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RESEARCH PAPER

Capturing the Contribution of Fuzzy and Multi-Criteria Decision-Making Analytics: A Review of the Computational Intelligence Approach to Classroom Assessment Sustainability

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ABSTRACT

This is a systematic literature review that discusses the contribution of fuzzy analytic (FA) and multi-criteria decision-making (MCDM) methods in classroom assessment. Due to a lack of knowledge and not being exposed to the importance and benefits of using computational intelligence approaches such as FA and MCDM, not many educators apply such methods. The issue of how it operates is also the cause of educators still adopting conventional assessment methods. Classroom assessment involves the orientation of data in the form of divergent, multiple, fuzzy, and terms of relation, so a more efficient approach to assessment is through modern mathematical methods and soft computing techniques as suggested by experts. This practical gap needs to be refined by providing a clear picture to educators about FA and MCDM as alternative assessment methods. Therefore, based on the PRISMA model, this systematic literature review is implemented to expose educators to the contribution of FA and MCDM in classroom assessment and conceptualize how to operate the method more easily and simply. Starting with article searches in several databases such as Google Scholar, ScienceDirect, and Elsevier using only specified keywords, 21 articles were selected for discussion after going through the steps of Identification, Screening, Eligibility and Included. Based on the findings, some aspects of assessment are very significant to be implemented using FA and MCDM, appropriate, more practical and show a meaningful contribution to classroom assessment. The conceptual model of the operation of FA and MCDM based on a summary of the workflow of selected studies can also help educators get insights and ideas to implement this alternative assessment method. This paper can prove that the computational intelligence approach greatly contributes to classroom assessment and if there are initiatives and facilitation implemented, surely educators can take advantage to strengthen the management and assessment of the classroom.

KEYWORDS: *Online teaching; Students' engagement; Students' mastery; Coronavirus outbreaks; Metacognitive regulation; Online mathematics teaching.*

1. Introduction

Quality in education is based on soundness in management and assessment practices. To date, not many studies have been done to analyze the relationship between student performance in learning and the factors that influence it. Student quality and performance can be influenced by several factors with different effects [33]. This situation illustrates the credibility of management and classroom assessment practices implemented in the current education system. The question is, does this practice meet the theory, components and needs of classroom assessment?

Classroom assessments are comprised of substantial, divergent and unclear data collection [31]. According to Brown (1990), aspects of classroom assessment are such as practice, student performance, achievement, teacher quality, curriculum, learning and teaching, research development and so on. Classified into conventional assessment (traditional) and alternative assessment [15]. However, the selection of specific methods,

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which are more significant, appropriate and practical for analyzing and describing data is more important [20]. Improper selection can invite problems [8]. In addition, each component of assessment has constraints, challenges and some factors that lead to the inefficiency of such assessment [15]. The main issue in determining classroom assessment methods is the objective or purpose of the assessment. Setting this goal will ensure that the evaluation method can be chosen more accurately. [15] explained that fewer empirical studies have been conducted to look at the effect of the selection of assessment methods on the purpose of assessment.

Among the purposes of the classroom, assessment is to measure achievement, performance and competence [33], classify or construct rankings [15], and select or evaluate teaching and learning methods or activities [24], construct methods, or develop a new model [30], [19] and so on. According to [32], there are weaknesses and gaps in practical assessment methods or tools for example when the purpose of assessment is to measure various performances or competencies but give results in the form of grades only. It does not specifically describe student achievement and competence without a clear description or rubric. Next, are issues related to data sources and how data are obtained. Data orientation greatly influences the selection of assessment methods, this is because otherwise, it will lead to a chaotic assessment process. [21] clearly stated that very little attention is given to the issue of data orientation, especially in the form of multiple stakeholders and multi-criteria assessments. This gap should be clarified with knowledge sources so that data orientation and classroom assessment methods do not negatively impact the effectiveness of classroom practice and management. If the results of the classroom assessment provide a clear picture based on various data sources, then specific actions, treatments and interventions can be implemented by focusing on data sources that tend to give unsatisfactory results [25], [32].

Another problem is also the weakness of the way of analyzing and interpreting the data. This is because the method used cannot be implemented efficiently and effectively [15], [13]. Constraints in analyzing and interpreting these data will lead to the result of not being able to explain the interrelationships between data sources, criteria and dimensions especially when involving multiple data orientations. Classroom assessment is based on human system theory, for example, learning activities are in the form of elucidation, decision-making, uncertainty, probability, big and also included in the quantitative and qualitative components [15], [31], [19], [38]. Therefore, evaluation methods and instruments, as well as analysis that can explain the influence, effect, weighting, ranking, predictive classification and so on, are very much needed. If the method can produce very meaningful mathematical and statistical figures it is even better.

As a way out of the problems discussed above, the implementation of a computational intelligence approach is the best option. Computational intelligence or also known as soft computing techniques [2], is used very widely covering various fields. Classified as an alternative assessment and among the methods in the computational intelligence approach used are fuzzy computing, neural networks, evolutionary computing, support vector machines, machine learning and probabilistic reasoning [2]. In this context, among the methods that are preferred and frequently used are fuzzy analytic (FA) and multi-criteria decision-making (MCDM) [38]. This method has also been varied and improved, and its use has also been integrated with several techniques so that more practical and efficient assessment and analysis can be implemented. This development has resulted in several more methods including Elimination and Choice Translating Reality (ELECTRE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Multiplicative Exponential Weighting (MEW), Simple Additive Weighting (SAW), Fuzzy Analytic Hierarchy Process (FAHP), Fuzzy Analytic Network Process (FANP), and Adaptive Neuro-Fuzzy Inference System (ANFIS) [2], [38], [33].

Therefore, computational intelligence approaches such as fuzzy analytics (FA) and multi-criteria decision-making (MCDM) methods are needed to ensure that classroom assessment can be implemented more effectively. In this context, the computational intelligence approach is highly significant because classroom assessment involves large, divergent, and unclear data, also related to psychology and behaviour [31]. In addition, data orientation in classroom assessment involves a variety of criteria and involves a selection and decision-making process. According to Muhammad and Cavus (2017),

most researchers choose MCDM to solve various problems in data collection and analysis that involve different criteria. [38] proved that understanding and managing quantitative and qualitative data using MCDM is easier and simpler when combined with FA.

