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A view of MCDM application in education

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Abstract. The effectiveness of the teaching and learning process by educators plays a significant role for countries to prepare students' potential in the forthcoming new industrial revolution (IR). However, the current COVID-19 pandemic and dynamic changes in the curriculum have created a significant shift of emphasis to educators. Hence, the teaching and learning process problems nowadays, including selecting appropriate effectiveness learning, have become a tough decision for educators. It can be solved using multi-criteria decision-making (MCDM) methods. The MCDM technique is widely applied and accepted in various fields but less in the teaching and learning context. This paper reviews and analyses the type of decision problems that were paid most attention to MCDM approaches, the adopted fuzzy set theory as well as inadequacies of those approaches. The purpose is to analyse and identify the literature review related to the applications of MCDM in education so new attributes and appropriate MCDM models for decision making can be suggested. The process involved comparing and analysing the MCDM application and fuzzy set theory in education by reviewing related articles in international scientific journals and well-known international conferences. Some improvements and more future works are recommended based on the inadequacies. The reviewed result may create an interest to the Ministry of Education (MoE) as it proposes teaching and learning process improvement, which will help to achieve greater satisfaction among educators and students.

1. Introduction

Empowering the development of human intellectual capital is the main ingredient of prosperous nations. The more production of human intellectual capital in a nation, the more viable the country is. The quality of human intellectual capital of a country must include developing skills such as inquiry, exploration, invention, reflection of interest, communicative and collaborative skills among students. Thus, a nation may attract the immigration of skilled personnel or allocate more resources to the education sector. In Malaysia, STEM (Science, Technology, Engineering, Mathematics) education have been developed in the education system to achieve such goal. Comparatively, recent research underlines the importance of STEM implementation at the early stage of education (preschool to secondary level) as it found to be more beneficial to prepare the students in facing 21st century than tertiary education since it is a long- term process [1].

Hence, educators play a prominent role in achieving this and driving the nation's economic development. One of the challenges in this modern education is imparting knowledge in STEM



education to a student who has a various capacity to accept the learning rates. Educators are expected to deliver the knowledge that allows students to master and apply the concept of STEM in daily life that meets future STEM jobs. Multiple strategies have been encouraged to be implemented in the classroom that make students to be actively involved in learning activities and increased the students' motivation and creativity [2]. Currently, STEM approaches in 21st-century teaching and learning such as blended learning, e-learning, and scientific inquiry-based learning have become the keys to effective and meaningful learning [3]. However, not all educators are exposed to STEM approaches and have the knowledge of appropriate STEM implementation. The time-consuming and available resources on the internet may make educators more confused in selecting the appropriate approach to carry out the learning activities.

Improper appropriate learning and teaching style may expose the students to situations and real-world problems that require a solution. Thus, statistics from the Ministry of Education states that the percentage of students pursuing the STEM field decreases to 42 percent in 2018 [4]. This result can also lead to the failure of students' performance in cultivating 21st-century skills. Thus, the efficiency development of human intellectual capital, and the aspiration of Ministry of Education have affected adversely.

In order to address effective teaching and learning, different strategies have been used in the literature, but only a few literatures have been used in mathematical modelling. Due to its vast applications in various fields, such as evaluating students' and teachers' performance and learning processes, decision-making theory has been the topic of significant study activity in recent decades [2]. The decision-making theory approach has become an important tool for giving real-time answers to uncertainty problems, particularly those involving human cognitive capability, which is pertinent to educational concerns. Multi-criteria decision-making is one of the most popular decision-making strategies.

Multiple criteria decision-making (MCDM) is a popular method used in different areas of education, primarily in tertiary education. MCDM approaches have been used in several previous studies in many areas of education [5], [6], and [7]. In addition, some prior publication [8], [9], [10], and [11] have reviewed the application of MCDM and fuzzy theory in several areas of education. MCDM provides a systematic methodology that simultaneously gives a definite decision when the best alternative selection and the perspectives of decision-makers in selecting an optimum alternative from a list of alternatives become exceedingly complex in the decision-making process. Mardani et al. [12] looked through 393 articles about MCDM and its applications that were published from 2000 to 2014. However, only a few focused on the application of MCDM in education.

The primary goal of this study is to review the literature on the application of MCDM approaches in the educational sector. Another goal is to analyse various decision problems while focusing on MCDM approaches and fuzzy set theory adopted. Then, new attributes and appropriate MCDM models for decision-making will address the teaching and learning process issues. Furthermore, this review may be beneficial for further studies in many fields of education as it demonstrates how MCDM methods can be the applied for decision-making processes in education. This paper present unique and exciting information for all participants in MCDM processes of education. In addition, this paper, to the authors' knowledge, is the first review of the literature in STEM education from the perspective of the MCDM methods application.

