Maximizing Learning Outcomes through Fuzzy Inference System and Graph Theory Based on Learning Analytics

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Abstract*—Teachers are urged to explore innovative instructional methods, including technology integration and personality-oriented approaches, to enhance learning outcomes and foster better upbringing. The unique tactic proposed in this study involves incorporating learning analytics and feedback data into pedagogy improvement efforts. Teachers get access to visual classroom data about the active learning facilitation strategies they use in their classes using the automated feedback platform TEACHActive. In addition to discussing the system's information flow from an autonomous observation model to the feedback data, including the technological architecture, the study also examines the core necessity of the TEACHActive system improving teaching practises through reflection. To gather these data, a fuzzy inference method and graph theory are used. By combining graph theory and fuzzy logic, the conventional approach is innovatively modified in order to enhance instruction. By utilising these strategies, teachers can enhance their pedagogical practises and individualise learning experiences. The integration of the TEACHActive automated feedback platform, which utilizes learning analytics and feedback information, to improve teaching practices and personalize learning experiences through the fusion of graph theory and fuzzy logic, resulting in enhanced education outcomes. This research fills the gap in conventional instructional techniques by introducing TEACHActive, a system that integrates learning analytics and feedback data through fuzzy inference and graph theory. By providing insightful information on active learning strategies, the study uniquely improves teaching practices, enhancing student learning and improving academic results. The study's unique approach offers teachers valuable insights into active learning techniques, leading to better pedagogical procedures for improved learning and upbringing results. The method is feasible to run fuzzy inference systems and statistical analysis using Matlab software. The results show that four variables have the most impact on how well pedagogical processes work.

***Keywords*—pedagogy, learning activities, feedback data, fuzzy inference system, graph theory**

I. Introduction

The implementation of state standards for learning has placed additional demands on educators to accomplish the objectives of learning procedure that match the demands of contemporary society. A novel ideological and methodological for learning as an ideal and technique of creative teaching is formed as a result of the profound mechanisms occurring inside the educational system. Advanced technologies for learning need to be viewed as a tool for implementing the contemporary educational framework. The implementation of instructional innovations that serve as a tool for improving enthusiasm for academic achievement and improve the efficacy of learning, as well as the growth of the creative skills of learners in the courses of special areas of study, is one of the modifications in methods to the organization of the educational procedure that can be made to ensure the highest possible standard of schooling in the present context. The topic of educators' usage of technology for learning is very pertinent in today's schools. The importance of this issue stems from the realization that just one of an instructional organization's most significant

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duties, improving the effectiveness of the teaching and learning procedure, is being accomplished nowadays employing educational technology [1]. After all, instructional technology is a system where a prearranged procedure is regularly carried out, resulting in an outstanding outcome. The use of pedagogic technologies is an organized framework of the instructor's activities in which all of the activities that are a part of him standing in an established sequence and credibility, and the execution of those tasks assumes the attainment of the intended outcome. "Pedagogical technological advancement, according to Likhachev [2], is an assortment of mental processes and educational perspectives which establish a specific set and the arrangement of types, techniques, strategies for instructing, and instructive means; it is an organizational and scientific toolkit of the instructional procedure". Teaching technological devices, or instructional technology, is the adaptation of instructional methodologies to particular circumstances while taking into consideration the time, location, particular subjects being taught, organizational needs, and duration of the pedagogical procedure. So, rather of discussing technology's usefulness generally, the study may limit the discussion to specific children and instructors [2].

The capacity of educators to do qualitative research is also constrained by other reasons. For instance, the environment of the school might not typically be conducive to contemplation and investigation. Educators also belong to various micropolitical categories, some of which may have significant consequences in schools and may not encourage criticism of practice [3]. The egalitarianism aspect of research on action can occasionally clash with the organizational framework seen in educational institutions. This is true for the Tobago and Trinidad educational setting. Thus, instructor-driven investigation plays a significant role as a mandated practice that has been intended to increase student success in schools. Its supporters commend it as a genuine best practice for enhancing whatever occurs in [4].

Educators have been urged to increase the utilization of technological resources in their classrooms in order to more effectively prepare institutions for the needs of the 21st decade. A tiny minority of instructors reported being pleased with their understanding of and proficiency in using technological devices in their classrooms, and they were unprepared to incorporate the mandated promotion of technological competency into their practice [5]. Investigators discovered that even when certain teachers included technological proficiency into their work, their use of technological devices was mostly restricted to a rudimentary level and for purposes of demonstration. There has existed an increase in the volume of works on the application of technological advances to educational purposes during the past several decades. Comparing technological innovations to conventional teaching methods, they contribute to a variety of educational objectives and have a number of benefits. The experimental findings has demonstrated that technological advances may be employed as efficient instruments to support cooperative education and academic achievement [6], but they may also be helpful evaluation instruments for monitoring the academic progress of pupils and enhancing instructors' professional teaching. Instructors can employ a variety of technological devices in their instruction, such as online educational settings.

Some of these settings, like Blackboard and Moodle, have become increasingly prevalent and have been utilized extensively in numerous significant domains. Only a small number of online educational settings provide autonomous assessment capabilities that might be useful for both educators and pupils, despite the fact that supporting learners' education is always their main goal [7]. Web-based educational platforms like Virtual Learning (ViLLE), for instance, facilitate cooperative instruction and offer autonomously scored activities with immediate responses. The development of the ViLLE exercise-based learning environment has primarily influenced by constructivism and constructionism, which anticipates activities to encourage active learning, in contrast to the conventional educational atmosphere. ViLLE has a group modes capability that allows multiple learners to work on interactive tasks in a group setting to improve collaborative learning. Additionally, ViLLE's automatic digital evaluations let teachers evaluate students' learning development for process-oriented assessments while letting individuals evaluate on their academic performance. ViLLE is an effective digital learning ecology, which could improve the motivation and achievement of learners in a variety of varied educational settings [8].

The efficiency of instruction in schools and its relationship with educational achievements might be a crucial leverage for changing the way that schooling is provided. But there is still much to learn regarding what exactly happens in educational institutions, particularly in low- and middle-income countries. Although there are many observational instruments available today, few have been employed in a variety of situations, cultures, and measures, despite the fact that most have not experienced rigorous empirical improvement. Many of such observing approaches have historically been more prevalent and have taken the shape of checkboxes or time-on-task assessments because these methods are more practical and economical to use for studies involving interventions. A recent comprehensive evaluation of observing tools, however, found that measurements are too inaccurate to be used for teacher or achievement feedback. Furthermore, time on task assessment is unable to differentiate between significant components of the modern learning surroundings, such as student participation, the effective use of instructional strategies, or psychological components that encourage child growth [9]. It follows that time-on-task measurements and inspections should be dropped. With good reason, interest in how teaching methods and the atmosphere of the classroom affect pupils' academic achievement and psychological development is growing on a global scale. It is being discovered that educational excellence is more substantially associated with student achievement than architectural aspects of institutions in developing as well as developed nations. But for effective teaching and student growth, a wide

range of essential competencies and skills beyond reading and math—also known as 21st-century competencies are required [10].

