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This themed issue honors Professor Ekedimogu Eugene Nnuka, celebrating his distinguished career upon his retirement. His legacy of exemplary scholarship, mentorship, and commitment to advancing knowledge is commemorated in this collection of works.

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Evaluation and Engagement of STEM Learning Strategies in Industrial Engineering Discipline: Nigerian experience

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Abstract

Industrial Engineering (IE) education is a SCIENCE, Technology, Engineering and Mathematics (STEM) discipline that requires an appropriate instruction approach, thus making it imperative to look deep into finding a suitable learning approach. Surprisingly, in Nigeria, there is an absence of course-specific studies that utilized a hybrid Multi-Criteria Decision Method (MCDM) approach to evaluate STEM learning strategies in order of importance in deploying IE subjects for the utmost academic fulfilment of the pedagogical requirements as provided in the curriculum. Analytical Hierarchical Process and Preference Ranking Organization Method for Enrichment of Evaluations (AHP-PROMETHEE) model were used to develop the hierarchical model of the problem and illustratively rank the STEM alternatives and core STEM competent criteria to facilitate appropriate learning for IE education. The results show that the prioritised STEM approach for IE education is Challenge-Based LEARNING (CBL), followed by Project-Based Learning (PJBL). The core competence associated with these two STEM learning strategies ranges from collaboration, critical thinking, independent learning, problem-solving and digital literacy.

Keywords: STEM, Industrial Engineering, higher education, multi-criteria decision-making methods, Nigeria

1. Introduction

IE education is a STEM discipline that requires an appropriate instruction approach in line with the contextual provisions of its pedagogical requirements. The interdisciplinary nature of IE encourages teaching approaches to be more practical with less theory for effective outcomes (Gladysz, 2019). However, the curricular content of engineering schools in the developing world designed to accommodate theory-based learning with complementary adequate practical training of professional standards is still in doubt (Achebe et al., 2020). The current practical teaching approaches and content employed in IE education are insufficient to meet the realistic requirements (Chen et al., 2019; U-Dominic et al., 2017), thus making IE education very challenging in this part of the globe. Universities can serve as an inspiration for defining the vocation of future graduates and are adopting new teaching practices and companies are also playing an important role through transference-oriented collaboration agreements (Nogales-Delgado et al., 2022). A leading role is expected from the IE higher education system to bridge the gap between university research and development and regional industry development (Chen et al., 2019). Digital transformation is now changing the industry and society. Fostering students' acquisition of high-level digitized engineering and problem-solving skills has become a crucial issue in IE education (Chen et al., 2019).

Implementing STEM education has not reached the expected results in many countries and regions (Hu and Guo 2021), and many countries have started formulating their own educational goals for the core STEM competencies (Zhan et al., 2023). The significance of promoting integrative STEM education has been widely recognized and a considerable number of studies have been conducted in recent years. Still, there is a need to assess STEM learning strategies based on their capabilities and ways to re-align their corporate strengths to a specific course objective for easy adaptation and replication. IE differs from general engineering disciplines, it originated from scientific management and has management characteristics (Zhang et al.,2021), and relying on traditional teaching methods cannot make students fully grasp IE and cannot cultivate the IE talents needed by society (Liu, 2017). It is then imperative to look deep into finding appropriate strategies for deploying STEM educational concepts in schools as world problems are becoming more complex, thus demanding the integration of multiple disciplines, concepts, and skills to solve them (Roehring et al., 2021). Considering the above, it is a clear opportunity for IE disciplines in Nigeria to evaluate and eventually adopt new ways to deliver knowledge to their students.

In previous works that have been done on STEM learning in Nigeria, Umoh, (2016), attributed the problems faced by STEM learning in Nigeria to poor teacher supply, deficient curriculum, inadequate incentives, and poor work environment. Onile-ere et al., (2021) explored the factors that may affect the choice of STEM in pre-university female students in Ogun state, Nigeria. Ubawuike (2018) comprehensively detailed the problems with the STEM approach starting from conceptual difficulties in propagating the right STEM education, lack of STEM curriculum in integrative forms, unavailability of qualified STEM teachers, and poor academic funding to adequately engage in STEM education. There is this impression that traditional education in Nigeria is failing (Agboola, 2021). STEM education is the worst hit, as students are largely uninspired to pursue their passion in STEM-related fields (BHM, 2018). STEM education is yet to be understood in Nigeria, and its implementation is still abysmal (Ubawuike 2018). Although the development of STEM education is being prioritised in Nigeria through initiatives, such as the US-backed Tech Women program, Interswitch SPAK, educators are still faced with great difficulties in finding appropriate teaching methods and strategies(Çevik & Bakioğlu (2022; Ubawuike (2018). Significant work has been done on integrating STEM education into teaching-learning approaches by many researchers to make it more effective than the lone STEM approach. (Wang et al., 2023; Roehring et al., 2021; Costa et al., 2022). Surprisingly, even with the level of reported integrations of STEM education to influence engineering outcomes, there is a dearth of study in Nigeria that specifically attempts to understudy the STEM demands of IE discipline. This study attempts to analyze the current educational capabilities and realities in STEM learning in Nigeria, by taking a synergistic advantage of a hybrid MCDM approach in ranking the STEM learning alternatives, appropriate to the course-specific demands in the IE discipline.