This paper is organised as follows. Section 2 presents the review methodology, including the databases and searching criteria used to find the relevant journal articles. In Section 3, a brief description of different MCDM methods is indicated. Meanwhile, Section 4 analyses the review results and finds out the research trends in the past five years. Section 5 discusses the improvement of approaches proposed by previous researchers and suggests new attributes in the research issue for future work. Finally, the conclusion of this paper is in Section 6.

2. Methodology

In this paper, the literature investigates applying MCDM methods in education by reviewing previous work done by researchers. The international journal articles and conferences classified within 2015 and 2020 were included. The primary purpose for sorting out articles within this period was to find the recent research issue relating to MCDM. Therefore, IEEE Xplore, ScienceDirect, and Google Scholar were utilized because these are known for its large and comprehensive databases. The authors filtered the title, abstract, and keywords fields in each of the above databases rather than the full-text paper to ensure the selected journal paper were relevant. In addition to the query “education”, keywords such as Secondary and Tertiary Education, Multi-Criteria Decision Making (MCDM), Fuzzy MCDM, Evaluation Performances, and Teaching and Learning Process, considered relevant, were also searched simultaneously. After filtering, only 32 journal articles and conferences met the criteria and studied the related research issue and techniques. On the other hand, there were many limitations to the search methodology. One significant limitation was the availability of the papers to the authors.

2.1 MCDM methods

MCDM was introduced in the early 1970s and has become the fastest growing methods in many different applications to structure information and evaluate everyday problems with multiple, conflicting, and non - commensurable goals. MCDM method helps one to choose the alternative from various criteria by analyzing the scope of the criteria, weighting criteria, and choosing the optimal results using multi-criteria decision-making techniques [13]. The technique is a well-known tool for solving complex real-life problems due to its intrinsic ability to judge diverse alternatives regarding various decision criteria. Some of the popular MCDM techniques utilized for solving decision problem are Analytic Hierarchy Model (AHP), Analytic Network Process (ANP), preference relation, Elimination, and Choice Expressing Reality (ELECTRE), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETEE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting Method (SAW), multidisciplinary optimization compromise solution (VIKOR), and Decision Making Trial and Evaluation Laboratory (DEMATEL). In recent years, most stakeholders combined two or three MCDM techniques, known as hybrid, and integrated it with the fuzzy theory to meet the limited MCDM technique for more reliable results. Table 1 demonstrates the summary of famous MCDM tools, which indicate the function and inventor, year of invention, capabilities, and drawbacks.

Table 1. Summary of the MCDM method [14], [15], [16], [17], [18], [19],[20], [21], [22], [23].

No	MCDM Method	Function	Proposed by/Year	Capabilities	Drawbacks
1.	Weighted Sum Model (WSM)	The best value of weighted sum is the optimal solution. Beneficial criteria as maximum value. Non-beneficial criteriaas minimum value	L. A. Zadeh: 1963	Use simple Mathematical Calculations	It is only suitable problem that have the same type criteria only which either beneficial or non-beneficial.
2.	Weighted Product Model (WPM)	Similar to the WSM but multiplication operation performed in WPM	Bridgeman: 1922	The implementation is simple and can be used without software	Easy applicable in the type of criteria is same unit
3.	Analytic Hierarchy Process (AHP)	The optimal solution based on the most importance criteria and alternatives	Thomas Saaty: 1970	No bias in decision making	The approach become complicated when criteria and alternative are increase