However, due to a lack of information sources and lack of disclosure about such methods, this practice has not yet been fully utilized [15]; [2]. Educators and individuals involved with educational data, especially classroom assessments are less clear and do not know how to implement such analytical methods [21]; [11]. This problem is explained by [15] that is, most experts and researchers have suggested more practical and up-to-date alternative methods to implement classroom assessment, but what is practised and continued by the educator is conventional methods. There is a gap between the expert recommendation assessment methods and the assessment practised by the educator. Among the reasons for the gap is a lack of understanding and not knowing how to operate the FA and MCDM.

There is a need to disclose and articulate the contributions and ways in which FA and MCDM operate that can be utilized by those involved in classroom assessment. This initiative will provide more systematic knowledge, ideas and explanations so that the FA and MCDM methods can be implemented optimally. Therefore, the content of this article will unravel a systematic discussion of several past studies to provide and reveal a knowledge base of FA and MCDM contributions. In the next section, the researcher first provides brief information on the meaning and components of classroom assessment as well as the theory and basis of fuzzy sets and fuzzy logic. The next section will discuss the methodology for conducting a systematic literature review and tabulation of article search results. In the finding and discussion section, a meta-analysis of the contributions of FA and MCDM is presented and explains how it operates.

2. Theoretical Foundations

2.1. Classroom assessment

Classroom Assessment is used to identify students' weaknesses and strengths so that educators can provide academic support or specific interventions. According to Brown (1990), classroom assessment is a process that includes four basic components, measuring improvement over time, motivating students to study, evaluating the teaching methods and ranking the students' capabilities concerning the whole group evaluation. Classroom assessment can also be administered broadly either individually or in groups, including students, teachers, lecturers, district administrators, universities, private companies, education departments, and possibly even a combination of these individuals and groups. In the management of classroom assessment, it is usually the educators themselves who develop, administer and analyze the data, so they are more likely to apply the results of the assessment to strengthen their teaching. [15] asserts that classroom assessment management is conceived as a classroom context experienced by students as the educator establishes assessment purposes, assigns assessment tasks, sets performance criteria and standards, gives feedback, and monitors outcomes. Therefore, the credibility of classroom assessment is to be able to provide feedback on the effectiveness of educators' teaching and to be able to predict the status of students in the form of a measure of their progress. In this regard, Brown (1990), clearly states two strengths of the classroom assessment function namely, first, to indicate whether or not learning is successful, and second to explain educator expectations from the student's point of view.

[9] suggested that each educator should have his or her teaching methods and assessment methods specific to each student. In this regard, [32] argue, educators' preferences are provided through both test and non-test, generally in a numeric value, from which the final results are then converted into letters or linguistic values. This is because classroom assessment deals with the process of deciding on the quality or performance of student achievement in several competency standards. Thus, based on data orientation, the best analysis for classroom assessment is to use computational intelligence approaches such as Fuzzy Analytic (FA) and Multi-criteria Decision-making (MCDM) methods. Education is one of the sectors that is using computer technologies for training and delivering learning information to learners [41].

2.2. Fuzzy analytic and multi-criteria decision-making methods

Fuzzy analytic and multi-criteria decision-making methods are based on fuzzy sets and fuzzy logic theory. The fuzzy set theory was created in response to the need to have a mathematical representation of such kinds of

situations [30]. According to Tseng (2010), fuzzy set theory can express and handle vague or imprecise judgments mathematically. Fuzzy logic is an extension of classical Boolean logic that can use the concept of partial truth [38], was introduced by L.A. Zadeh, in 1965 as a decision-making tool to validate ambiguous and unclear issues, along with unreliable human decisions. According to [19], when statistical data deals with the ambiguity, uncertainty and vagueness of individual arbitration and valuation in the process of decision-making, then accurate mathematical analysis methods are needed. [38] also stressed that fuzzy analytic and multi-criteria decision-making methods are required when the decision-making process or the choice of some of the available alternatives and their ranking is based on several attributes that have different importance and that are expressed using different scales. This shows that data analysis in an evaluation adheres to the theory of fuzzy sets and fuzzy logic. Their role is significant when applied to complex phenomena not easily described by traditional mathematical methods when the goal is to find a good approximate solution. Fuzzy set and fuzzy logic have been applied to virtually all branches of science, engineering and socio-economic sciences [41], [33], [20].

In short, fuzzy analytic and multi-criteria decision-making methods are based on a mathematical fuzzy system that includes steps such as:

1. Fuzzification, determine all input values into fuzzy membership functions
2. Execute all applicable rules in the rule-base (if-then rule) to compute the fuzzy output functions
3. Defuzzification, converting output functions to get crisp output values

According to Zadeh (1965), let X U be a collection of objects, then, the fuzzy system $A \subset X$ is a set of ordered pairs $A = \{(x, \mu_A) ; x \in X\}$ is the classical set $A \subset U$, characterised by the function $\mu_A(x)$, which take value 1 or 0, indicating whether or not $x \in U$ is a member of A:

$$\mu_A(x) = \begin{cases} 1 & \text{for } x \in A \\ 0 & \text{for } x \notin A \end{cases} \quad \text{Eq (1)}$$

As a result, $\mu A(x) \in [0, 1]$. In equation (1), the function $\mu_A(x)$ only accepts one of two values: 1 or 0. Suppose that the function $\mu_A(x)$ has a range of values between [0, 1]. As a result, the concept of membership becomes fuzzier in the sense of representing partial belonging or a degree of membership [40]. R is defined as a fuzzy set by:

$$R = \{(x, \mu_R(x)) \; or \; x \in A, \; \mu_R(x) \in [1,0]\} \quad \text{Eq (2)}$$

where $\mu_R(x)$ is called a membership function; $\mu_R(x)$ specifies the grade or degree to which any element in A belongs to the fuzzy set R. The value of membership degree of x in A, express the degree to which x verifies the characteristic property of A. Thus, the nearer the value $\mu_A(x)$ to 1, the higher the membership degree of x in A [30].