2.0 Material and Methods

The proposed research modelling framework in the current study comprises the steps weighing the criteria using the Analytical hierarchical process (AHP) and subsequent ranking of STEM learning alternatives in IE courses in Nigeria using a decision methodology presented in Figure 1. The decision methodology was developed by Integrating AHP and PROMETHEE. This synergetic approach is especially advantageous, utilizing the strengths of both individual methods. AHP enables the decomposition of a complex problem into its constituent parts and the determination of weights for criteria (Canco et al.,2021; Petrillo et al., 2023), while the PROMETHEE method allows the researcher to determine the preference function, complete ranking, and analysis of the robustness of the results (Abdullah et al., 2019; Sikalo, 2023). Eight STEM competencies considered in the study are critical thinking, problem-solving, creativity, communication, collaboration, data literacy, digital literacy, and independent learning. These highlighted STEM competencies are the criteria on which different STEM approaches will be assessed. The different STEM approaches such as project-based learning, inquiry-based learning, design-based learning, and challenged-based learning can be regarded as an alternative with multiple attributes. Thus, it is worth developing the MCDM model for selecting the appropriate STEM approach in teaching IE education in Nigeria where in-depth future work is critically needed. A detailed explanation of the modeling steps within the integrated decision models is highlighted in the following subsections.

2.1 The AHP method

Step 1: The first step in an AHP analysis is to build a hierarchy for the decision, by breaking down the decision into a hierarchy of goals, criteria, and alternatives. By so doing, it now becomes easy to better understand the decision to be made, the criteria to be used and the alternatives to be evaluated. A semi-structured questionnaire was used as the basis of the selection of the eventual Six academic staff, mainly from the Industrial and Production Engineering Department who had worked in the university environment and were knowledgeable on the curricular provisions of STEM learning strategies. Among the selected group for the study, a relevant questionnaire was also formulated and an initial pilot study was conducted to ensure conformity and clarity of the research objectives before the main survey.

Step 2: The second step is the estimation of the relative weights of the criteria. Under this, the first task is to derive by pairwise comparisons the relative priority of each criterion concerning each of the others using a numerical scale for comparison developed by Saaty (2012) as shown in Table 1. and equations (1) & (2)