4.	Data Envelopment Analysis (DEA)	The optimal solution obtains by measuring the relative efficiencies against criteria and alternative.	Thanassoulis, Kortelainen, and Allen, 2012	Capable of handling multiple criteria and alternative	The criteria and alternative are known
5.	Analytic Network Process (ANP)	Similar to AHP but optimal solution by concerning network structure in criteria and alternative	(Saaty T. T., 1986)	Allow dependence and include independence among criteria and alternative	Time consuming, complexity in calculation
6.	ELimination and Choice Translating REality (ELECTRE)	Develop solution based on outranking method by concordance analysis. Have extension to ELECTRE I and II.	Benayoun Roy: 1968	Solution can be made even having incomplete data	In operation, sometimes unable to identify the preferred alternative
7.	VIKOR (Multicriteria Optimization and Compromise Solution)	The technique determines the solution by ranking and selecting from a set of alternatives in the presence of conflicting criteria.	S. Opricovic: 1990	The approach is extension variety to the TOPSIS	The calculation must be complex due to presence of conflicting criteria.
8.	Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)	Optimal decision based on evaluates the optimum alternative by applying distances to positive and negative solution.	S. Opricovic: 1990	The approach is straightforward and regardless of the number of decision criteria and alternative, the solution procedure remains the same	Its use of Euclidean Distance does not consider the correlation of criteria and alternatives
9.	Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)	The optimal solution obtains based on comparison pair per pair of possible decisions along each criterion.	J. P. Brans and P. Vicke: 1982	No requirement assumption that shows the criteria are proportionate	In operation, no clear method is providing to assign weights of criteria.
10.	Best Worst Method (BWM)	The optimum weight of the criteria for solution is obtained, by formulating max-min problem.	Rezaei, 2015	Require less data and easy to use due to the less of computation dan pairwise comparisons	Too simple calculation in obtained criteria and sub criteria
11.	Case Based Reasoning (CBR)	Propose ideal decision-making solution based on the most similar cases which retrieves cases similar to a problem from an existing database of cases	Li and Sun, 2008	The operation requires little maintenance which database already exist and can improve over time.	Sensitivity to inconsistency in data
12.	MAUT (Multi Attribute Utility Theory)	This methodology provide a method for systematic trade-off among decision criteria in order to select the best alternative from the set of alternative	P.C. Fishburn: 1965, R.L. Keeney: 1969, H.R. Raiffa: 1969	At each stage of method, incorporate the preferences of each consequence	Preferences of the decision makers need to be precise (subjective)

13.	DEMATEL (DEcision-Making Trial and Evaluation Laboratory)	Matrixes or digraphs can be used to visualise the structure of complex causal interactions.	Geneva Research Centre of the Battelle Memorial Institute	Analyse the cause-and-effect relationships	Interdependence among factors
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3. Application of MCDM methods in education – a review

Application of MCDM methods in education, more specifically in the educational system are reviewed. This task is a little bit challenging because decision-making process in the literature involves limited interest and less conflicting decision criteria. Thus, in the literature, suitable specific application in education employed MCDM methods such as AHP, DEMATEL, and TOPSIS has been reported. The tools were used both separately and in combination to solve the decision problems. The detailed reviewed literature elaborated below are subjected to the AHP, DEMATEL, and TOPSIS as the many articles that appeared among other MCDM method.

3.1 Analytical Hierarchy Process (AHP) method

The application of the AHP method in education is quite extensive compare to other MCDM techniques. Five out of 13 journal articles are consisted of AHP only, without combining other MCDM techniques, to address the educational problems reported in the literature. Naveed [7], one of the examples, designed an AHP method to evaluate critical success factors that define multiple criteria such as design contents and system technologies to implement an e-learning system. At the same time, Yadegaridehkordi [24] utilised the AHP technique to identify the key factors influencing user adoption of cloud-based collaborative learning technology. Four criteria; performance and effort expectancy, social influence, facilitating condition, were considered, and the best alternative by the authors for decision criteria were selected. The AHP method was chosen by the authors in [24] because make analysing quantitative and qualitative data in the decision-making process relatively simple.

Five of the articles utilized a combination of MCDM methods, either two or three combination methods, adopted the fuzzy theory. For example, Myint and Thein [25] applied AHP and SAW methods to support decision-makers of Myanmar education sectors in estimating and analysing the regional education development levels. The authors of [25] considered the following decision criteria; school's profile, teaching quality, infrastructure quality, school's facility, school's staff as a basis of choosing the right developed school in one of the districts in Myanmar. The result showed that their applied method was tolerable and allowable by the combination of AHP and SAW. Besides, Tuan [26] applied fuzzy AHP and intuitionistic (INS) TOPSIS to evaluate lecturers' research productivity to identify lecturer performance [26]. The authors in [26] applied the AHP method because past researchers have used the method to solve teacher performance problems in different fields.

Some researchers adopted only fuzzy set theory in the AHP method. This methodology becomes more common in the education field when the decision problem involved the natural language. Kustiyahningsih [27] employed fuzzy AHP and COPRAS for new students admission in Indonesia religious secondary school. [27] provided eight multi-criteria, including prayer reading, prayer movements, fluency in reading Al- Quran, Maharaj, recitation, shohih writing Al- Quran, neatness of Al-Quran writing, and the average value of report cards to select the suitable students. The authors of [27] considered applying Fuzzy AHP as it provides more accuracy in weighting the criteria compared to AHP itself. Some authors such as [28], [6], and [29] constructed new linguistics scales, but others implied Saaty's scales in the fuzzy set theory in this method.