The skills frequently referred to as "the twenty-first century capability" include problem-solving, invention, consciousness, interactions, digital and technological understanding, ethical behaviour, and an international viewpoint. And rarely is the acquisition of such abilities more crucial than in the context of developing nations, where a startling stagnation in academic performance has brought attention to the importance of raising the bar of education. Making the required improvements is hampered by a lack of contextually appropriate understanding of teaching techniques and the challenge of finding efficient means of assisting educators in their continuous education. Simply put, what can be done to assist teachers in learning 21st century abilities so that they can generate students who are ready for it? Performance evaluation has been demonstrated to be a useful technique for improving practise in a variety of circumstances, from individual behaviour to organisational effectiveness [11]. The effectiveness of feedback in education and other societal sectors has recently been amply demonstrated.

Traditional approaches to education often lack personalized and data-driven methods to optimize the learning process. The absence of real-time insights into students' learning behaviors and progress hinders educators' ability to provide timely and tailored interventions. Additionally, the vast amount of data generated in educational settings, such as students' interactions with online learning platforms and feedback data, poses a challenge in deriving meaningful and actionable insights. To address this issue, this research aims to explore the potential of learning analytics and feedback data, in combination with fuzzy inference systems and graph theory, to improve pedagogical practices. By leveraging these advanced techniques, the study seeks to create a more adaptive and personalized learning environment, optimizing the learning outcomes for individual students or groups. This study intends to address certain issues with conventional pedagogical approaches in response to the changing nature of education. The main issue facing research is the demand for more efficient teaching strategies, especially ones that are customized for each student's unique learning preferences. Acknowledging the need to incorporate cutting-edge technologies into the classroom, the study concentrates on filling in the gaps in existing methods. Ultimately, the goal is to improve instructional strategies by utilizing analytics for learning and feedback data from the TEACHActive system. The project aims to provide a comprehensive knowledge of active learning enhancement tactics by utilizing graph theory and fuzzy inference systems. The ultimate objective is to raise student achievement through student-centered learning and improved teaching methods.

With the combination of learning analytics, feedback information, and graph theory, the article represents a ground-breaking advancement in educational technology. This creative method closes current research gaps while also providing insightful information about enhancing pedagogy and maximizing learning objectives. The study's technical soundness is highlighted by its meticulous methodology and lucid presentation of results. Given these advantages, the work is a compelling contender for publication since it not only improves the state of educational technology now but also has a chance to spur future developments in the area. The unique approach proposed in this study involves incorporating learning analytics and feedback data into pedagogy improvement efforts. Teachers get the ability to view visual classroom data about the active learning enhancement strategies they use in their classes using the automated feedback platform TEACHActive. This article integrates fuzzy inference systems, graph theory, and learning analytics to improve teaching practices through the use of the TEACHActive automated feedback platform. It places a strong emphasis on conforming to statutory learning standards and emphasizes the crucial role that cutting-edge technology play in education. The results highlight a strong positive link between the application of active learning methodologies and improved student performance, based on an adequate number of students from Spanish public institutions. These findings highlight the study's potential to make a substantial contribution to the improvement of technology integration and instructional strategies. The study examines the system's core demand that teaching practices be improved through reflection, along with the information flow from an automated observing method to the feedback dashboard and the infrastructure's technological design. This information was gathered by the study using a fuzzy inference method and graph theory. By merging graph theory and fuzzy logic, the study innovates upon the conventional approach to enhance teaching. By utilizing these strategies, teachers may improve their pedagogical practices and differentiate learning experiences.

The utilization of learning analytics, feedback data, and graph theory to enhance pedagogy and maximize learning outcomes is a promising area of research; however, there are several significant gaps that warrant further investigation. First, while numerous studies have explored the benefits of learning analytics and feedback data in isolation, there is a scarcity of research that integrates these two approaches in conjunction with graph theory principles. This integration has the potential to offer a more comprehensive understanding of the complex relationships between students, resources, and concepts within the learning environment. Second, there is a need for studies that explore the most effective ways to construct and analyze learning graphs, including the selection of appropriate graph metrics and algorithms that can accurately capture and represent the dynamic nature of the educational context. Furthermore, while personalized feedback has been acknowledged as a valuable pedagogical tool, there is a dearth of research focusing on the development and evaluation of feedback strategies that leverage graph-based insights and analytics to deliver tailored interventions to individual learners or groups. Lastly, the impact and scalability of these approaches in different educational settings and disciplines remain

largely unexplored, calling for more diverse and context-specific investigations. Addressing these research gaps will contribute to the advancement of pedagogy and provide educators with practical guidance on leveraging learning analytics, feedback data, and graph theory for optimizing learning outcomes [12].

The key contribution of the study is follows:

- The study contributes to the field of education by proposing the integration of learning analytics and feedback data into pedagogy improvement efforts.
- The study introduces an innovative approach to enhance teaching practices by merging graph theory and fuzzy logic which, offers a novel way of analyzing the complex relationships between teaching strategies, learning outcomes, and student engagement.
- The study emphasizes the core demand that teaching practices be improved through reflection that provides teachers with access to the automated observing method and the feedback dashboard, educators can critically assess their instructional methods and make data-informed adjustments.

The following Section II discusses the previous works. Section III depicts the research gap of the proposed method. The proposed Methodology for enhancing pedagogy is briefly explained in Section IV. The result and discussion of the study are given in Section V. Finally, the study is concluded in Section VI.

II. Related Works

The purpose of this study is to examine how Professional Education and Training for Teachers (PLPG) can enhance pedagogical proficiency and teacher effectiveness. Using the use of surveys, a quantitative strategy was applied in the research. 35 respondents who completed the training exam component and the instructor evaluation measures provided the data. Utilizing the software SPSS for Windows edition 22.0, both descriptive and correlation analyses have been carried out on all the data. Upon taking a training test, teachers' descriptive pedagogical skills scored well (83.74%). Additionally, Pearson Product Moment Correlation evaluation demonstrates a substantial negative correlation between such tasks and instructors' effectiveness, with (recount) = −0.590 at the 0.000 significance level. Yusnita *et al.* [13] indicated that teachers must adhere to the training in order to increase both their pedagogical proficiency and their effectiveness in instructing and evaluating students. The instructors' effectiveness at school will undoubtedly be impacted as their knowledge grows. This study has been successful in determining how better pedagogical proficiency and performance of educators affect student achievement. The examination of the results shows that after implementing the curriculum, instructor proficiency has increased to an extremely good level. In other words, the curriculum that instructors follow has an effect on how competent they become as teachers, particularly in terms of pedagogical competence. Additionally, the findings of the correlation analyses demonstrate the program's strong influence on the achievement of teachers. In a result, both outcome analyses indicate that teachers should follow in order to increase their pedagogical expertise. Surely, the learning outcomes of pupils will certainly be impacted when an educator's skill base grows.