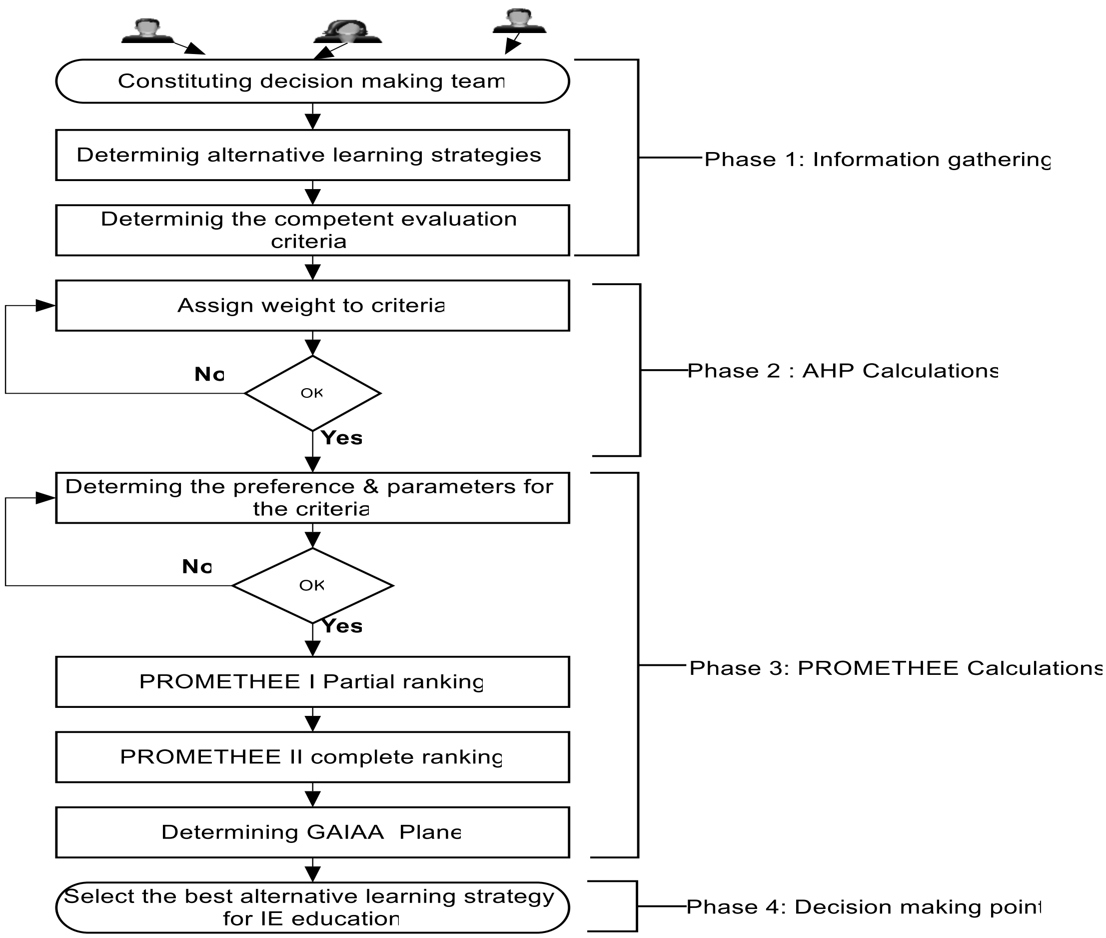

Figure 1. Research Methodology

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Table 2. Saaty's pairwise comparison Table.

Verbal judgment	Numerical value
Extremely important	9
	8
Very strongly more important	7
	6
Strongly more important	5
	4
Moderately more important	3
	2
Equally important	1

Let $C = \{Cj \mid j = 1, 2, \ldots, n\}$ be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in an $(n \times n)$ evaluation matrix A in which every element $ai\,j$ $(i, j = 1, 2, \ldots, n)$ is the quotient of weights of the criteria, as shown in Eq. 1:

$$A = \begin{pmatrix} a11 & a12 & a1n \\ a21 & a22 & a2n \\ an1 & an2 & ann \end{pmatrix}, aii = 1, a\,ji = 1/ai\,j, ai\,j \_= 0. \quad (1)$$

$$b_{ij} = \frac{a\mathrm{ij}}{\sum_{i=1}^{n} aij} \quad (2)$$

Step 3: Normalization of the pairwise comparison matrix is done followed by calculating the average of the elements in each row of the normalized pairwise comparison matrix to develop a priority vector.

$$w_i = \frac{\sum_j^n aij}{n} \tag{3}$$

Step 4: Determine the consistency ratio (CR) of the pairwise comparisons, and determine the CR first thing is to determine the weighted sum matrices by multiplying pairwise comparison matrices by the priority vectors.

$$CR = CI/RI \tag{4}$$

Where R.I is the random index, and C I the consistency index which is computed as follows:

$$C.I = {(\lambda \max - n)}/{(n-1)} \tag{5}$$

Where n is the matrix size and λ_{max} the principal eigenvector, computed by dividing all the elements of the weighted sum matrix by their respective priority vector element (Polat, 2016).

3.2. *The PROMETHEE method*

Step 5: A first step in the PROMETHEE modelling is thus to compare each action with each other. This is done by computing a multicriteria preference index in the following way:

$$\begin{cases} \prod (a, b) = \sum_{j=1}^{k} Wj * Pj(a,b) \\ \prod (b, a) = \sum_{j=1}^{k} Wj * Pj(b,a) \end{cases} \tag{6}$$

∏ (a, b) Is expressing with which degree is preferred over all the criteria and ∏ (b, a) how bis preferred over a. The following properties hold for all (a, b) Є A.

$$\begin{cases} \prod (a, a) = 0 \\ 0 \leq \prod (a, b) \leq 1 \\ 0 \leq \prod (a, b) \leq 19 \\ 0 \leq \prod (a, b) + \prod (b, a) \leq 1 \end{cases} \tag{7}$$

∏ (a, b) = 0 implies a weak global preference for a over b, and ∏ (a, b) = 1 implies a strong global preference for a over b.

Step 6: PROMETHEE is required to associate a preference function to each criterion to model the way the decision-maker perceives the measurement scale of the criterion. The decision maker chooses a preference function (Q & P) and the Gaussian threshold (S) depending on the nature of the data available.

Step 7: Equations (8) & (9) are used for the PROMETHEE I partial ranking, while equation (10) is used for the PROMETHEE II complete ranking.

$$\Phi^+ (a) = \frac{1}{n-1} \sum_{b \neq a} \prod (a,b) \tag{8}$$

Equation (8) is Phi+ (f +(a)): positive (leaving) flow measures how much an action *a* is preferred to the other *n*-1 ones. The larger f+(*a*) the better the action.

$$\Phi^- (a) = \frac{1}{n-1} \sum_{b \neq a} \prod (a,b) \tag{9}$$

Equation (9) is Phi- (f – (a)): negative (entering) flow measures how much the other *n*-1 actions are preferred to action *a*. It is a global measurement of the weaknesses of action *a*. The smaller f-(*a*) the better the action.

$$\Phi (a) = \Phi^+ (a) - \Phi^- (a) \tag{10}$$

Step 8: Equation (10) is Phi (f (a) is used for the PROMETHEE II complete ranking (net flow The net preference flow f(*a*) is the balance between the positive and negative preference flows It thus takes into account and aggregates both the strengths and the weaknesses of the action into a single score.