Generally, according to Saaty [30] AHP is a method for organising ill-structured multi-attribute problems that consists of three primary operations: hierarchy construction, priority analysis, and consistency verification. Most researchers approached this strategy by defining it as the multiple complex criteria decision problem where the possible alternative is arranged using hierarchical

levels. Then, using a pairwise comparison matrix they compared the decision maker's judgment in each alternative at the same level. The majority of the literature mentions these two steps. The consistency measurement of the pairwise comparison of the alternatives is one of the grounds for using the methodology, as it helps to minimise decision-makers' inconsistency.

3.2 *Decision-Making Trial and Evaluation Laboratory (DEMATEL)*

Application in DEMATEL technique is the second higher applied in the reviewed literature with eight articles. Majority of the method applied were integrated either with the fuzzy set theory or hybrid with two or more MCDM methods. Yang [31] applied the DEMATEL based on the analytic network process (DANP) method to establish the model of E-Learning service quality. The authors used the DEMATEL to confirm each criterion's effect and explore the relevance of the various connection service parameters. Subsequently, the DANP was used to calculate the influential weights of each criterion. This method was used to develop a complete decision model by displaying the direct/indirect influential relationships. At the same time, Permadi [32] integrated the DEMATEL and ANP by evaluating lecturer learning material to students. The authors of [32] considered conformity of material, competency conformity, presentation format, and personalization as the crucial criteria to carry out in the methodology operation. This method evaluates learning materials to provide suitable learning materials based on the right factors or criteria. Jeong and Gomez [9] applied the fuzzy DEMATEL method to identify and analyse e-learning systems by characterising the essential criteria such as sustainability and e-learning and technology for sustainable science education. Although the use of the method was not stated, the authors could visualize the interrelationships between criteria. Jeong and Gómez [8] in other papers, adopted the same method by classified and ranked the criteria and sub-criteria for mathematics education in the sustainable development of the teaching of flipped e-learning to adapts to Pre-Service Teachers' pedagogical changes. The authors characterized the same criteria but applied it in a different context. One of the method's advantages is that the criteria and alternative prioritization are based on the types of relationships. Their interdependencies quickly suggest the most relevant criteria that influence other criteria without voluminous information.

3.3 *Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method*

The TOPSIS methodology to analyse the problem of the educational system has been reported in the literature. The report in this paper indicates the use of the conventional TOPSIS method and the enhanced versions. In students' learning performance, Kazan [33] applied the TOPSIS method to present success performances of schools whilst relying on subject names as decision criteria such as Turkish, Mathematics, and Science and Technology. However, the authors of [33] did not state the reason for utilising the TOPSIS method in the decision-making process. Koltharkar [34] prioritized the requirements of students in the case of the techno- managerial institute, taking into consideration two alternatives, actual performance and importance were determined by TOPSIS concerning eight decision criteria. Husam [35] applied hybrid TOPSIS, the AHP- TOPSIS approach, for ranking the most suitable e-learning type. Alternatives such as blended learning and flipped classroom were ranked according to decision criteria such as specific ICT infrastructure and basic ICT infrastructure for e-learning. The motivation for selecting the fuzzy TOPSIS method was based on the relative importance analysis of the criteria and aggregated each e-learning approach's overall performance. Paunović [11] applied the Fuzzy TOPSIS technique to achieve more efficient educational processes by evaluating the Learning Management Systems (LMSs). They applied several decision criteria such as functionality, price, and user support in determining the essential tools. Although the reasons for choosing the TOPSIS method was not stated, the authors in [11] indicated that they combined fuzzy set theory with it to address the uncertainty involved in the decision-making process. The most common reason for using TOPSIS in the methodology was to consider distances as an ideal solution by demonstrating the efficiency of solving the decision problem and its value.

3.4 Others method

According to the literature, the application of MCDM method in the educational system is limited to PROMETHEE, MACBETH, Weighted distance-based approximation, fuzzy COPRAS, PAPRIKA, and ANN-WSM. The MCDM has appeared in one article where the author constructed the MCDM method by adopting several step-in methodology approaches. The remainder were applied either by combining the other MCDM or adopting fuzzy theory or using the method itself. This paper did not consider the detailed review of other MCDM. The summary of various MCDM methods application in the educational system is shown in table 2.

Table 2. Summary of application of MCDM method in education.