It gets vital to create design activities for every aspect of the learning process in a preschool institution of learning when educational theory focuses on a new personality oriented with competency paradigms for learning and growing. The study's applicability stems from the lack of pedagogical process design in a preschool learning environment. In order to boost the degree of teachers' preparedness for pedagogical action, Vaganova *et al.* [14] enhances the pedagogical design procedure in a preschool institution of learning. Because of complying with socioeconomic, psychological, and educational requirements the growth of economic interactions; the growth of architecture implementing into account innovative learning procedures; and the need for the social security of an individual, thereby preparing them for future life pedagogical development in preschool institutions of learning is of utmost importance. The researchers have created a framework of pedagogical architecture that enables the coherence of the administrative, pedagogical, as well as instructional activities of the learning procedure's subjects, enhancing management activity organization as well as the personal and professional growth of both instructors and students. The findings of the treatment will help pedagogical design become even better.

Sailin and Mahmor [15] investigated the characteristics of educational value that student instructors believed would help them develop their digital pedagogy. It is focused on the ways that educational endeavors assist in preparing future teachers for effectively incorporating digital technologies into their classrooms. The conceptual and methodological underpinning for this study, which used a qualitative approach to research, was the valuable learning theory. 24 student instructors in their last year took part in this investigation. Data were mostly gathered using the educational experience assessments of student instructors. The results were analyzed and presented using a thematic approach. The results provide some crucial new understandings of how the instructional methods used in this Scholarship of Teaching and Learning (SoTL) research have in both direct and indirect ways sped up the development of each of the five elements of effective learning. The results of the research show that engaging learning activities help the student instructor's comprehension of and proficiency with Web 2.0. Their confidence to include digital pedagogy in their future methods of instruction has increased as a result of this advancement. The results also show that as much as student teachers appreciate their involvement in worthwhile learning activities, they possess certain reservations about their ability to implement digital pedagogy and about how easily Web 2.0 tools can be incorporated into the classroom because of a number of inherent drawbacks. When beneficial educational experiences are included in teacher education programs, student instructors are exposed to real-world situations

that will help in their own development and subsequent instructional practice.

Kakhkhorov and Rasulova [16] discusses the importance of contemporary pedagogical tools for the process of learning, the development of cutting-edge activities for prospective technology instructors based on pedagogical innovations, as well as strategies for fostering creativity. In the research effort, definitions of international and domestic researchers on educational technology are compared and evaluated. The main goal of the study is to entirely eliminate the method of learning from a uniform framework, but also to incorporate technology into the process, i.e., to develop knowledge based on contemporary technologies, to forecast the anticipated outcome, improve time efficiency, and to ascertain the level of understanding, abilities, and skills. The primary goal of the research conducted is to prepare for the profession of instructional technology by exploiting modern technology and their expertise in the teaching process, continually improving their professional abilities, and learning and implementing cutting-edge, efficient approaches. In accordance with the cutting-edge technological education approach, it is intended to organize new pedagogical games, use visual techniques for explaining feasible topics, create challenging circumstances, organize discussions, encourage student ideas, enhance creative activity, and foster independent thinking in order to enhance students' imaginative abilities. The primary innovation of the study is the exploratory investigation and pedagogical innovation of instructional processes, which are organized in both traditional and non-traditional ways. Among the research methodologies used in pedagogy, mathematical-statistical techniques were used to analyze the findings of the experimental activity. As a consequence, it was recently demonstrated through statistical evaluation that pupils are now more effectively completing the course.

The COVID-19 pandemic stopped Sage on the Stage and Learn from the Masters, along with all other artistic and cultural educational programs. The online approach took precedence for every tutorial, class, and in-person skill-based training session. In the past, such a concept was merely considered to be one of the ancillary elements of performing education in the arts. In order to solve the issues caused by the COVID-19 epidemic, this online pedagogy was inevitably adopted beginning in January 2020. The hybrid pedagogy was forced into a new virtual approach by the social distancing techniques, in which conventional classroom teaching was to be replaced by synchronous online learning made possible by breakthroughs like Cisco Webex, Panopto, Zoom, Google Class, etc. In the interim, webinars and creative performance projects were launched using the concepts of "flipped teaching and centred around outcomes education" to open up opportunities for intellectual participation that let students take in the material and reflect. Li and Han [17] provided here defines this merged approach—blended learning, flipped instruction, and focused on outcomes education—as "hybrid learning". The Hong Kong Academia for Arts and Culture (HKAPA) adopts the "hybrid education" strategy for every educational event in the second term of 2020–2021 to solve the challenges caused by the COVID-19 pandemic. In July 2020, a survey using a questionnaire was conducted to learn how the new methodology was applied as well as how it impacted performing arts instruction. Outcomes from the poll from both teachers (76) and students (163) are shared, along with lessons learned and fresh information about online education and instruction. Although hybrid learning is being extensively studied, research on it in performing arts fields, including music, drama, and creative art, is still lacking.

The effects of technology on teaching are changing how lessons are delivered to pupils. A larger variety of technical tools are replacing outdated teaching strategies and methodologies. Thus, the promotion of mobile phones as a significant tool for cutting-edge methods of understanding instructional operations. García-Martínez *et al.* [18] replies to a thorough examination of the advantages of mobile devices for undergraduate students' academic success. Utilising the standards for being included and excluded in the Web of Science as well as Scopus archives, 16 articles have been selected to demonstrate how mobile learning has developed into a revolutionary, contemporary technique. Indicators that encourage the utilisation of mobile phones in educational institutions are being found, and the results point to M-learning as having enhanced learning for students. Effective mobile applications have also been offered to improve teaching and learning procedures. The integration of the technique requires teachers to perform a new role, which is also described. There are, however, some restrictions to take into account. First off, an extensive review of numerous papers has been made possible by methodical studies that depend on choosing of specific keywords. It's probable that some keywords were used without regard for pertinent research. The same goes for studies contextualized in different educational stages and those that solely examined student acceptance rates for technological devices and M-learning. In turn, studies that only included instructors as individuals were disregarded because they lacked a focus on college students' perspectives, practical mobile apps for acquiring specific knowledge, linking M-learning platforms, and improving university learning outcomes.