Step 9: The major features of the decision problems can be graphically described on a GAIA Plane using the single criterion net flows table, and the single criterion net flow for criterion *fj* is then defined by equations (11) & (12).

$$\Phi_j (a) = \frac{1}{n-1} \sum_{b \neq a} [\, Pj(a,b) - Pj(b,a)] \quad (11)$$

consequently

$$\Phi (a) = \sum_{j=1}^{k} Wj \ * \ Pj(a) \quad (12)$$

The single criterion net flow values are always numbers between -1 (worst possible value) and +1 (best possible value). Table 2. The extended multicriteria table that into account the scales of the criteria with the preference functions as defined by the decision-maker.

Table 2. Single criterion net flow table

	Φ_1	Φ_2	. . .	Φ_j	. . .	Φ_k
a_1	$\Phi_1 (a_1)$	$\Phi_2 (a_1)$	. . .	$\Phi_j (a_1)$	. . .	$\Phi_k (a_1)$
a_2	$\Phi_1 (a_2)$	$\Phi_2 (a_2)$	. . .	$\Phi_j (a_2)$	. . .	$\Phi_k (a_2)$
:	:	:	. . .	:	. . .	:
a_4	$\Phi_1 (a_4)$	$\Phi_2 (a_4)$	. . .	$\Phi_j (a_4)$	. . .	$\Phi_k (a_4)$
:	:	:	. . .	:	. . .	:
a_n	$\Phi_1 (a_n)$	$\Phi_2 (a_n)$	. . .	$\Phi_j (a_n)$	. . .	$\Phi_k (a_n)$

This table is similar to but contains more information than the original multicriteria table because the preference functions defined by the decision-maker are taken into account. It also means that each criterion is expressed on the same normalized net flow scale (scores between -1 and +1). Each action is thus associated with a *k*-dimensional profile and can be seen as a point in the *k*-dimensional space.

3.0 Results and Discussions

In this section, we present the steps in the data analysis; firstly, the selection of the eventual subject (team) for the study, and the AHP-based computation to obtain the importance weights of some STEM core competence, and subsequent PROMETHEE ranking of the alternatives. The team was rightly selected based on their knowledge of STEM subjects and their willingness to positively contribute to this knowledge study. The demographic characteristics of respondents for this study are shown in Table 1. The team was well intimated on the purpose of the study with a clear objective on the research needs. The decision hierarchy for choosing appropriate STEM learning for the IE course is represented in a three-level structure as shown in Figure 1. The first level is the research goal, followed by the evaluation criteria (criteria; critical thinking (CTc), problem-solving (PSc), creativity (Cc), communication (Cc1), collaboration (Cc2), data literacy (DLc), digital literacy (DLc1), independent learning (ILc).) at the second level, and lastly, the alternative learning strategies (IBL, PBL, PJBL, CBL, DBL). using the AHP methodology, the team assigned a weight to the criteria on the precept that some criteria are more influential considering the subjective needs of the institution and other adaptive capability requirements and enablers.

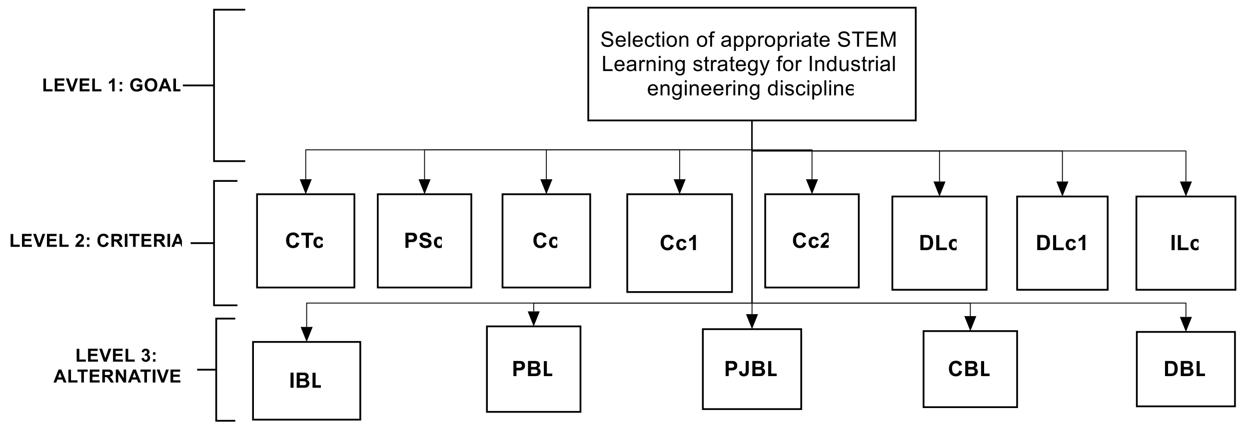
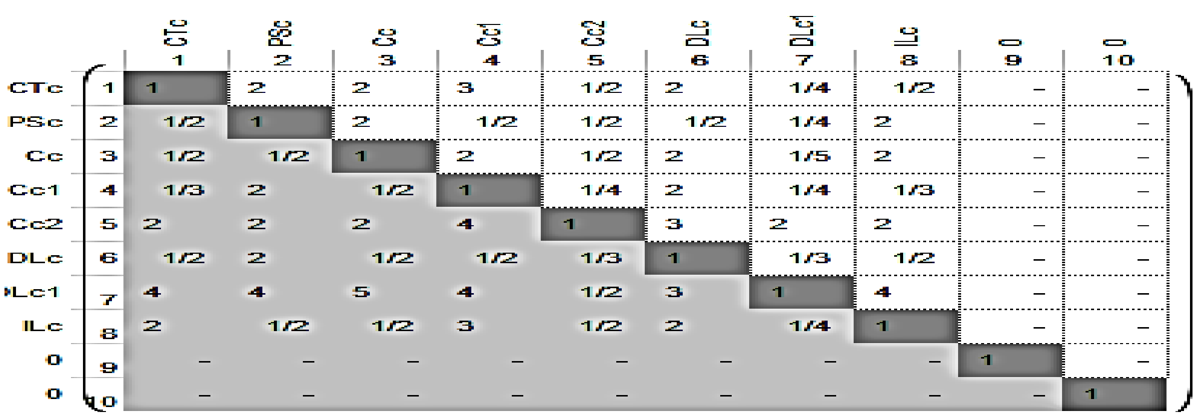