Author	Objective	Criteria	MCDM method	Application of area
[34]	Prioritize the requirements of students in the case of techno- managerial institute.	Students, faculty, staff, employers, government and society	Fuzzy TOPSIS	Tertiary Education-students requirement
[27]	Determine the admission of new students	Prayer reading, prayer movements, reading fluency, Al- Quran, makhraj, recitation, shohih writing Al-Quran, the neatness of Al-Quran writing, and the average value of report cards	Fuzzy AHP and COPRAS	Secondary Education-Students requirement
[36]	Evaluation decision matrix (DM) in young students' using English mobile applications (E-apps)	Learning and speaking Reading Writing	BWM and TOPSIS	Preschool education-Learning tools
[37]	New framework in assessing the rank of English skills for pre-service teachers	Learning and speaking Reading Writing	Fuzzy Delphi Method and TOPSIS	Secondary Education-Learning Skill
[38]	Selecting teacher model by eliminate subjective factors in	Pedagogical Professionalism Social, Personality, Achievement Discipline	PROMETHEE	Secondary Education-Learning Skill
[39]	The influence of barriers on the teaching-learning process (E- Learning)	Student and Instructor, Infrastructure, Technology and Institutional Management.	Fuzzy AHP	Tertiary Education-Learning skill
[24]	To identify the factors that influence user adoption on cloud-based collaborative in learning technology	Performance and Effort expectancy, Social Influence, and Facility condition	Fuzzy AHP	Tertiary Education-Learning approach
[33]	To present successful performances of schools	Various of subject in turkish education.	TOPSIS	Secondary Education-Learning performance
[40]	Identify Learning Management System (LMS) evaluation criteria in e-learning	Accessibility Evaluation Tools Multilingual Portability Security Support Sustainability User satisfies	Fuzzy DEMANTEL	Tertiary Education-Learning tools

[41]	To rank and selection of the E- learning websites	Functionality, maintainability, reliability, usability learning community, personalization, system, content	Fuzzy AHP and PIV(Proximity Indexed Value)	Tertiary Education- Learning tools
[42]	Assist educators in choosing from the numerous multimedia options	Working Environment Students Participation Retention Rate Material Factors Technology Competencies	MACBETH	Tertiary Education- Learning tools
[28]	To evaluate Student Performance Task in Chemistry assessment (case study)	Ability in presenting descriptive information, physical properties, chemical properties, exploratory information Ability in demonstrating its position in periodic system Ability in explaining its uses in daily life and basic use of area in industry Ability in giving explanations about the effects on human health and environment Ability to set the objective and up-to-date information Ability in making a study plan applicable to performance Ability to identify the necessary resources And 10 more criteria evaluation	AHP-TOPSIS	Secondary education – Learning Performance
[43]	Develop performance evaluation and the strategic objectives of the higher education institution	Final Students Internal Process Learning Growth	FDEMATEL and ANP	Tertiary Education - Learning performance
[44]	Assessment of physical education teaching quality among five college	Five colleges in India	Intuitionistic fuzzy information measure and weighted averaging operator (IPWAO) and TOPS	Tertiary Education - Learning Quality
[11]	Evaluate of the Learning Management Systems (LMSs) as an important tool in achieving more efficient educational processes	Functionality, Price, User Support, Usability and Evaluation tools	Fuzzy TOPSIS	Tertiary Education – learning tools
[45]	To assess in selection and rank the E- learning website	Understandable content Complete content Personalization Security and Navigation Interactivities User interface	weighted distance-based approximation (WDBA)	Tertiary Education – E-learning

[46]	Evaluation of Teacher Quality for certified teachers sustainably	Pedagogic Personality Social Professional Innovation development Utility of technology	AHP	Secondary education-Learning Quality
[10]	Provide decision support to leaders in analyzing and managing the e-learning system effectively	Functionality, maintainability, usability, portability, reliability, efficiency, ease of learning, community,	Fuzzy COPRAS	Tertiary Education – E-learning
[7]	Evaluate critical success factors in implementing E-learning system	Students’ Instructors’ Design and Contents’ System and Technological Institutional Management	AHP and Fuzzy AHP	Tertiary Education – E-learning
[47]	Investigate various aspects of flipped technology in exploring flipped classroom model efficiency	Teaching Aids Effectiveness Working Environment Teaching Techniques Learning Flexibility Student Participation Potential for adaptation Time and Material factors Technological competence	PAPRIKA	Secondary education-Active Learning
[31]	Establish the model E-learning Quality	Unlimited Time, Increase Knowledge, Repeated learning, Quick access	DEMATEL, DANP, VIKOR	Tertiary Education – E-learning
[9]	Identify and analyze the most criteria in sustainable science education	Sustainable science education, e-learning	FDEMATEL	Tertiary Education – E-learning
[48]	To identify and analyze factors in development of science education	Sustainable development, science education, flipped e- learning and technology infrastructure	MCDA-FDEMATEL	Tertiary Education – E-learning
[5]	Evaluate Higher Learning Institution instructors teaching performance	Preparation Organization Delivery Effectiveness	AHP	Tertiary Education – Learning Performance
[35]	Strategic of e-learning application includes decision making for the most suitable type of e-learning	Human Resources Specific and basic ICT Infrastructure Strategic Readiness Legal and Learning Implementation	AHP-TOPSIS	Tertiary Education – E-learning
[6]	Investigate the factors of U-Learning with Near Field Communication	Perceived Ease of Use and Usefulness	AHP	Tertiary Education – U-learning
[49]	Ranking Teacher performance	Understand the characteristics of students, Curriculum development of subjects Educating learning activities Understand and develop potential Communication with students	AHP-WASPAS	Secondary education-Learning Performance