In the fuzzification stage, the crisp values become fuzzy values and the membership functions are defined for the inputs and outputs. Among different kinds of membership functions such as triangular, trapezoidal, *Z*-shaped, Gaussian, sigmoidal, and *S*-shaped [40], [26], [30]. For the decision-making or inference engine, the linguistic rules, if-then, which are commands of the system behaviour are set up. These rules determine the relations between inputs and outputs. Accordingly, it takes minimum values for input fuzzy sets. Later the value obtained by the union of the fuzzy output set is found. At the last stage of defuzzification, fuzzy values are transformed into crisp values [41]. There are different types of defuzzification methods such as centroid, bisector, middle of maximum (MOM), smallest of maximum (SOM), and largest of maximum (LOM) [1], [26], [40].

3. Methodology

The present study's purpose is to capture the contribution of fuzzy and multi-criteria decision-making analytics to classroom assessment and conceptualize the operational design aspects of fuzzy and multi-criteria decision-making analytics in classroom assessment. Therefore, the research question was formed to achieve the objectives:

RQ1: *What is the contribution of fuzzy and decision-making analysis methods to classroom assessment?*

RQ2: *What are the operational designs for implementing fuzzy and decision-making analysis methods in classroom assessment?*

Next, the related articles and journals search is in two steps; i) looking for articles related to classroom assessment to identify the principles and operation of fuzzy and multi-criteria decision-making analytics, ii) searching for articles based on the implementation of fuzzy

and multi-criteria decision-making analytics to determine how is impacting and contributing to classroom assessment. Research articles are based on a search using two keywords, is fuzzy decision-making approach in classroom assessment, and computational fuzzy approach in classroom learning from the database of Google Scholar, ScienceDirect, and Elsevier. Of the two keywords, a total of 1129 articles were found in the first round.

In the next round, articles relevant to the area of study are chosen by first reviewing the abstract and, if meeting and relating, the journal contents are explored in considerable detail. Literature, data, findings, results, and discussion will be fully referred to. Based on the methodology of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) proposed by Moher et al. (2009), 21 articles are selected after going through the steps such as Identification, Screening, Eligibility and Included. The following table is an analysis of the implementation of fuzzy and multi-criteria decision-making analytics in classroom assessment.

Tab. 1. Analysis of assessments' aspects, impacts and operational design.

Author(s)	Research objective and method use	The aspect of assessment and impact(s)	Operational design
[1] Tseng (2010)	To proposes a hybrid approach: the ANP, DEMATEL and the fuzzy set theory to evaluate student performance Fuzzy analytic network process (FANP) DEMATEL	Student performance Assess student performance through four aspects and criteria as well as the dimensions of those aspects	Define the decision objectives Generate and establish evaluation objectives Determine aspects and criteria Assessing the performance rating of each aspect and its associated criteria
[2] Francesco Sgrò et al. (2010)	To define the student module of an experimental ITS implemented to obtain an objective assessment of physical activity education using neuro-fuzzy Neural network Fuzzy logic	Physical activity Develop a physical activity assessment system for the learning of physical skills	Development of a specific Neuro-Fuzzy Model samples Generated the training set for the network using the fuzzy rule and the parameters of the membership function propose Implement to software IMS LIP
[3] Voskoglou (2011)	To introduce principles of fuzzy sets theory and possibility theory to describe the process of mathematical modelling in the classroom Fuzzy set	Capacities of students' modelling of mathematics concepts Build quantitative instruments to see the process and mathematical modelling abilities of students	Administer the test with 10 maths problem-solving questions Build a rubric of the modelling process, student performance through linguistic labels (characteristics) Analyze profile, and student behaviour while answering
[4] Osman Yıldız et al. (2012)	To model the data of distance education and predict students' academic performance Fuzzy Logic Genetic Algorithm	Academic performance Predicting student academic performance only uses data in a short period	Specify fuzzy membership inputs criteria Processing in a fuzzy logic system Determine the population Apply genetic algorithm techniques Develop and evaluate the model
[5] Tosunoğlu (2018)	To investigates the effect of achievement in statistics on students' attitude toward statistics using the Adaptive Neuro-Fuzzy Inference System (ANFIS) Adaptive Neuro-Fuzzy Inference System (ANFIS)	Achievement in statistics Establish the model of attitude towards statistic Determine the students' attitude based on achievement	Administer attitude tests to students Use midterm test scores to assess achievement Analysis through ANFIS using Matlab software.
[6] Do & Chen (2013)	To investigate the predictive ability of two models: the hierarchical ANFIS and ANN Adaptive Neuro-Fuzzy Inference System (ANFIS) Artificial neural network (ANN)	Academic performance Discuss the potential of the hierarchical ANFIS model as a predictor Accurate prediction of student academic performance is of importance for making	Identifying input and output variables Doing pre-processed for the prediction model Range the input and output Development of the Hierarchical ANFIS Model Develop the ANN Model Evaluate model performance