Figure 1: Decision hierarchy for choosing an appropriate STEM learning for IE Department

The pairwise comparison matrix is set up using equations (1) & (2), as shown in Figure 2, while the normalized principal eigenvector (Priority vector) in Figure 3 was derived using equation (3). The consistency of the normalized principal eigenvector was standardized using equation (4) & (5).

Table 2: Demographic characteristics of respondents used in the study

Demographic attribute	*Number of respondents*
Age	
41-50	3
51-above	2
Gender	
Male	4
Female	1
Highest educational qualifications	
PhD	5
Area of specialisation	
Industrial engineering	2
Production Engineering	1
Mechanical Engineering	1
Years of experience	
5-10	2
11-20	3
21- Above	
Associate Professor	2
Senior Lecturer	3



		CTc 1	PSc 2	Cc 3	Cc1 4	Cc2 5	DLc 6	DLc1 7	ILc 8	0 9	0 10
CTc	1	1	2	2	3	1/2	2	1/4	1/2	–	–
PSc	2	1/2	1	2	1/2	1/2	1/2	1/4	2	–	–
Cc	3	1/2	1/2	1	2	1/2	2	1/5	2	–	–
Cc1	4	1/3	2	1/2	1	1/4	2	1/4	1/3	–	–
Cc2	5	2	2	2	4	1	3	2	2	–	–
DLc	6	1/2	2	1/2	1/2	1/3	1	1/3	1/2	–	–
DLc1	7	4	4	5	4	1/2	3	1	4	–	–
ILc	8	2	1/2	1/2	3	1/2	2	1/4	1	–	–
0	9	–	–	–	–	–	–	–	–	1	–
0	10	–	–	–	–	–	–	–	–	–	1

Figure 2. Experts pairwise comparison matrix of the criteria

Matrix		CTc 1	PSc 2	Cc 3	Cc1 4	Cc2 5	DLc 6	DLc1 7	ILc 8	0 9	0 10	normalized principal Eigenvector
CTc	1	1	2	2	3	1/2	2	1/4	1/2	–	–	11.08%
PSc	2	1/2	1	2	1/2	1/2	1/2	1/4	2	–	–	8.34%
Cc	3	1/2	1/2	1	2	1/2	2	1/5	2	–	–	8.89%
Cc1	4	1/3	2	1/2	1	1/4	2	1/4	1/3	–	–	6.56%
Cc2	5	2	2	2	4	1	3	2	2	–	–	21.77%
DLc	6	1/2	2	1/2	1/2	1/3	1	1/3	1/2	–	–	6.34%
DLc1	7	4	4	5	4	1/2	3	1	4	–	–	27.02%
ILc	8	2	1/2	1/2	3	1/2	2	1/4	1	–	–	10.00%
0	9	–	–	–	–	–	–	–	–	1	–	0.00%
0	10	–	–	–	–	–	–	–	–	–	1	0.00%

Figure 3: Pairwise comparison matrix of the criteria and the normalized principal Eigenvector.