[32]	Evaluate lecturer learning material to students.	Conformity of Material Competency Conformity Presentation Format Personalization	DEMATEL and ANP	Tertiary Education – Learning Tools
[50]	Provide a recommendation of collaborative activities to learners	Group Discussion Shared tasks Competitive activities Role playing Information exchange activities	ANN and WSM	Tertiary Education – Learning Style
[29]	Learning Management System (LMS) selection for effective distance system in organizations	License Cost Flexibility Security Market Share	AHP	Tertiary Education – Distance Learning
[51]	Determine the best teaching and learning tool in the education system.	Accessibility Performance Time Communication Application	AHP	Tertiary Education – Learning Tools
[8]	Investigate criteria for mathematics education in flipped e-learning on Pre-service teacher.	Mathematics education, sustainable flipped-learning technology	FDEMATEL	Tertiary Education – E-learning

4. Descriptive Analysis

The reviewed literature has consisted of journal articles that appeared in 2016-2020 and were classified under the educational system context. The term ‘educational system’ identified for the purpose of this paper refers to preschool education, primary education, secondary education, post-secondary education, and tertiary education. [52]. The number of the categories of the educational system investigated in the review literature is represented in table 3.

Table 3. Categories investigated in the reviewed literature.

Categories	Preschool education	Primary & Secondary education	Post secondary & Tertiary education
Article/Journal	1	7	24

Table 3 clearly shows that most journal articles were executed for post-secondary & tertiary education, university, and institutes. The MCDM was widely used in the tertiary education subjects as one of the operation research since most of the researchers were from that category. The less studied setting was the secondary, primary, and pre-school educational systems. Based on these findings, future work should include these setting when applying MCDM in the educational system.

This paper reviewed journal articles that appeared from 2016 to 2020, in the teaching and learning settings of the educational system. Thus, students, teachers, and school administrators were also involved in the educational decision problem. In this context, relevant journal articles were classified according to this context, as shown in table 4. The classification of journal articles used in the major educational decision problem are listed in table 5.

Table 4. Description of major educational decision problem in the reviewed literature.

Decision Problem	Description
Students Requirement	Students' admission and needed in the learning process
E- learning	Implementation, critical factors, sustainable of e-learning
Learning Tools	Type of teaching aids used in learning styles
Learning Skills	Teachers and students' skills required in learning
Learning Performance	Performance evaluation of teachers and students in learning process
Learning Quality	Factors that influence teacher quality in the learning process
Learning Approach	Effectiveness and barrier in teaching process
Active Learning	Implementation of active learning in classroom
Ubiquitous Learning	Factors that influence ubiquitous learning implementation
Distance Learning	Effectiveness of Distance learning in the education process

Table 5. Summary of the classification of journal articles used in major educational decision problem.

Decision Problem	Research	MCDM Techinque
Students Requirement	[34]	Fuzzy MCDM
	[27]	Fuzzy + Hybrid MCDM
E- learning	[45]	Classical MCDM
	[10]	Fuzzy MCDM
	[7]	Fuzzy + Hybrid MCDM
	[53]	Fuzzy MCDM
	[31]	Hybrid MCDM
	[9]	Fuzzy MCDM
	[48]	Fuzzy MCDM
	[35]	Hybrid MCDM
	[8]	Fuzzy MCDM
Learning Tools	[36]	Hybrid MCDM
	[40]	Fuzzy MCDM
	[41]	Fuzzy + Hybrid MCDM
	[42]	Classical MCDM
	[11]	Fuzzy MCDM
	[32]	Hybrid MCDM
	[51]	Classical MCDM
Learning Skills	[37]	Fuzzy + Hybrid MCDM
	[38]	Classical MCDM
	[39]	Fuzzy MCDM
Learning Performance	[33]	Classical MCDM
	[28]	Hybrid MCDM
	[43]	Fuzzy + Hybrid MCDM
	[5]	Classical MCDM
	[49]	Hybrid MCDM
Learning Quality	[44]	Fuzzy +Hybrid MCDM
	[46]	Classical MCDM
Learning Approach	[24]	Fuzzy MCDM
	[50]	Hybrid MCDM
Active Learning	[47]	Classical MCDM
U- Learning	[6]	Classical MCDM
Distance Learning	[29]	Classical MCDM