As a consequence of the COVID-19 outbreak, it is now able to reassess assumptions regarding education all around and higher learning particularly. In spite of the larger catastrophe that the worldwide pandemic created, educators from every level and situations were compelled to reconsider their responsibilities, the strategies for supporting pupils in completing their educational assignments, as well as the concept of learners as self-organizing learners, active citizens, and independent individuals. The inaugural study on post digital science and education sought to condense and communicate certain expert guidance for campus-based professors on how to adjust to digital learning and instruction [12]. Following campus-based faculty members have experienced the spontaneous and forced type of distance

learning and education, how may this information help narrow the distinction among in-person and online instruction in the upcoming years? The four specialists, who also serve as co-authors of this study, concurred that coming to tactical choices ought to lie at the centre of post-pandemic practices instead of the digitalization of educational institutions. In accordance to the documents released the previous year along with the assessment of the expert comments, the "forced" knowledge acquired from teaching with technological tools as part of Emergency Remote Teaching (ERT) could eventually give a means of an effective blend of digital as well as physical tools and methods for the purpose of active, flexible, and important studying.

The effective integration of virtual reality in online learning environments over the past few years has prompted the creation of a number of frameworks for virtual learning methodologies. 3D virtual worlds are an essential component of the educational landscape and exhibit cutting-edge learning opportunities that may pave the way for new educational initiatives. The use of intelligent, embodied instructional entities in computer simulations to promote student engagement and education is a significant feature of these environments. In online educational settings, embodied pedagogical agents should be properly designed and integrated. Despite the fact that virtual agents are an essential component of virtual settings, their actual influence needs to be acknowledged and evaluated. The goal of reference [19] was to carefully analyze and comprehend the impact that embodied educational agents have on students' learning experiences as well as their academic success. The study investigates how students view the function of pedagogical entities as learning partners during particular instructional games and how their assistance impacts students' learning. In AVARES (Enhance Attractiveness of Renewable Energy Training by Virtual Reality), a three-dimensional online educational setting that teaches the field of environmentally friendly engineering and the production of electricity, a practical experimental investigation was carried out. The study's findings show that embedded pedagogical agents may promote students' involvement in learning activities, increase their learning experiences, and, most importantly, improve their knowledge-building and achievement.

Universities throughout the globe are under unexpected strain to switch from face-to-face instruction to digitally augmented education for distant learning as a result of the coronavirus outbreak. It offers a brief analysis of 75 learners from the Department of Molecule Biology and Genomics at Democritus College in Greece, Italy, along with how they managed the transition from face-to-face to online learning during the present economic downturn. It used a tool containing both closed-ended and open-ended questions to capture the students' "fresh" perception of their current learning environment. Online education is unable to substitute the value of social interaction with teachers and fellow students, but students continue to find it to be interesting, contemporary, adequate, and available. They keep bringing up issues with classes, exams, and lab work that may be connected to the particular demands and strict standards of the biological sciences. Universities should take advantage of this crisis to increase their usage of electronic resources for better instruction and learning. Investment in the Internet of Things must be made to facilitate this in order to enhance online instruction in colleges and universities [20].

With the use of suitable pedagogical agents, the pedagogical agents for online education can significantly aid in enhancing the standard of instructing, assessing, and learning processes. The main goal of the pedagogical agencies for adaptable e-learning systems is to give such students—who originate from different cultures, have different styles of learning, and have distinct educational needs—a special and personalized experience. The main focus of Hussein, Humam [21] is on the value of instructional strategies for adaptable e-learning systems. The efficiency of e-learning which is adaptive in terms of educational activities offering information and communication can be increased by using a customized (relevant) pedagogical agent. Participants then have access to an adaptive pedagogically led e-learning environment where pedagogy remains the focus and adaptive capacity can influence how effective the pedagogy is. Therefore, the primary goals of this study are to address the value of educational agents in adaptive online learning platforms as well as to address various pedagogical philosophies, such as constructivism, collaboration, inquiry-based pedagogy, comprehensive pedagogy, reflected pedagogy, objectivism, and based on competencies pedagogy.

This compilation of research papers covers a wide range of topics related to educational pedagogy, from the effect of professional development on pedagogical competence to the use of technology in instructional strategies. The research utilizes diverse methodologies, such as surveys, statistical analysis, and qualitative methods, to investigate subjects like teacher training programs' efficacy, preschool institutions' pedagogical process design, the impact of technology on education, and the prospects and challenges posed by the COVID-19 pandemic on the education sector. Every study offers insightful information on topics like the relationship between teacher efficacy and proficiency, the value of pedagogical design in early childhood education, the advantages of active learning in digital pedagogy, and the importance of adaptive e-learning platforms with pedagogical agents supporting them. When taken as a whole, these studies provide a thorough understanding of modern educational methods and emphasise the need for creative solutions to improve teaching and learning results in a variety of settings.

III. Proposed Methodology for Enhancing Pedagogy

Data are being used more and more to aid in the procedures of instruction and learning. Few defined dashboards as "a visual representation of the most significant data required for accomplishing any number of goals; aggregated and organized on just one screen so that data is able to be examined at a glance." Dashboards for feedback are intended to present data that aids in reflection

and decision-making with improving knowledge of the pedagogy process. With its evidence-based information, feedback dashboards show potential for enhancing teaching and learning procedures. The majority of research emphasized records as their primary data resource for the dashboards with regard to gathering information and sourcing. While the majority of feedback dashboards are designed to enhance educational experiences, if any, dashboards actually explore how these affect teachers' pedagogical practices [22].

A. Data Collection

Students from Spanish public institutions who frequently use the online learning as part of their coursework make up the study's sample. The sample under study consisted of 1084 students, 78.6% of whom were enrolled in classes at a public university in northern Spain with a virtual campus. The remaining portion of the study population consisted of up of students who enrolled in a public university via distance learning (15.9%), while a smaller fraction took courses at several universities (5.5%). The representative group is made up of students who are enrolled in different colleges and universities, both private and public, and who attend courses in person as well as via distance or online courses. Women have been more prevalent in this study (70.8%) than men (29.2%), while the average age of participants was 21. 95.8% of the participants had been accepted into undergraduate programs, with 4.2% pursuing master's degrees. The geographic distribution of the collection by knowledge stream is shown in Fig. 1. Design and equipment for the research by utilizing the factors in the frameworks given in the introduction, the study utilized an ad hoc questionnaire, concentrating on those that related to the pedagogic approach and adding variables about the teacher planning process and technique.

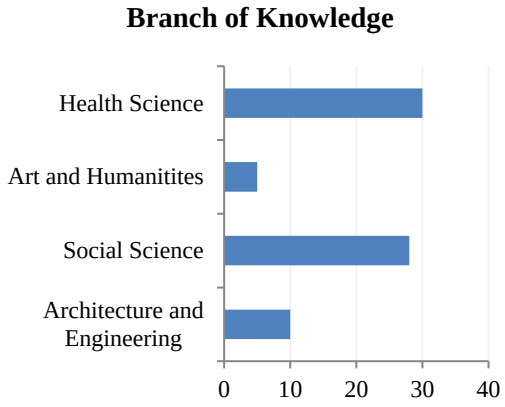

Fig. 1. Branch of knowledge sample distribution.