		admission decisions as well as providing better educational services	
[7] Muhammad & Cavus (2017)	To suggest a fuzzy DEMATEL model to determine the interrelations between LMS evaluation criteria, their effects DEMATEL	Learning criteria The fuzzy DEMATEL method was chosen to find the relationships between the identified LMS evaluation criteria Discovering the connections among elements and requesting the criteria because of the kind of connections and seriousness of their consequences for the other criteria	Choose an expert Define the goal, and criteria, and construct the fuzzy scale Govern and get an expert opinion Build a fuzzy matrix Set up and determine cause and effect
[8] Jeong & Gonzalez-Gomez (2020)	To identify and analyse e-learning systems' the most essential criteria for sustainability science education using Fuzzy DEMATEL Fuzzy DEMATEL	Learning criteria Identifying and analyzing the most significant criteria of sustainable science e-learning education systems in a more long-term and life-long learning program	Choose the criteria and sub-criteria of F-DEMATEL Employed the F-DEMATEL technique to process the coefficients of criteria and sub-criteria worth Betrothed the fuzzy-logic arrangement to normalize and systematize the data Apply Pair-wise Comparison Matrix (PCM) along with the Consistency Ratio (CR) Matrix
[9] Sato-Ilic & Ilic (2013)	To exploit the latent classification structure of variables to the distance and propose a new dissimilarity and multidimensional scaling of learning activities Fuzzy c-means (FCM) Multidimensional Scaling (MDS)	Cooperative learning and collaborative learning (CL) activities- student collaborative homework assignments Propose a new dissimilarity of objects in high dimension and low sample-size data (HDLSS) including the classification structure of variables	Defining the following dissimilarity of objects (area study) Collecting data as log data indicating access time, a difference in students, devices, and details of actions over 8 months
[10] Gopal, Salim & Ayub (2020)	To evaluated the perceptions of learning statistics among students based on their attitudes towards statistics Fuzzy conjoint analysis	Statistics learning attitude Analyzing the rating attributes of attitudes to evaluate students' perceptions	Identify dimensions of attitudes Determine the attributes for each dimension Deciding the nature of perceptions (positive, neutral or negative) for an attribute based on the attribute's sentiment Ranking the attributes using FCA, based on the degree of similarity
[11] Volarić, Brajković & Sjekavica (2014)	FAHP and TOPSIS methods are proposed to be integrated for the selection of the best multimedia application for learning and teaching Fuzzy Analytic Hierarchy Process (FAHP) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	Multimedia application for learning and Teaching Determining the weights of each criterion and priority values of multimedia applications Select more suitable multimedia applications for learning	Showing and comparing criteria Make of overview of the criteria of the multimedia applications for learning Presenting fuzzy logic, fuzzy sets and fuzzy numbers method for determining the weight of criteria in MCDM problems Apply TOPSIS method for final ranking Selecting appropriate multimedia applications for learning and teaching
[12] Sarala & Kavitha (2015)	To develop a model for mathematics teaching and analyses the skill of teachers using fuzzy logic Fuzzy set	Mathematics teaching Modelling the teacher's performance during the teaching mathematics process based on ordinary, inspired, practical, innovative, and excellent characters.	Identifying dominant and distinctive views of how to teach mathematics Determine the characteristics of teaching mathematics Present fuzzy set and organise classroom experiment Modelling the teacher performance based on characters
[13] Stojanović et al. (2021)	To analyzing of pupils' knowledge in mathematics by adaptive neuro	Influence factors of pupil performance	Identify data set from the statistical and questionnaire surveys Present analysis by a statistical process

	fuzzy inference system (ANFIS) after implementation of distance learning application or e-learning Adaptive neuro-fuzzy inference system (ANFIS)	Reveal an information system for improving lectures and improving achievements in mathematics Explain the combination of prior knowledge and the use of educational software is most effective and motivates students for learning mathematics and present the best pupils' results.	in the MATLAB software based on the ANFIS system
[14] Crockett, Latham & Whitton (2017)	To propose a new method that uses fuzzy decision trees to build a series of fuzzy learning style predictive (FLSP) models using behaviour variables for the four dimensions of the Felder and Silverman Learning Styles model Fuzzy decision trees	Learning styles Proposes a new method that uses fuzzy decision trees to build a series of fuzzy predictive models	Identifying an overview of learning style (area of study) and methods used Present the architecture and describes the model Doing experimental studies and writing the report
[15] Chai, Tay & Lim (2015)	To propose a new fuzzy peer assessment methodology for the evaluation process in a cooperative learning environment Perceptual computing (Per-C) Fuzzy ranking algorithm	Cooperative learning A fuzzy peer assessment methodology can be deployed as an effective evaluation tool for cooperative learning of students	Present the definition Determine linguistic grades and their respective interpretations for learning activities and process rubrics Data collection by doing the case study Analysis and present the report
[16] Kwok et al. (2001)	To demonstrate that a fuzzy set collaborative assessment approach Implemented with a group support system (GSS) Fuzzy set	Collaborative learning Produce the method to assess student behaviour and outcome in a collaborative project	Brainstorming, voting and weighting the GSS collaborative activities Planning the methodology of assessment Apply the fuzzy set approach to evaluate learning outcomes
[17] Owusu-Agyeman et al. (2017)	To evaluates the effects of Continuing Professional Development Programmes (CPDP) on the conceptions of lecturers in the teaching and learning processes in a higher education setting Fuzzy Analytic Hierarchy Process (FAHP)	Teaching and learning processes Evaluate the impact of CPDP on conception changes in the teaching and learning processes of lecturers	Establish a hierarchy structure of assessment factors Organising hierarchy of decision elements into 3 levels, 14 factors, and 42 indicators Run the programme in terms of data gathering Present FAHP for analysis of data
[18] Sri Andayani et al. (2017)	To extend the concept of solving Multi-Criteria Decision Making (MCDM) problems under a linguistic environment, to solve the problems of learning competency evaluation 2-tuple fuzzy linguistic Fuzzy Analytic Network Process (FANP)	Student learning assessment Enrich the learning assessment techniques, by the exploitation of linguistic variables as representation preferences provide flexible space for teachers in the assessments Diagnose and estimate students' levels of each competency, students' mastery of each attribute and their progress in learning	Determining weights of learning competency Present the 2-tuple fuzzy linguistic approach and some aggregation operators Transforming numerical and determining the weight of learning competencies
[19] Hwang & Yang (2009)	To applies the fuzzy logic analysis of learner facial images when participating in class Fuzzy logic	Student attention A proposed effective system for detecting learner attentiveness in class	Designing Fuzzy membership function based on the regions of features, including the eyes and lips, feature movement and edge distance between features and the face Apply fuzzy rule Present simulation Analysis of data of all behaviours using fuzzy logic to prevent erroneous judgments of a single behaviour

[20] Ramli, Mohamad & Sulaiman (2010)	To evaluate the teaching performance using the fuzzy evaluation method Fuzzy Jaccard ranking index	Teaching performance Explain how to trim data to determine the teaching performance of lecturers Demonstrates intelligent assessment with an accurate and more reasonable decision approach to provide better prospects in the assessment of teaching performance	Identify criteria and sub-criteria Apply experimental study Analysis data using the fuzzy evaluation method Ratings and weighting of the assessment aspects
[21] Rouyendegh, Ergin & Salar (2011)	To determine a way in improving the creativity of the students in introductory engineering courses. Fuzzy Analytic Network Process (FANP)	Students' creativity Improving the creativity of the students in introductory engineering course Deciding the factor that ignites creativity	Administered a questionnaire Grouped considering the similarities between them by asking experts Determine the important order of the factors, the results are analyzed by using the fuzzy ANP method

Based on Table 1 above, shows the aspects of assessment in terms of operations and impacts on classroom management derived from research reports. Some of the methods contained in the classroom assessment have been found and the impact on teaching and learning management is also visible. A total of 21 articles are selected and meet the requirements of the study to be discussed. These articles clearly explain how fuzzy and multi-criteria decision-making analytics is operated and also report the effectiveness and impact of these practices.