In order to get a better picture of how the MCDM application is used in diverse fields of educational context, these subjects were further investigated by identifying the types of decision problems that were given the most attention to, the frequency with which different MCDM methods that have been applied and the potential future works after a comprehensive analysis of the approaches.

4.1 Educational decision problem

The educational decision problem serves as the foundation for analysing each alternative material's performance. Various authors have applied multiple combination of educational decision criteria.

Table 6. Number of journals articles in each higher education decision problems.

Decision Problem	No of articles	Percentage
Students Requirement	2	6
E-learning	8	25
Learning Tools	7	22
Learning Skills	3	9
Learning Performance	5	16
Learning Quality	2	6
Learning Approach	2	6
Active Learning	1	3
U- Learning	1	3
Distance Learning	1	3

Table 6 shows the number of times occurrences of each decision problem was used by different authors from 2015- 2020. The data in table 2 is used to obtain the information in table 6. With eight appearances in table 6, it is proven that e-learning is the most commonly used in decision problem for education. It is not surprising that e-learning issues are the most common decision problem in the educational system, since it involves in the development of students who do have not only excellent soft skills but also technology savvy in facing a competitive STEM career. E- learning is always employed in most educational decision problems, however performance indicators have a different identity. It is then followed by a decision problem for learning tools, appeared seven times, and learning skills, appeared three times. Comparatively, decision problems involving students' requirements, learning quality, and learning approach attracted less attention. There were only two studies in each of these categories. Active learning, U-learning, and distance learning are the decision criteria that have proven to be the least beneficial in the educational analysis, with each of them being used only once over the study period. This occurrence was due to the new involvement technology advancement in teaching and learning methods after the e-learning. Therefore, decision-makers need to conduct new teaching and learning methods such as blended learning, for STEM. Hence, the quality of the educational system can be improved continuously based on the bench-marking results and the MoE aspiration. However, the implementation of new learning method is highly related to the students' and teacher's learning skills and learning performance. Thereby, it is crucial to study this issue in the immediate future.

4.2 MCDM technique used

One of the objectives of this paper is to identify the most prevalently MCDM method used in educational decision problems. MCDM techniques used in table 2 can be classified into four categories; Classical MCDM adopted fuzzy set theory in MCDM technique, hybrid MCDM, and hybrid fuzzy MCDM technique.

As shown in table 7, the classical MCDM and Fuzzy MCDM approaches were adopted by ten and nine researchers respectively. However, Hybrid Fuzzy MCDM was paid less attention with seven articles, which is slightly less than the Hybrid MCDM approach. It is interesting to find Fuzzy MCDM as the most favored method applied by researchers for e-learning issues rather than the hybrid fuzzy MCDM as suggested in Kustiyahningsih [27]. Most of the researchers in [31] and [27] stated that multiple, conflicting, and incommensurate criteria always occur in the real-world decision problem involving human judgment. In this perspective, a hybrid fuzzy MCDM method is a practical, applicable technique to coincide with it. Thus, it is worth investigating the application of MCDM in educational decision problems in the future.

Table 7. Numbers of articles in each MCDM technique.

MCDM Technique	No. of Articles	Percentage
Classical MCDM	10	31
Fuzzy MCDM	9	28
Hybrid MCDM	7	22
Fuzzy + Hybrid MCDM	6	19

The MCDM methods and their corresponding number of decision problems are indicated in table 8. Counting approach:

- For hybrid method count, a combination of two or more MCDM methods was used to solve a problem, i.e., AHP and DEMATEL.
- For a classical MCDM count, only one MCDM method was used to solve a problem, i.e. AHP.
- For a Fuzzy MCDM count, i.e., Fuzzy AHP and Fuzzy DEMATEL.
- For hybrid fuzzy MCDM count, i.e., AHP-TOPSIS

Table 8. Most MCDM tools and their corresponding number of a decision problem.