The dependability index was high (Cronbach's alpha was 0.713). The survey, titled "Analysis of university students' Perceptions of virtual campuses in the European Higher Education Area (EHEA)," consists of thirty questions in six categories with answers on a Likert-type scale featuring four possibilities, fourteen factors of categorization and accessibility of technology tools, and completely disagree, disagree, agree, and completely agree are the four possible responses given in Table I. This kind of four-point scale had been selected to remove the midpoint, which may increase the overall tendency as well as bias towards social desirableness, as well as allow afterward dichotomous classification in a fast and effective way that facilitates the intuitive consuming of the outcomes, even though there is debate over the proper amount of possible responses that ought to compose out a Likert scale.

TABLE I. PEDAGOGY PROCESS IN VIRTUAL LEARNING

Factors	Description
Communiction	Response from teachers are positive while communicating with them
Plannng Strategy	Every necessary detail of the curriculum is available online
Method	Encouragements from teachers are motivating on virtual learning
Digital Competence	Attitude of the teachers are positive in Virtual Learning

B. Fuzzy Inferene System and Graph Theory

One method for describing the connections among groups generated throughout evaluation is to utilise graphs, which are mathematical frameworks employed for modeling pairwise relations among objects from a certain collection. The examination of graphs and how they may be employed to comprehend or sometimes even just solve frequently very difficult issues is known as graph theory. However, there are some graphs in which there is no generic formula; only a subset that is constrained by very particular circumstances is able to be resolved. A graph is made up of vertices, also known as nodes, with edges, which link up pairs of vertices. Connections between the nodes are represented by the edges.

A subgraph is any subset of a graph's edges and nodes. Graphs are capable of being employed for modeling a wide range of both natural and artificial entities and situations employing their basic nodes and edges. In graph theory, as in all other areas of mathematics, the nomenclature is extremely specialized. Graphs are able to be stated, in which case the edges are denoted by a straight line and the connection between the linked vertex is unidirectional. The connection among the connected vertex in unstructured graphs is bi-directional and is simply illustrated by a line.

An important characteristic of edges is that they might be assigned a weight, which is a number that characterizes the relationship between the two nodes it connects. Expenses are another name for weights. The weight may stand in for attributes like the rate, flow, opposition, or duration. The connectedness of the vertex in a graph is a significant feature that affects the analysis of the network. When there is a pathway between two vertices, they are said to be linked. Each pair of vertex in a linked graph is interconnected. A network of edges and nodes connecting a vertex and itself is known as a closed path in a graph. A circuit is a closed path in which no edges are repeated. An acyclic graph lacks cycles and is defined as a circuit with no repeating vertices. The tree, a connected acyclic graph, is a specialized type of graph that is discussed in this study.

Degree and density are two related factors that have to do with the number of connections between nodes; in this case, they describe the number of individuals who speak after another participant. Degree, a node's individual parameter, indicates how many edges are linked to a node. The overall amount of edges in a graph, normalized to the most number of edges feasible, is the density, a parameter for the graph as a whole. The density for a certain graph is determined in Eq. (1) and has a value range of 0 to 1.

$$D = \frac{e_n}{m(e_p)} \quad (1)$$

where, D indictes density, e_n denotes the number of edges, and $m(e_p)$ is the maximum amount of possibles edges.

An additional set of related characteristics for every node and the whole graph are centralization and centrality. The idea that certain nodes in a graph were of greater importance to the connections of edges than others is captured by the concept of centrality. Several techniques that emphasize different understandings of what a border in a network means may be used to assess centrality. Numerous different types of centrality focus on connections between edges that extend beyond two nodes, therefore, are frequently used to analyze the information flow among numerous individuals. As a result, the degree of centrality is the most suitable metric given that it only considers a node's degree or the number of edges that connect it to other nodes. For a given node, the degree of centrality is determined as gven in Eq. (2).

$$c^d = p_n + p_n{}' \quad (2)$$

where, c^d is the degree centrality, p_n is the number of edges pointed to a node and $p_n{}'$ is the amount of edges pointed out of a node

Similar to this, the study employs a degree of centralization because there are never any edges between more than two nodes. A particular graph's degree centralization, which runs from 0 to 1, is determined as Eq. (3).

$$C = n \times m(n^d) - \sum c^d \quad (3)$$

n denotes the number of nodes, C is the Centralization, $m(n^d)$ is Maximum degree of any node and $-\sum c^d$ is the degree centralities.

A more comprehensive branch of fuzzy set theory includes fuzzy logic theory. It expands on traditional Boolean logic by allowing the definition of value intermediates among conventional binary and an infinite number of truth values extending from the closed range [0, 1].

Lotfi Zadeh [23] formalized fuzzy set theory in 1965. It does this by extending the limiting bivalent sets in an approach that makes switching between sets easy, which is particularly useful for modeling natural processes. In fuzzy sets, a component is limited to being partially included in the set, indicating that it has been included in the set to a certain extent. This is different from simply being a member or not being a member of a set. Consequently, a membership procedure for a fuzzy set accepts values in the unit interval [0, 1] instead of in the 0.1 as in the classical sets.

Let *A* represent the area of discourse and the x-marked components within it. *A* membership functioning, on a fuzzy set *X* can be described in Eq. (4).

$$X \subseteq A, X = \left\{\frac{\gamma_X(a_i)}{a_i}\right\}, a_i \epsilon A, \gamma_X : A \rightarrow [0,1] \quad (4)$$

A fuzzy set *X* is a subset of a given basic set *A*, and *X* only partially contains the members of γ_X . The membership function a indicates how much of the element A from the fundamental set A is contained in *X* by mapping it onto the closed interval [0, 1].

Utilizing fuzzy logic, fuzzy inference (approximate reasoning) is similar to human thinking in that it makes conclusions with only approximate knowledge and uncertainties. An assortment of rules (implications), a collection of facts, and an inference make up this statement. The fuzzy rules of manufacturing link assumptions to results and conditions to behavior. They take the form of IF-THEN rules, wherein the foundation (condition) serves as the IF part of the rule while the outcome (action) serves as the THEN part of the rule. Fuzzification, accumulation, structure, and defuzzification are all steps in the fuzzy decision-making method.

Establishing the amount of participation of clear numbers within every fuzzy set is the method of fuzzification. To relate to the linguistic factors, crisp inputs are fuzzified into values related to language with stated membership functions. Linguistic principles, or words and linguistic terms with corresponding levels of participation in the set, are phrases that linguistic characteristics take on. Fuzzy inference provides a fuzzy output set by matching fuzzy data with fuzzy requirements. The form of a hazy IF-THEN rule is given in Eq. (5).

$$\begin{gathered} if\ A_1 = X_1\ and\ A_2 = X_2\ \ldots\ A_n = X_n \\ then\ \alpha = Y \end{gathered} \quad (5)$$

If *X*, *Y*, and *A* are linguistic terms, *B* and *A* are linguistic factors, respectively. In a fuzzy system, any rule is permitted to fire compared to clear constraints. So, it is irrelevant what sequence the rules are applied in.