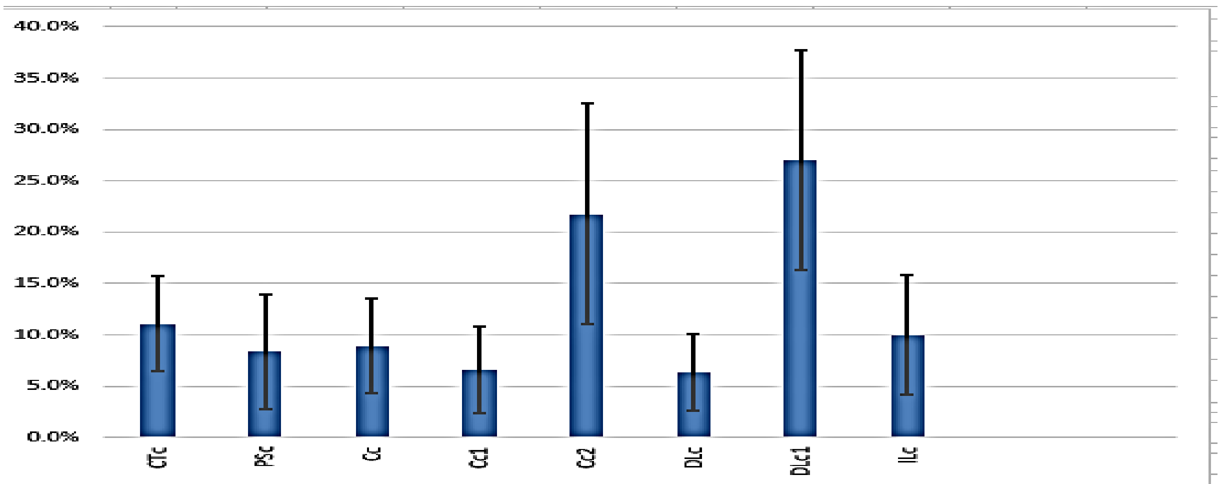


Figure 4. Graphical representation of the criteria weights

In Figure 2, the detached column on the extreme right contains the normalized principal eigenvector for all the weighted criteria. DLc1 is the most-rated criterion, followed by Cc2, while the least-rated core competent criterion is DLc. Realistically, the demand for IEs with knowledge and skills related to both DT and traditional IE is required in this digitized manufacturing era and a new practical teaching scheme and implementation measures are required in the universities (Chen et al., 2019). Pictorially, the expert's evaluation of the criteria was also represented in Figure 3, virtually showing the level of differences among the weighted criteria.

PROMETHEE I Partial ranking

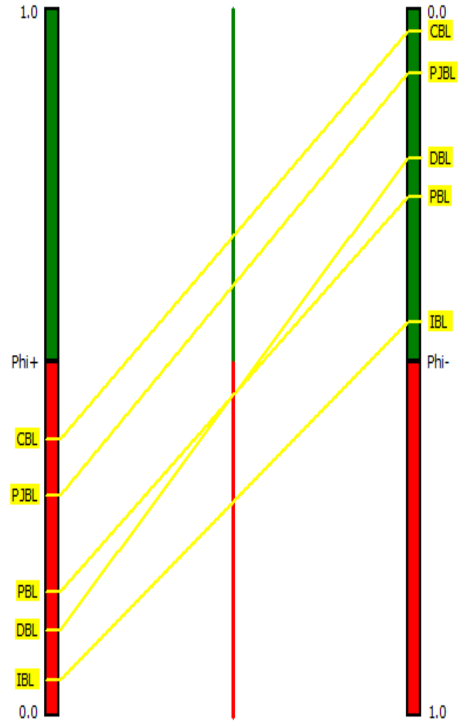


Figure 5a. PROMETHEE I Partial ranking

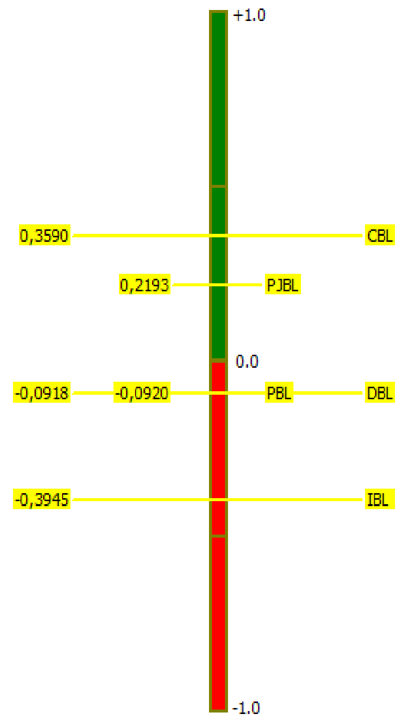


Figure 5b. PROMETHEE II Complete ranking

The PROMETHEE I Partial Ranking as shown in Figure 5a shows the ranking of the alternative STEM learning strategies(actions) based on the computation of two preference flows, Phi+ and Phi-. CBL is top-ranked, followed by PJBL, PBL, DBL, and lastly IBL. In the PROMETHEE II complete ranking (Figure 5b) is based on the net preference flow Phi: CBL is still on top and is preferred to all other actions in the PROMETHEE II ranking, followed by PJBL. DBL and PBL are incomparable to each other, and IBL. From the two ranking approaches, CBL is preferred to all the other actions in the PROMETHEE I & II rankings. CBL has a higher Phi+ score of 0.3590, However, DBL and PBL are very close but have negative scores, while IBL is at the bottom of the PROMETHEE II ranking with a negative score of -0.3945.