Problem	AHP	TOPSIS	DEMATEL	ANP	VIKOR	PROMETHEE	MACBETH	COPRAS	OTHERS	TOTAL
Students Requirement	1	1						1		3
E-learning Learning	3	1	4	1	1			1	1	12
Learning Tools	2	1	2	1			1		1	8
Learning Skills		1				1			1	3
Learning Performance	3	2	1	1					1	8
Learning Quality	1	1							1	3
Learning Approach									1	3
Active Learning	1									1
U- Learning Distance	1									1
Learning TOTAL	15	7	7	3	1	1	1	2	6	43

5. Discussion

From the detailed description of the approaches in the previous section, two major possible future research areas can be recommended. First, it is noticed that most researchers studied e-learning as a decision problem. However, only a few researchers investigated distance learning, u-learning, and active learning in the decision problem. Generally, the researcher's learning styles mentioned above are the new vision of teaching style, a teaching style that is embedded with an element of technology advancement to enable new possibilities. This teaching style promotes students to learn skills and knowledge that are needed and identify the source to learn the skills and knowledge. This changing style has transformed traditional teaching into blended learning. However, limited knowledge among teachers and students in selecting multiple resources may interfere with the learning process. To support students in maintaining their focus and assisting teachers in resources materials, different approaches from the STEM context and suitable methods are utilized to design the blended process. The different STEM approaches such as flip classroom activity, hands-on activity, project-based learning, and inquiry-based activity can be regarded as an alternative with multiple attributes. Thus, it is worth developing the MCDM model for selecting the appropriate best STEM approach in the blended learning process where in-depth future work is critically needed.

Second, the most prevalent technique found in the previous section is AHP, when the decision problem is based on complex multiple criteria. It is applied to almost all major decision problems. Most researchers adopted AHP since decision-makers' judgment consideration is subjective and inconsistent, and AHP is capable to reduce the subjectivity and inconsistency. However, AHP is widely criticized for being a tedious process, especially with inconsistent judgments [35]. In AHP, the problem is decomposed into a hierarchy structure by considering the distribution of a goal among the criteria by finding the weights of criteria. Then, an alternative is judged to find one with

a more significant influence on the goal.

In determining the priority level of the goals, the decision-makers must identify an alternative that is closest to the ideal solution and the farthest to the negative ideal solution in mathematical form. Following that, it is desirable to incorporate the TOPSIS approach. The ideal alternative has the best level for all criteria, whereas the negative ideal is the one with all the worst criteria values. Thus, the use of the AHP-TOPSIS approach can bring effectiveness and efficiency to the decision problem process. By adopting the fuzzy set theory, the imprecise and vagueness judgment by decision-makers can be normalized. In the intermediate future work, the hybrid MCDM method, AHP-TOPSIS with its fuzzy extension, can tackle the first major future work mentioned.

6. Conclusion

This paper mainly reviewed the application of the MCDM techniques in ten major educational decision problems, namely students' requirement, e-learning, learning tools, learning skills, learning performance, learning quality, learning approach, active learning, u-learning, and distance learning. It was found that 9 out of 33 journal articles collected in the past five years (2015 to 2020) studied e-learning. The previous researchers chose to evaluate or identify the implementation, barrier, critical factors, and sustainability of e-learning. Since traditional learning has shifted to technology-oriented learning, active learning, distance learning, and ubiquitous learning (U-learning), blended learning are relevantly evaluated for its learning approaches and tools. Both play a crucial role in evaluating and improving the students' skills to fill the STEM career. Thus, STEM approaches are required to employ in educators teaching and learning process. Hence, more research can be done to find the appropriate STEM learning approaches and tools in other learning styles. More future work in blended learning was in depth researched.

Generally, this issue involves multiple and conflicting objectives. For instance, the school's decision makers (teachers) plan to employ these new versions of learning styles to improve the quality and quantity in teaching. The new attributes of the MCDM model were introduced in this paper to aid the decision-makers. For example, hands-on activity, station rotation, project-based learning, and inquiry-based learning are regarded as the criteria of the model. The development of a hybrid fuzzy MCDM model for future work. Looking at the MCDM technique, there are relevant to used AHP-TOPSIS with fuzzy number adopted due to the review's preference and consistency. Thus, the development of a hybrid fuzzy MCDM model is a suggestion in-depth for future work.

There are some notable limitations to this study that can be considered as suggestions for future work. First and foremost, this review paper focused on the application of MCDM approaches. Articles published earlier than 2015 and after 2020 were not included in the present study due to limited reporting time. The authors propose that the decision-making scope of a potential evaluation be extended further. Due to the weaknesses in the methodology technique, some good papers on MCDM application may have been overlooked in this study. The data collected for this paper were not included textbooks, doctorate and master dissertations, PhD thesis, and unpublished articles in the MCDM issues. Future research can look into those articles were not covered in this review paper.

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