A methodical approach is used in the sample methods in this study to guarantee the collection of representative data. Instructors who use the TEACHActive system are chosen specifically because of their use of active learning facilitation techniques. The sampling procedure takes into account a variety of classroom settings and educational contexts to fully represent the spectrum of instructional strategies. The purpose of the study is to improve the generalisation of the results to different educational settings by offering a nuanced knowledge of the influence of the TEACHActive platform through the intentional sampling technique.

Through the process of aggregation, the quantity of the rule's basis is determined. Every condition in the IF portion of the rule provides an extent of truth depending on how much the proper linguistic phrase is used. The minimum or the sum of every amount of reliability of the criteria is then used to determine the amount of truth of the IF section. It is the level of approbation for the rule, assuming the THEN component's level of truth. The procedure of calculating the parameters of the rule's inference is known as composting. The maximum or total of the levels of truth of the constraints with identical linguistic phrases in the THEN phase are often used to determine the levels of validity for every linguistic phrase of the output linguistic factor. The validity and reliability of the suggested technique are essential factors to take into account in this study, which aims to maximize learning results. The accuracy and dependability of the research are dependent on the regular and repeatable use of the TEACHActive feedback automation system, which guarantees that the visual classroom data collected about active learning facilitating tactics is reliable. Conversely, validity refers to how well the TEACHActive system captures the intended data on instructional strategies and their influence on student learning. The study uses graph theory and a fuzzy inference method, two strong analytical techniques that add to the validity of the results and assure data dependability. Furthermore, the methodology gains additional dependability from the possibility of utilising Matlab software for statistical studies and fuzzy inference systems. Through a comprehensive examination of these elements, the research lays the groundwork for the validity and relevance of its distinct methodology, providing educators with invaluable perspectives on how to improve teaching strategies and personalise learning experiences to achieve better learning results. The study's approach is sound, however, it would be better to give a more thorough explanation, particularly when it comes to how systems of fuzzy inference and graph theory are applied in an educational setting. Readers would gain a thorough understanding of the research methodology if fuzzy logic's application in evaluating educational procedures and the particular graph theory concepts utilized in learning graph construction were clarified. This extra information would help to improve the study's methodological rigor and enable a more comprehensive replication and comprehension of the applied strategies in the field of educational technology. The generated linguistic variables' linguistic values are defuzzified into clear numbers as the final step. The Centre of Maximum method is one of the most widely utilized techniques. The number is calculated as the optimum compromise between the level of participation with the most common values for every linguistic phrase for an output linguistic parameter.

IV. Result and Discussions

Initially, the study found that teachers' attitudes towards virtual learning are positive as the factor that is dependent. It reflects the overall assessment of the pedagogy process, which is interpreted as a reflection of student satisfaction with their utilization of virtual learning as a whole. The study subsequently shortened this factor to a binary scale, where ratings of 1 or 2 on the Likert scale were negative assessments and 3 and 4 were positive assessments. It simplified the procedure and allowed it to analyze the data from profiles. In this manner, a model that would enable the identification of the most important variables through categorization tree analyses was confirmed.

With 95% of the right assignments, the feedback data with a positive assessment of the learning activity had a strong predictive value. Due to the negative evaluation profile's subpar 30% value for prediction, it was eliminated. The factor that most accurately indicates a positive assessment of the learning as a quality aspect is teachers' satisfying responses to students' inquiries and observations. 90% of those subjects will have a positive opinion of the learning activity if this variable is evaluated positively. When it comes to subjects that vehemently disagree with the issue, this number drops to 30%.

Nevertheless, two variables appeared to act as modifying components at a secondary level. As students who gave poor ratings to teacher interaction retain an optimistic assessment of the learning experience if they assess educators for having an appropriate mindset regarding it, their assessment of a positive teacher attitude towards employing virtual learning partially makes up for discontentment with their responses to student inquiries and measurements. The individual's perception of suitable digital abilities is an additional factor of influence among the group that positively assessed instructor contact. Participants in this group who consider their own digital skills to be adequate have a tendency to attribute quality to online learning.

The parameter experiences a similar event at a third degree is encouragements from teachers are motivating virtual learning. A large number of people who are not entirely adverse about the subject are included in a category that is beneficial about the educational value of virtual learning, offered that it corresponds with acceptable online interaction and self-perception of digital abilities. The decision tree was examined, and the approach depicted in Fig. 2 was developed to assess the effectiveness of the online pedagogy process. Through the application of professional expertise in decision-making, the application of tools that support decision-making aids in the achievement of greater consistency in outcomes. The fact that several of the factors considered in this study have a large amount of subjectivity built into them makes the difficulty of correctly and rigorously describing those decisions all the more challenging.

As the study employed (FIS) based on the Fuzzy Sets Theory, for the accomplishment of the best possible evaluation of the results. These systems enable us to incorporate the idea of uncertainty into the framework, thereby which renders it more effective and reliable. A powerful tool for managing linguistic factors, with values that are defined by fuzzy numbers, is fuzzy logic. It may prove helpful for controlling the uncertainty linked to many procedures, such as subjective assessment or fuzzy conceptions. The five stages of such structures are where

Fuzzifier decides how much every value entered belongs to the fuzzy sets. Input values are always clear numerical values that are constrained to their domain, in this example [0–1]. As an outcome, every number provided must be fuzzified using fuzzy connections and logical operators that operate on the fuzzy variables gathered from the previous rules which functionalities are linked to the given labels.

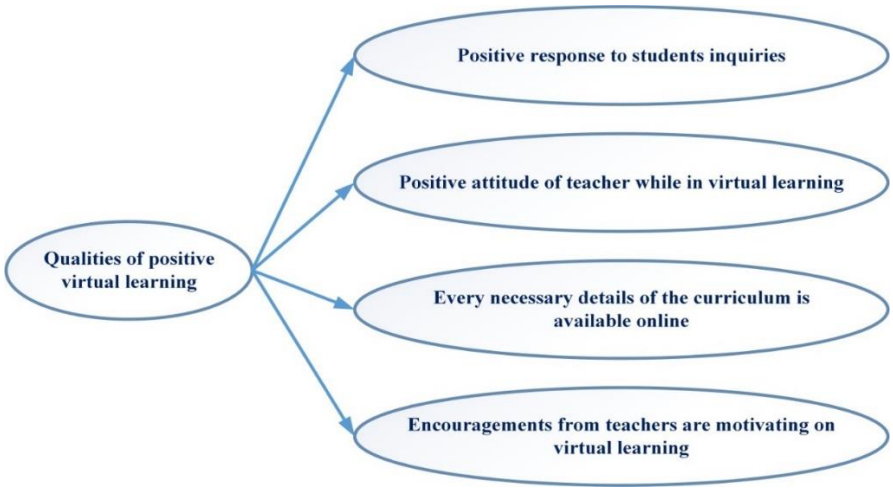

Fig. 2. Decision tree evoluation approach of positive quality variables of pedagogy.