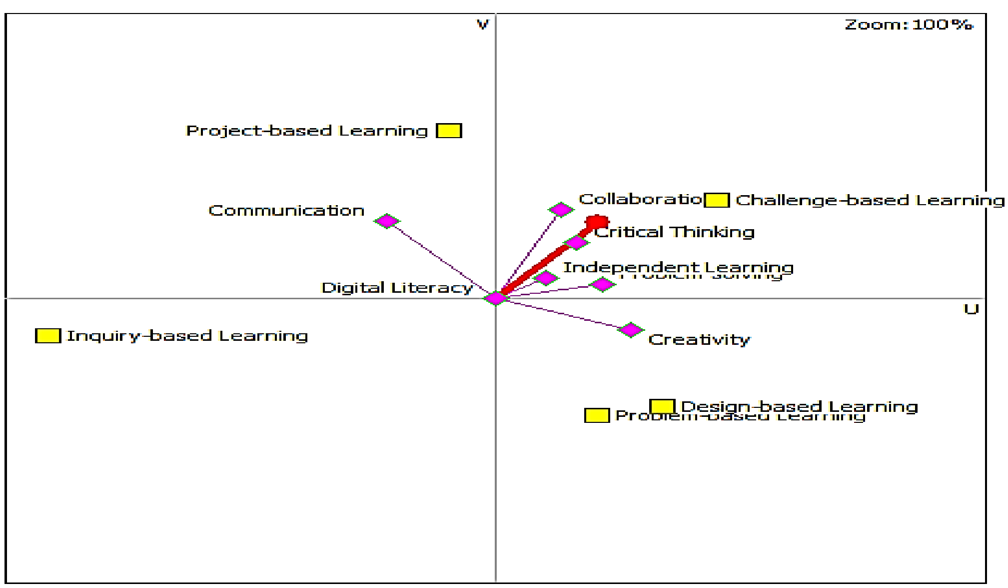


Figure 6. The GAIA plane for the STEM alternatives

The GAIA is the descriptive complement of PROMETHEE rankings, and each action is represented as a point in the GAIA plane, and actions with similar profiles are close to each other such as the DBL & the PBL. Conflicting criteria have their axis in the opposite direction just like creativity and communication. Inquiry-based learning, project-based learning, and challenge-based learning are different from each other. In the first quadrant, key competent criteria collaboration, critical thinking, independent learning, and problem-solving were attributed to CBL alternatives. Creativity is the only ranked competent criterion in the fourth quadrant associated with design-based and problem-based learning. Inquiry-based missed in ranking for all the evaluation criteria as shown in the third quadrant of Figure 6. On the second quadrant, PJBL is highly ranked on communication and digital literacy criteria.

3.1. Sensitivity Analysis

Figure. 8 The Walking Weight (sensible score analysis) used for sensitivity analysis. Results were generated by the PROMETHEE-GAIA software. Top and bottom analyses show the ranking of the STEM learning approach after considering the respondents' weight, equal weight, and variable weights.

Assessing weights to the criteria is not straightforward, as it involves the priorities and perceptions of the decision-maker, thus performing a weight sensitivity analysis now becomes essential. Add to this, outranking results are influenced by the weights allocated to the criteria, so it is important to know how the ranking changes when the weights change (Talukder, and Hipel, 2018; Abdullah et al., 2019). In response to this issue, an interactive tool called walking weights is used to check the sensitivity of the result. The walking weights feature of the Visual PROMETHEE 1.4 Academic Edition software contains two graphics; the upper part shows the PROMETHEE II Phi net flow scores for the active actions, and the lower part shows the relative (per cent) weights of the criteria. For example, in the first graphics of Figure 8, with the initial weight of the criteria as assigned by the selected respondents, the two best-ranking alternatives were displayed in the graphics and the three worst-ranked alternatives. When the criteria were given an equal weight, sensitivity analysis showed that the ranking of the five alternatives was rather stable as displayed in the second graphic. However, when the weight of criterion CTc, PSc & DLc1 were increased by 40%, 20%, and 14%, a slight change was observed in ranking, though it does not affect the best-ranked alternative. Most of the criteria and their weights do not influence the final ranking. It is noticed that the result does not have an impact on the first-ranked alternative. From this analysis, it is clear that most of the criteria and their weights do not influence the final ranking

3.2. Discussion

This methodology calculates the relative weight and rankings by comparing different STEM approaches and also indicates the weak and strong criteria of the different STEM approaches in teaching IE subjects. As STEM learning approaches depend on complex considerations, the assessment should consider multiple criteria. The evaluation model AHP- PROMETHEE system is very robust as AHP enables the decomposition of a complex problem into its constituent parts and the determination of weights for criteria, while the PROMETHEE method allows the researchers to determine the preference function and complete ranking. The ranking result has shown that CBL is the top-ranked STEM alternative suitable for IE education, and the educational concept of CBL is an evolution from approaches including Problem-Based Learning (PBL), Project-Based Learning (PjBL), and Design-Based Learning (DBL) (Beemt et al., 2023). Consensual to other attributed claims, the GAIA plane of Figure 6 has shown that key competent criteria such as collaboration, critical thinking, independent learning, and problem-solving were attributed to challenge-based learning alternatives.