4. Discussion

Based on the two stages of the objective of the review, the first step is to capture the contribution of fuzzy and multi-criteria decision-making analytics to classroom assessment and the second is to conceptualize the operational design aspects of fuzzy and multi-criteria decision-making analytics in classroom assessment, so on this part of the discussion will be implemented according to the stage and based on the following two research questions.

4.1. RQ1: What is the contribution of fuzzy and multi-criteria decision-making analytic methods to classroom assessment?

The first stage of studies can answer the question, namely fuzzy and multi-criteria decision-making analytic methods are very significant and contribute to classroom assessment. The management and implementation of classroom assessments will be more efficient and effective with the help of the computational intelligence approach. The following is a discussion of aspects of assessment, methods that can be used and forms of contribution and impact to educational management, especially on classroom governance.

Tab. 2. Meta-analysis of aspects, contributions and impacts of assessment based on FA and MCDM methods suggested

Aspect of assessment	Suggestion Method(s)	Contribution and Impact	References
Factor, Causal, Effect	i. Fuzzy Analytic Network Process (FANP) ii. DEMATEL iii. Fuzzy c-means (FCM) iv. Multidimensional Scaling (MDS) v. Adaptive neuro-fuzzy inference system (ANFIS)	i. Determining factors that influence students' performance, motivation, learning style and so on ii. Measuring more impactful factors, causes and effects iii. Predicting effects and causes of factors	Rouyendegh, Ergin & Salar (2011) Muhammad & Cavus (2017) Stojanović et al. (2021) Sato-Ilic & Ilic (2013)
Perception, Opinion	i. Fuzzy conjoint analysis (FCA) ii. Adaptive Neuro-Fuzzy Inference System	i. Get views, opinions and feedback ii. Determine the weighting or ranking of the measured features	Gopal, Salim & Ayub (2020) Chai, Tay & Lim (2015)

	(ANFIS) iii. Perceptual computing (Per-C) iv. Fuzzy ranking algorithm		Tosunoğlu (2018)
Method, Strategy, Model, Activity	i. Neural network ii. DEMATEL iii. Fuzzy Analytic Hierarchy Process (FAHP) iv. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) v. Fuzzy decision trees vi. Fuzzy ranking algorithm	i. Evaluate the applicability of methods, strategies and models ii. Calibrating the capabilities of a model or activity affects the factors being evaluated iii. Can be used as an analysis in experimental studies	Francesco Sgrò et al. (2010) Jeong & Gonzalez-Gomez (2020) Volarić, Brajković, and Sjekavica (2014) Crockett, Latham & Whitton (2017) Chai, Tay & Lim (2015)
Performance, Achievement	i. Fuzzy Analytic Network Process (FANP) ii. 2-tuple fuzzy linguistic iii. DEMATEL iv. Genetic Algorithm v. Adaptive Neuro-Fuzzy Inference System (ANFIS) vi. Artificial neural network (ANN) vii. Fuzzy Analytic Hierarchy Process (FAHP)	i. Aggregating students' performance, achievement or competencies ii. Seeing relationships or influences on performance and achievement iii. Predictors determine the strength of expectations for achievement	Tseng (2010), Osman Yıldız et al. (2012) Tosunoğlu (2018) Sri Andayani et al. (2017) Do & Chen (2013) Owusu-Agyeman et al. (2017)

Table 2 displays the aspects of assessment used in classroom assessment such as determining factors or effects, translating opinions or perceptions, determining the suitability of strategies, methods, models or activities and also determining or predicting performance and achievement. Alternative methods that can be applied here are based on FA and MCDM as listed by the researcher in Table 2 depending on the aspects and purpose of the assessment. In summary, the reports of these studies prove the contribution and effectiveness of FA and MCDM compared to the conventional methods commonly used by educators. This new knowledge is very meaningful to educators. If previously, conventional methods could not provide accurate analysis in determining the effectiveness of factors or finding the impact of a feature, then methods such as Fuzzy Analytic Network Process (FANP), DEMATEL, Fuzzy c-means (FCM), and Adaptive neuro-fuzzy inference system (ANFIS) can be used [28], [33], [31]. The impact analysis explains that FA and MCDM can meet the objective gap and the purpose of education assessment, where this method can be flexibly applied based on the objective of assessment implementation. Such methods can provide strengths and how those factors influence them. To obtain or collect opinions, views, suggestions or perceptions either from teachers, lecturers or students themselves, [11], [36] report on the effectiveness of methods such as Fuzzy conjoint analysis (FCA), ANFIS, Perceptual computing (Per-C), and Fuzzy ranking algorithm.

In evaluating or determining the effectiveness of a new method or strategy in teaching and learning or management model, Neural network analysis, DEMATEL, Fuzzy Analytic Hierarchy Process (FAHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Fuzzy decision trees, and Fuzzy ranking algorithm can be expected. Studies by [9], [19], [38], [7], [4] have reported the contribution of the method this method can specifically analyze the weaknesses if any and can provide solutions, for example, the TOPSIS method. In addition, one of the main purposes of classroom assessment is to determine student performance and achievement. If the method of analysis is inaccurate, then a true picture will not be obtained. So based on the highlights, [73], [36], [32], [8], [24] give the idea of

implementation of methods such as FANP, 2-tuple fuzzy linguistic, DEMATEL, Genetic Algorithms, ANFIS, Artificial neural network (ANN), and FAHP. These method options can also assess and analyze in more detail the relationship or strength of factors that tend to influence student performance or achievement.

The findings and discussion clearly show that FA and MCDM work efficiently based on the data source and data orientation, which conventional evaluation methods cannot be manipulated based on data source. Therefore, analysis management will also be more accurate and effective despite having diverse and fragmented data. But with wisdom and accurate formulation based on FA and MCDM, the results and what should be explained can be translated so perfectly.