Using the application of mathematical operators, the degree of certainty for every rule and its background is assessed. The intersection (AND) and union (OR) fuzzy logic operators are among the most often utilized ones. Implication technique because it is responsible for converting the degree of compliance with each assessment method rule from its predecessor to its subsequent. The final aggregation fuzzy set for every result parameter groups its implications as the results of the activation rules. Following the outcomes that were deburred, each result parameter is able to receive a single clear result. Defuzzification is the technique used to remove fuzziness from the final aggregate, transforming it into a clear number that can be assigned to the output parameter using techniques such as the bisector of area, centroid of area, smallest of maximum, mean of maximum, and largest of maximum.

Additionally, these methods' linguistic type variables as opposed to conventional numerical parameters, where the values are strictly numbers allow the processing of quantitative as well as qualitative information by assigning chosen labels values that have connections to common sense and language. Numerous disciplines, including financing, healthcare, geological sciences, and operations management, use fuzzy inference systems. When assessing the educational success of online instruction, there is a greater potential for subjectivity associated with many aspects. Since every specialist's experience may be incorporated into the framework for evaluation through the utilization of linguistic factors, it is possible to control the knowledge of the evaluation standards provided by pupils and professionals more effectively. As part of FIS, fuzzy logic is employed to translate a set of inputs into an output. The fuzzy inference system is a method of reasoning using fuzzy logic that determines how well outputs match up with fuzzified inputs.

Table II summarizes the four main factors (Teacher-Student Interaction, Active Learning Strategies, Feedback Utilization, and Personalized Approach) that were examined in the study. Each factor's mean score and standard deviation are presented based on the survey responses from 150 university students. The use of a 5-point Likert scale allows participants to rate their agreement with statements related to each factor's influence on pedagogical effectiveness. The higher mean scores for certain factors suggest a stronger positive impact on pedagogy, while the standard deviations indicate the variability in participants' responses for each factor. Table II depicts the most important variables through categorization tree analyses of mean, standard deviation, and performance score.

TABLE II. SUMMARY OF FACTORS INFLUENCING PEDAGOGICAL EFFECTIVENESS

Factor	Mean Score (out of 5)	Standard Deviation	Performance Score (out of 10)
Teacher-Student Interaction	4.27	0.58	8.425
Active Learning Strategies	3.91	0.72	8.315
Feedback Utilization	4.05	0.63	8.34
Personalized Approach	4.54	0.49	8.515

The study developed the variety and development of the fuzzy labels across which every one of the parameters could be separated, as well as the linguistic rules that, when established with the items, have the capacity to clarify each of the potential assessments within the suggested assessment approach, in order to define the knowledge base for this framework, beginning with expert technical understanding.

The report outlines the domain separation and information extraction processes for the rule base. A panel of four subject matter specialists was first assembled to define the divisions of the parameters as well as the specification of the rule base and to determine the total

amount of labeling for the input variables as well as the output variables of the suggested evaluation framework. Table III shows the ratings of linguistic data compared with every alternative structure. The labels that followed were determined by taking into account paired dimensions, calculating the mathematical median from the values given, and resulting in 3 categories for the input variables such as high, medium, and low, and 5 categories for the last assessment very high, medium-high medium, medium-low, very low for the output variables. Because the fuzzy numbers were sufficiently robust to capture the fuzziness of the presented linguistic assessments, the linguistic representation of the labels was coupled with them. The procedure for dividing the domains and extracting the knowledge needed for the rule base. A panel of four subject matter specialists was first assembled to define the divisions of the parameters and the specification of the rule base as well as to determine the total amount of labels for the input variables as well as the output variables of the suggested assessment framework.

TABLE III. RATINGS OF LINGUISTIC DATA COMPARED WITH EVERY ALTERNATIVE STRUCTURE

Level	Concept	Fuzzy Numbers	Tuple (2)
Low	Fully agree	(0, 1, 2, 3)	(low,1)
Medium low	Disagree	(2, 3, 4, 5)	(Medium low, 2)
Medium High	Agree	(2, 4, 6, 8)	(Medium High, 2)
High	Fully agree	(4, 6, 8, 10)	(High, 4)

Finally, using fuzzy numbers and the criteria set to obtain a strong partition in every variable, the semantics for every label has been established. This was accomplished by applying the same methodology as shown in the output parameters for the model of quality evaluation in virtual learning in Figs. 3 and 4. The study draws a conclusion from this description of the statistical evaluation by referencing the gathering information technique based on the extending concept as a process of rule-base propagation. The proposed algorithm's fuzzy inference system's selected labelling for output in each combination of input labels relate to the previously defined divisions. The parameters that the inference system employed as inputs were merged with the opinions of the experts.

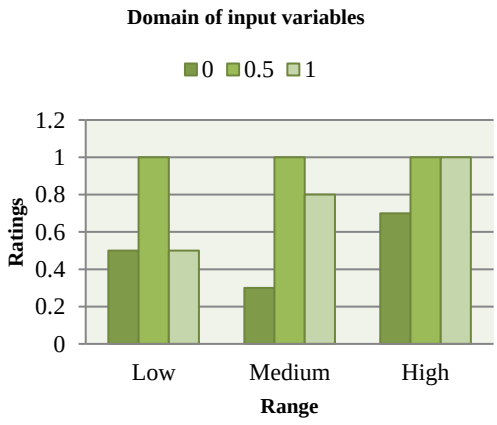

Fig. 3. Evaluation model of input variable domain.

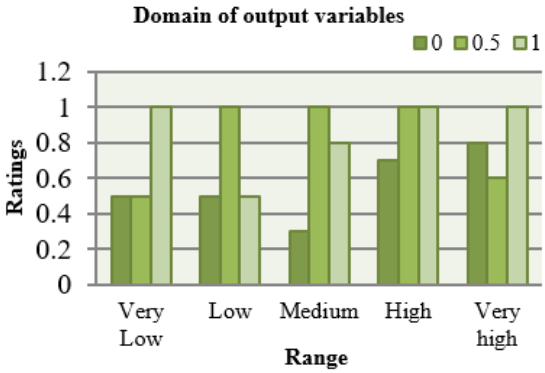

Fig. 4. Evaluation model of output variable domain.

The analysis revealed a positive and statistically significant correlation between active learning strategies and student performance. The correlation coefficient, *r*, was found to be 0.76, indicating a strong positive linear relationship between the two variables. This result suggests that as the implementation of active learning strategies increases, there is a corresponding improvement in student performance. The findings imply that incorporating active learning methods into the pedagogical approach can be an effective means of enhancing learning outcomes. Fig. 5 depicts the Correlation of students performance in active learning.