Recently, the CBL educational approach has increased in higher education institutions, thus fostering student transversal competencies, knowledge of sociotechnical problems, and collaboration with industry and community actors (Gallagher and Savage (2020). IE requires synergy between academia and industry, and this form of collaboration is seriously lacking in our curricular provision or teaching disposition. Most of the problems solved are imaginary without any real impact on society, by this most of the supposed solutions are answers to wrongly imagined problems. Challenge-based learning (CBL), allows the student to develop tools and strategies to confront problems similar to what they may find in professional development (Gutiérrez-Martínez et al., 2021). Second on the ranked STEM learning alternatives, is the PJBL which entails actively involving the students in learning by utilizing multifaceted projects as a central organizing strategy (Garcia, 2016; B.I., 2019; Granado-Alcón, 2020). Engineering is all about making an impact on the environment through the application of actively learned instruction, and PJBL is increasingly promoted among educators to cultivate creativity and innovation in the classroom (Mohammed, 2017; Guo et al., 2020). Compared to traditional teacher-led instruction, PJBL has been found to result in greater academic achievement (Chen & Yang, 2019), due to its active learning methodology that engages students in their learning process and thus promotes competencies that none other course by itself promotes, such as critical thinking, communication, collaboration and creativity (Alaves et al., 2019). Add to this, the result on the second quadrant associates PJBL with communication and digital literacy criteria from the graphic display of Figure 6.

One of the major drawbacks of IE education is that many of the industrial applications of a litany of proposed inventions are still in a crude state of untapped nature due to a lack of transformational prowess. It is highly debated that most of the academicians in the engineering education domain do not possess the necessary competence to radically initiate the required industrial revolutionary change. Most of the educational anomalies militating against the proper propagation of engineering education in Nigeria can be linked to the mode of appointing academic staff, which is not fulfilling and not in tune with the present societal academic needs. Engineering staff should be a blend of academic professionals from diverse fields of science, engineering, and management. It is pertinent to note that any concept that is widely analyzed from different perspectives obviously will have a wide range of applications. IE subjects should be taught from three dimensions, mathematics, physics, and computers. It is rather quite unfortunate that these tripartite academic fields are not considered in appointing staff for IE courses. For instance, IE needs to have on their staff list, academicians with strong mathematics, computer and physics backgrounds to have a wider transformation of engineering ideas and solutions.

In this era of digital transformation, it is required that IE should lead in the transmission of soft skills and other industrial 4.0 technologies. It should be classified as a challenge when there is a limited number of academic staff with the prerequisite knowledge to meaningfully influence digital change. The second drawback, observed in the current IE education is likened to poor funding in R & D and upscaling of staff on innovative concepts. Pathetically, IE education is transferred to the student based on the limited knowledge of most academic staff in innovative ideas, and teachers require an adequate training program with design proficiency assessment instruments for successful deployment (Membrillo-Hernández et al., 2021). One of the reasons engineering graduates are termed unemployable is hinged on the ailing university system that has failed to provide the students with relevant skills, apart from obvious scientific facts. Most of the methods used in the universities in teaching IE courses are not challenged-based, in the sense that it does not rightly encourage the required industrial exposures and engagements to graduates, but class works that are teacher-centred. In CBL, students work in multidisciplinary teams when working on the challenge, thus improving their creative outputs, teamwork skills, knowledge transfer, and digital capabilities (Vilalta-Perdomo et al., 2020; Yang et al., 2018).

Despite the recorded gains from this study, a few limitations were also noted as well. In this study, few respondents were chosen due to time and budgetary constraints. Secondly, only core competencies were considered, which might significantly influence the selection of the eventual top-ranked learning strategy. Thirdly, classical AHP MCDM was used to assign weight to the criteria, which does not have the capabilities to contain uncertainties that characterize qualitative decision-making, and thus does not consider the fuzziness of the qualitative judgments. Another drawback is the use of Type I, the usual preference for the criteria due to the small number of evaluation levels used in the study, while empirical studies have shown that the PROMETHEE method is rather robust concerning the use of threshold values preference function.

4.0. Conclusion

The ways STEM education is implemented across different countries are influenced by economic and socio-cultural factors, and developing countries tend to focus more on pedagogical practices (Zhan et al., 2022; Forawi, 2019). Engineering studies are particularly unique within university systems around the world, and past studies have identified the necessity for improving the educational approach to teaching industrial engineering (Bilge and Severengiz, 2019). This research apart from determining the best STEM learning alternative, further highlights the core competencies that are relevant for IE education by taking a synergetic decision across different STEM learning strategies. This study has ushered unwavering quest to review and revalidate academic curriculum to subject domains, student cognitive abilities, teacher-competent skills, and infrastructural requirements. It seems obvious that the traditional curriculum design method lacks real-world connections (Lin et al., 2021), and universities have started streaming their curriculum to meet the prevailing education realities and demands (Lai, 2018). In this paper, a hybrid multi-criteria-based model was used to assess and evaluate the STEM learning approach, suitable for the proper deployment of IE subjects in higher education. It is the recommendation of this study to review the existing curriculum contents used in teaching IE in higher education and make amendments to inculcate the pedagogical provisions of CBL and PJBL STEM learning strategies for an impactful outcome among the students.

5.0 Recommendation

We recommend that this study should extend further to make good with all the identified limitations in terms of human resources, ranking parameters, and choice of methodological approaches for analysis. Specifically, further studies should consider using a model that will consider the fuzziness of qualitative judgements. More so, subsequent studies should consider an increased number of experts, thus the use of threshold values preference function.

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