In addition, several methods are seen as universal and can be used in various assessment purposes including fuzzy set and basic fuzzy logic as implemented by [21], [39], [17] and [30]. However, the development and modification of the basic method further increase efficiency and effectiveness. Researchers can conclude that methods such as ANFIS and DEMATEL are more universal and multi-purpose either to analyze the effects of factors, perceptions and evaluating models or strategies and can also be used in predicting performance and achievement.

4.2. RQ2: What is the operational design for implementing fuzzy and multi-criteria decision-making analytic methods in classroom assessment?

With knowledge of the role and contribution of fuzzy and multi-criteria decision-making analytic methods in classroom assessment, educators can determine options for implementing such methods following their respective objectives. Next, to answer the question of how this method operates, the researcher discusses presenting an appropriate and accurate operating framework based on the findings and disclosures in the 21 selected articles. This conceptual framework is more appropriately referred to as the intelligence model of classroom assessment.

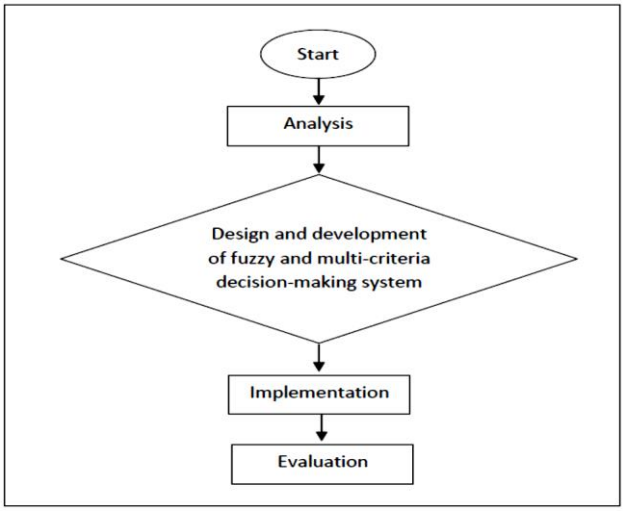

Fig. 1. Conceptual framework of operational design of FA and MCDM: Intelligence model of classroom assessment

4.2.1. Analysis

This is the first stage in operating. At this stage, educators need to perform analysis on several things as implemented by some researchers, such as determining the purpose and objectives of the assessment conducted [37], who to assess, what aspects will be tested [39], methods to be adopted [7], [38], time for management and administration [31] and including also early decision assumptions [7]. Turning back to the issue of data administration and orientation, the implementation of the analysis stage will make it easier for educators to manage assessments so that there is no conflict of purpose and methods used. in terms of time, educators can organize it more effectively, either formative or summative based on the original theory of classroom assessment as discussed by Brown (1990).

4.2.2. Design and development of fuzzy and multi-criteria decision-making system

The second stage is to design and develop an assessment system. After the decision to use any method in fuzzy and multi-criteria decision-making analytics, then the next step is to develop a system based on the formulation of the chosen method. This method includes three steps namely fuzzification, execution and defuzzification. However, there are certain specific steps based on the respective methods. It also depends on the aspects of the assessment and how to administer it, for example, if a questionnaire is required, then the development of a fuzzy questionnaire is one of the steps in the design and development of the system as implemented by, [28], [33]. Next, according to [11], [27], [30], [38], in the fuzzification step, among the processes performed are determining the criteria and sub-criteria or also called attributes based on the aspects to be assessed. Then, this step will be followed by a fuzzy mathematical process in more detail, which is to determine the triangular fuzzy number or fuzzy value based on membership functions [21], [17]. Membership functions are the premises that form the criteria and sub-criteria in the aspect of the assessment. Premises that were originally in the form of words (language) are converted into the form of mathematical numbers or called fuzzy values which in turn will become scales in the assessment. The next more executive mathematical calculation steps are to channel the fuzzy value so that it can be in the form of options, levels, weights, relationships, predictors or aggregates. It is these forms that will differentiate computational intelligence approaches whether fuzzy or multi-criteria decision-making analytics. After the data is obtained (assessment is administered), it can now be referred to as fuzzy data, next is to process the data in the defuzzification step to obtain the final result of the assessment [33], [24]. Upon completion of this stage, then conceptually an assessment model based on the formulation of a mathematical fuzzy system has been developed.

4.2.3. Implementation

This stage is the process of implementing and testing the constructed model. There are several ways to implement a smart assessment model, depending on the FA and MCDM methods that have been formulated and used. According to the implementation by [33], who used DEMATEL and ANFIS methods respectively, started by administering fuzzy questionnaires, and subsequently, the data were analyzed using the help of software such as Microsoft Excel, IMS LIP or Matlab based details of the mathematical formulation of the methods involved. [9] performed the assessment starting by collecting data, then the data was divided into two groups. The first group is labelled as training data and the second group is the actual data for the next analysis process. The training data set is a guide or way of introducing the model to the system, it is administered as testing or verifying the mathematical formulation, while the actual data set is the process of detailing the findings to the final result according to the orientation and purpose of the assessment. If the aspects of the assessment being tested are factors, causes or perceptions then results in the form of levels, weights or relationships are issued by the model. Whereas if the purpose is to evaluate the usability of the model, then the results in the form of predictions, rankings, weightings and so on can be calibrated.

4.2.4. Evaluation

It is the last stage, where the model being evaluated can either be used as an assessment model or requires a modification process. The level of usability or efficiency, as well as the way of operation, can be assessed based on the original purpose of the assessment.

Based on the framework above, researchers can explain how to manage and implement FA and MCDM wisely. The fuzzy concept contained in FA and MCDM forms a link between data sources and evaluation results with effective analytical formulations. Overall, the information contributed basic knowledge and an effective and simpler operating guide. This can reduce the knowledge and practicality gap in education assessment such as no relationship between objectives and results, the uncertainty of data sources and orientation, weak analysis and formulation methods and also the inefficiency of assessment management itself.