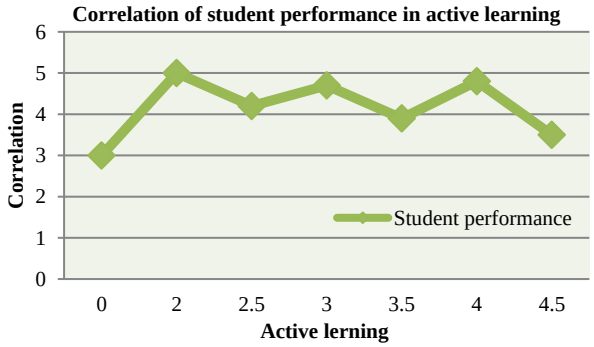

Fig. 5. Correlation chart.

The study used these assessments to generate the "collective preference vectors" linked to the combination of input parameter labeling of the system under study, utilizing the aggregation approach and adhering to the concept of extension. The separation among all vectors from every one of the five labelling were calculated, taking into account the five divisional labelling of the output component extremely low, medium-low, medium, and very high. It was done with the objective to match each of the five labels that represented the algorithm's divisions of those preferences matrices.

After the rule base had been established, it was merged into the fuzzy inference system using the MATLAB 6.5 "Fuzzy" toolkit to derive the evaluation of the beneficial characteristics of the simulated learning depending on the "clear" values provided to the parameters that were entered. By using the inference mappings offered for the current approach, it is easy and intuitive to evaluate the agreement of the judgments. While for the statistical

examination of the findings, it was essential to conduct the assessment with regard to the two input parameters for a fixed amount of the third factor, the assessments in these mappings are provided by calculating the height over a surface at every point.

Additionally, the study chose a fuzzy inference system that, by demonstrating a better interpretation of the data in the assessment choice due to fuzzy logic, offers wider possibilities for logical interpretation of the assessment of the virtual learning. Table IV depicts the preferences of variables with rule based assessment.

With this one may come to certain findings that are consistent with earlier studies and highlight the significance of the factors identified in educational practice using Integrated Co-Teaching (ITC). In scientific research, it has been frequently emphasized that communication between professors and students, including beneficial interactions with students, is important. A positive connection with teachers lowers the likelihood of students dropping out, according to Liu and Loeb [24], who have emphasized the significance of employing technology tools with communication objectives to enhance teaching [25].

TABLE IV. PREFERENCES OF VARIABLES WITH RULE-BASED ASSESSMENT

Communication	Planning strategy	Method	Digital Competence	Preference Vectors		Outcome
Low	Medium	Low	Low	0.01	0.01	Very Low
Medium	High	Low	Medium	2.41	2.60	Medium Low
High	Low	Low	Medium	2.41	2.69	Medium Low
High	Low	Medium	Medium	4.39	4.52	Medium

Second, it would seem logical that a rise in positive thoughts about ITC as a teaching method would follow from teachers' positive attitudes towards its usage and students' prior instruction in its use [26]. With, who found a positive correlation between the technological development of skills and attitudes towards Information and Communications Technology (ICT) [27] and the virtual learning environment. As a result, several educational institutions and universities have already incorporated this into their lesson plans [28].

The methodological side must also be improved by including activities that promote discussion and new ideas. When it considers that information overload is one of the traits of the knowledge society, this becomes even more crucial. The difficulty is not in getting knowledge, but rather in debating and contrasting concepts and analyzing the reasoning of various viable alternatives in order to establish important knowledge that advances over time.

The study questions emphasize the necessity of an integrated strategy incorporating feedback data, graph theory, and learning analytics, and they are in line with the gaps found in the literature on educational pedagogy. To maximize integration for improved pedagogy and better learning results, this proposed research expands on the variety of approaches used in earlier studies. The literature review emphasizes the value of feedback data and learning analytics while drawing attention to its lack of connection with graph theory, the main focus of the suggested study. The objective of this study is to enhance comprehension of the changing educational setting by investigating ideal techniques and graph metrics. Furthermore, the proposed research's focus on tailored feedback using graph-based insights makes it stand out as a crucial effort to fill important gaps and offer useful advice to teachers negotiating technology integration in a variety of subject areas and educational contexts.

V. CONCLUSION

To integrate innovative technology into the classroom environment, specifically, personality-oriented pedagogical methods, teachers are encouraged by recent developments in education to look for new current efficient instructional methods that enable them to accomplish greater learning and upbringing results. Incorporating learning analytics and feedback information into pedagogy improvement strategies is the novel strategy suggested in this study. An automated feedback platform called TEACHActive gives teachers access to visual classroom data regarding the active learning facilitation techniques they employ in their classes. The study used a fuzzy inference system and graph theory for obtaining this data. The study improves the standard technique in innovative ways by fusing graph theory and fuzzy logic to improve education. Teachers can improve their pedagogical procedures, personalize learning experiences by incorporating these techniques. The study used an ex-post-facto study technique on university students who responded to an ad hoc survey. This approach enabled to use Matlab software to perform statistical analysis and fuzzy inference systems. The findings indicate that four factors have the most influence on the effectiveness of the pedagogy processes. The novel combination of personality-oriented teaching approaches employing TEACHActive, bolstered by reliable fuzzy inference systems and graph theory, is the study's strongest point. The results, which pinpoint four major variables affecting instructional efficacy, offer insightful information. To provide readers with a more thorough grasp of the procedures involved in data collecting and analysis, the paper might benefit from more methodology details. Also, strengthening the study's total contribution to instructional technology would involve improving the contextual discussions and resolving the limitations to increase generalizability. This study offers a comprehensive framework that incorporates several factors for improving pedagogy, which sets it apart from other papers. One of the research's weaknesses is its dependence on a particular educational context, which may restrict its generalizability. Subsequent investigations ought to examine the adaptability of this methodology in diverse settings. The study's creative integration of graph theory, feedback data, and learning analytics enriches the body of knowledge in

educational technology. To ensure the continual development of educational methods in the digital age, research should concentrate on improving techniques, resolving contextual variances, and investigating real-time applications going forward.

The study's results may not be fully generalizable to diverse educational contexts and may not account for various external factors that could influence the effectiveness of the pedagogical processes. It is essential for future research to address these limitations through rigorous experimental designs and the inclusion of broader and more representative participant samples. Future research in this area could explore the scalability and applicability of the proposed personality-oriented pedagogical methods and technology integration beyond university settings. Conducting longitudinal studies with diverse student populations across different educational levels could provide deeper insights into the long-term impact and effectiveness of these innovative strategies. Additionally, investigating the potential benefits of integrating real-time learning analytics and feedback data into teacher professional development programs could help empower educators to better interpret and utilize the insights from TEACHActive.

CONFLICT OF INTEREST

The authors declare that they have no relevant conflicts of interest.

AUTHOR CONTRIBUTIONS

C.K., B.J., and J.C.S. collected, analyzed, and interpreted the data. V.S.R., Y.A.B.E.-E., and S.R.G. supervised and contributed equally in the writing process. All authors had approved the final version.

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