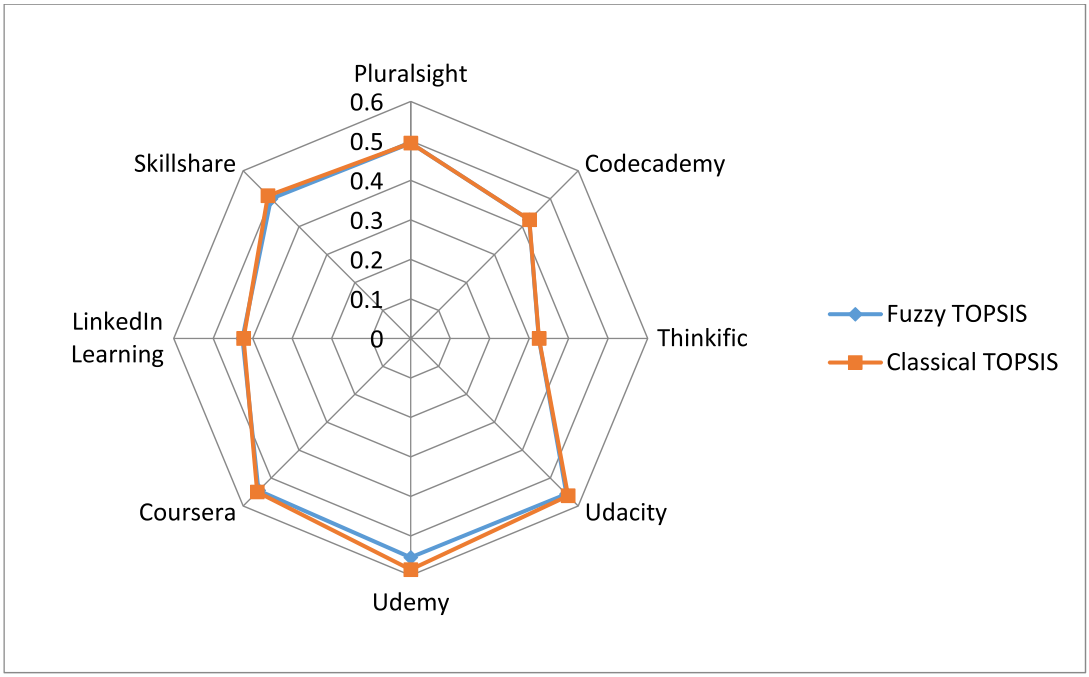

FIGURE 6. Radar chart comparison through classical and fuzzy TOPSIS technique.

obtained through the classical approach. In addition, TOPSIS under a fuzzy environment has improved efficiency as compared to the classical TOPSIS.

VII. CONCLUSION

The e-learning process is better suited for everybody. The technological age has resulted in significant changes in the ways information is accessed, processed, analyzed, and distributed. Office workers, as well as housewives, also can participate in online learning courses at their leisure. Numerous people prefer to attend classes on weekends or at night, based on their convenience and leisure. The system quality and content quality provided by an e-learning platform seem to be the most significant aspect of it. This includes more than just being simple to utilize and well-established with the other technologies. It is about giving teachers and students with a variety of perspectives that aid in the advancement of knowledge. Although most online courses are using a mixture of synchronous and asynchronous subject matter and involvement, the e-learning platform ought to be prepared

to deliver both synchronous (in real-time) and asynchronous (most comfortable to specific individuals) learning choices. In this study, with the help of fuzzy logic as well as fuzzy TOPSIS, a hybrid technique was adopted for the evaluation of different e-learning platforms. All variables have been rated by using fuzzy TOPSIS. In the fuzzy TOPSIS framework, we utilized content quality and system quality as the main factors. We can use fuzzy logic to realize the hidden level of factors listed by fuzzy TOPSIS. The results of this study revealed that content quality and system quality have a positive impact on the level of e-learning platforms. The results of this study also revealed that the Udacity e-learning platform is efficient and has the greatest positive impact on how online learners view the standard of an e-learning platform.

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