5. Conclusion

In this article, it is discussed that computational intelligence is the best solution to problems in the education system such as weaknesses in the management and analysis of classroom assessment. Integration between technology and soft computing techniques can further strengthen the management, practice and evaluation of the classroom. Many common

activities have been modified to be technology and internet-based. This is because, it can produce and improve methods, models, tools, and systems to be more practical, creative, innovative and efficient. A more dynamic assessment method that meets various measurement criteria allows the assessment of various aspects of classroom practice to be carried out more systematically, accurately and sustainably. In addition, the educator can also be benefited from the use of the FA and MCDM since the information on how to operate could help to improve both their teaching skills and the point of view of the subjects they teach.

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References

[1] Abdullah, M.L., Abdullah, W.S.W. & Md Tap, A.O. Fuzzy sets in the social sciences: An overview of related research. *Jurnal Teknologi*, Vol. 41, No. E, (2004), pp. 43-54.
Doi: 10.11113/jt.v41.726.

[2] Basaran, S. Multi-criteria decision analysis approaches for selecting and evaluating digital learning objects. *Procedia Computer Science*, Vol. 102, (2016), pp. 251-258.

[3] Brown, D. H. *Language assessment: Principles and classroom practices*. London: Longman, (1990).

[4] Chai, K. C., Tay, K. M., & Lim, C. P. A new fuzzy peer assessment methodology for cooperative learning of students. *Applied Soft Computing*, Vol. 32, (2015), pp. 468-480.
Doi: https://doi.org/10.1016/j.asoc.2015.03.056

[5] Chopra, S., Dhiman, G., Sharma, A., Shabaz, M., Shukla, P. & Mohit Arora Taxonomy of adaptive neuro-fuzzy inference system in modern engineering sciences. *Computational Intelligence and Neuroscience*, (2021).
Doi: https://doi.org/10.1155/2021/6455592

[6] Corrado Matta Neuroscience and educational practice: A critical assessment from the perspective of philosophy of science. *Educational Philosophy and Theory*, (2020), pp. 1-15.
Doi:https://doi.org/10.1080/00131857.2020.1773801

[7] Crockett, K., Latham, A., & Whitton, N. On predicting learning styles in conversational intelligent tutoring systems using fuzzy decision trees. *International Journal of Human-Computer Studies*, Vol. 97, (2017), pp. 98-115.
Doi:https://doi.org/10.1016/j.ijhcs.2016.08.005

[8] Do, Q.H. & Chen, J.F. A comparative study of hierarchical ANFIS and ANN in predicting student academic performance. *WSEAS Transactions on Information Science and Applications*, Vol. 12, No. 10, (2013), pp. 396-405.

[9] Francesco Sgrò, Mango, P., Pignato, S., Piccolo, A.L, Nicolosi, S., Schembri, R. & Lipoma, M. A neuro-fuzzy approach for student module of physical activity ITS. *Procedia Social and Behavioral Sciences*, Vol. 9, (2010), pp. 189-193.
Doi: 10.1016/j.sbspro.2010.12.134.

[10] Gentili, P.L. Establishing a new link between fuzzy logic, neuroscience, and quantum mechanics through bayesian probability: Perspectives in artificial intelligence and unconventional computing. *Molecules*, Vol. 26, No. 5987, (2021).
https://doi.org/10.3390/molecules26195987

[11] Gopal, K., Salim, N.R. & Ayub, A. F. M. Malaysian undergraduates' perceptions of learning statistics: study on attitudes towards statistics using fuzzy conjoint analysis. *ASM Science Journal*, Vol. 13, (2020), pp. 1-7.
https://doi.org/10.32802/asmscj.2020.sm26(2.15)

[12] Gruppen, L. D., & Fogarasi, M. C. Considerations on conducting research on wellness in the context of the learning environment. *Global Advances in Health and Medicine*, Vol. 10, (2021), pp. 1-9.

https://doi.org/10.1177/2164956121989708

[13] Haghighi, S. M. & Haghighi, S. M. Sustainability Risk Framework for Universities in the Context of Covid-19 Pandemic. *International Journal of Industrial Engineering & Production Research*, Vol. 33, No. 2, (2022), pp. 1-13.
Doi: 10.22068/ijiepr.33.2.6

[14] Hesami, M., Naderi, R., Tohidfar, M. & Yoosefzadeh-Najafabadi, M. Application of adaptive neuro-fuzzy inference system-non-dominated sorting genetic algorithm-ii (ANFIS-NSGAII) for modeling and optimizing somatic embryogenesis of chrysanthemum. *Front. Plant Sci*. Vol. 10, (2019), pp. 1-12.
Doi: 10.3389/fpls.2019.00869

[15] Hussain Alkharusi Effects of classroom assessment practices on students' achievement goals. *Educational Assessment*, Vol. 13, No. 4, (2008), pp. 243-266.
https://doi.org/10.1080/10627190802602509

[16] Hwang, G. J., Sung, H.Y., Chang, S.C. & Huang, X.C. A fuzzy expert system-based adaptive learning approach to improving students' learning performances by considering affective and cognitive factors. *Computers and Education: Artificial Intelligence*, Vol. 1, (2020), p. 100003.
https://doi.org/10.1016/j.caeai.2020.100003

[17] Hwang, K. A. & Yang, C.H. Attentiveness assessment in learning based on fuzzy logic analysis. *Expert Systems with Applications*, Vol. 36, (2009), pp. 6261-6265.
Doi: 10.1016/j.eswa.2008.07.025.

[18] Jayaswal, M.K., Mittal, M. & Sangal, I. Learning effect on inventory model in fuzzy environment with trade- credit financing. *Revista Investigicion Operacional*, Vol. 41, No. 6, (2020), pp. 854-871.

[19] Jeong, J.S. & Gonzalez-Gomez, D. Assessment of sustainability science education criteria in online-learning through fuzzy-operational and multi-decision analysis and professional survey. *Heliyon*, Vol. 6, (2020), pp. 1-11.
https://doi.org/10.1016/j.heliyon.2020.e04706

[20] Khezeli M, Najafi E, Haji Molana M, Seidi M. A. Mathematical Model for Sustainable and Resilient Supply Chain by Considering Synchronization in the Production and Distribution Network. *IJIEPR*. Vol. 33, No. 2, (2022), pp. 1-34.
http://dx.doi.org/10.22068/ijiepr.33.2.1

[21] Kwok, R. C. W., Ma, J., Vogel, D., & Zhou, D. Collaborative assessment in education: An application of a fuzzy GSS. *Information & Management*, Vol. 39, No. 3, (2001), pp. 243-253.
https://doi.org/10.1016/S0378-7206(01)00093-3

[22] Mourhir, A. Scoping review of the potentials of fuzzy cognitive maps as a modelling approach for integrated environmental assessment and management. *Environmental Modelling and Software*, Vol. 135, (2021), p. 104891.
https://doi.org/10.1016/j.envsoft.2020.104891

[23] Naresh, C., Bose, P. S. C. & Rao, C. S. P. Artificial neural networks and adaptive neuro‐fuzzy models for predicting WEDM machining responses of Nitinol alloy: Comparative study. *SN Applied Sciences*, Vol. 2, No. 314, (2020).
https://doi.org/10.1007/s42452-020-2083-y

[24] Owusu-Agyeman, Y., Larbi-Siaw, O., Brenya, B. & Anyidoho, A. An embedded fuzzy analytic hierarchy process for evaluating lecturers' conceptions of teaching and learning. *Studies in Educational Evaluation*, Vol. 55, (2017), pp. 46-57.
http://dx.doi.org/10.1016/j.stueduc.2017.07.001

[25] Pluck, G., Bravo Mancero, P., Ortiz Encalada, P. A., Urquizo Alcivar, A. M., Maldonado Gavilanez, C. E. & Chacon, P.

Differential associations of neurobehavioral traits and cognitive ability to academic achievement in higher education. *Trends Neurosci Educ*, Vol. 18, (2020), pp. 1-11.

[26] Ramli, N., Abdullah, N.H.M., Ujang, S., Mohamed, N. & Mohamed, R. An integrated fuzzy approach for evaluating mathematics mobile application. *ASM Sc. J.*, Vol. 14, No. 1, (2021), pp. 1-9

[27] Ramli, N., Mohamad, D. & Sulaiman, N.H. Evaluation of teaching performance with outliers data using fuzzy approach. *Procedia Social and Behavioral Sciences*, Vol. 8, (2010), pp. 190-197.
Doi: 10.1016/j.sbspro.2010.12.026.

[28] Rouyendegh, B.D., Ergin, M.H. & Salar, M. Improving the creativity in introductory engineering course applying fuzzy network process: A pilot study. *Procedia-Social and Behavioral Sciences*, Vol. 28, (2011), pp. 139-143.
Doi: 10.1016/j.sbspro.2011.11.028.

[29] Şahiner, A., Akbay, R., & Yılmaz, N. Fuzzy logic modeling and optimization of academic achievement of students. YILDIZ *Journal of Educational Research*, Vol. 4, No. 1, (2019), pp. 85-100.

[30] Sarala, N. & Kavitha, R. Model of mathematics teaching: A fuzzy set approach. *IOSR Journal of Mathematics*, Vol. 11, No. 1-1, (2015), pp. 19-22.
Doi: 10.9790/5728-11111922

[31] Sato-Ilic, M. & Ilic, P. Fuzzy dissimilarity based multidimensional scaling and its application to collaborative learning data. *Procedia Computer Science*, Vol. 20, (2013), pp. 490-495.

[32] Sri Andayani, Sri Hartati, Wardoyo, R. & Mardapi, D. Decision-making model for student assessment by unifying numerical and linguistic data. *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 7, No. 1, (2017), pp. 363-373.
Doi: 10.11591/ijece.v7i1.pp363-373

[33] Stojanović, J., Petkovic, D., Alarifi, I. M., Cao, Y., Denic, N., Ilic, J., Milickovic, M. Application of distance learning in mathematics through adaptive neuro-fuzzy learning method. *Computers & Electrical Engineering*, Vol. 93, (2021), p. 107270.
Doi:https://doi.org/10.1016/j.compeleceng.2021.107270

[34] Talpur, N., Salleh, M.N.M. & Hussain, K. An investigation of membership functions on performance of ANFIS for solving classification problems. *IOP Conf. Series: Materials Science and Engineering*, Vol. 226, (2017), p. 012103.
Doi:10.1088/1757-899X/226/1/012103

[35] Tang, W.L., Tsai, J.T & Chen, Y.M. Fuzzy logic and Gagne´ learning hierarchy for assessing mathematics skills. *Science Progress*, Vol. 104, No. S1, (2021), pp. 1-21.
Doi: 10.1177/00368504211014346.

[36] Tosunoğlu, N. Adaptive neuro-fuzzy inference system (anfis) approach for modelling the effect of achievement in statistics to students' attitudes toward statistics. *Cappadocia Academic Review*, Vol. 1, No. 2, (2018), pp. 38-53.

[37] Tseng, M.L. Implementation and performance evaluation using the fuzzy network balanced scorecard. *Computers & Education*, Vol. 55, (2010), pp. 188-201.
Doi: 10.1016/j.compedu.2010.01.004

[38] Volarić, T., Brajković, E. & Sjekavica, T. Integration of FAHP and TOPSIS methods for the selection of appropriate multimedia application for learning and teaching. *International Journal of Mathematical Models and Methods in Applied Sciences*, Vol. 8, (2014), pp. 224-232.

[39] Voskoglou, M. Measuring students modeling capacities: a fuzzy approach. *Iranian Journal of Fuzzy Systems*, Vol. 8, No. 3, (2011), pp. 23-33.

[40] Voskoglou, M. Fuzzy Logic as a Tool for Assessing Students' Knowledge and

Skills. *Educ. Sci*, Vol. 3, (2013), pp. 208-221.
Doi:10.3390/educsci3020208

[41] Wulandari, F., Hadi, S. & Haryanto Computer-based adaptive test development using fuzzy item response theory to estimate student ability. *Computer Science and Information Technology*, Vol. 8, No. 3, (2020), pp. 66-73.
Doi: 10.13189/csit.2020.080302.

[42] Yadav, R.S., Soni, A.K. & Pal, S. Modeling academic performance evaluation using hybrid fuzzy clustering techniques. *Australian Journal of Basic and Applied Sciences*, Vol. 8, No. 3, (2014), pp. 98-111.

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