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Analysis on Breaking Systematic Barriers to Women's Participation in Maritime Related - Science Technology Engineering and Mathematics Fields in West Africa

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***Abstract*-This study concentrates on breaking systematic barriers to women's participation in Maritime Science, Technology, Engineering and Mathematics (STEM) related fields, by identifying factors that prevent female participation in STEM and suggesting possible solutions to close the gender gap in maritime STEM related courses in West Africa. A convenient quantitative method, called, importance performance analysis (IPA) was incorporated with inputs from relevant experts in the STEM field. The respondents were drawn from women working in various maritime STEM fields. The analysis from this study reveals that, primitive societal believe and lack of role models were ranked as the most influential factors that affects women pursuing STEM careers in maritime science fields. Putting in place the right societal and global organizational interventions by decision and policy makers remains paramount in West Africa in promoting women participation in STEM.

Keywords- *Science Technology Engineering and Mathematics, Importance Performance Analysis, Expert Judgement*

I. INTRODUCTION

STEM stands for science, technology, engineering, and mathematics, and remains a significant factor for the development of lives in West Africa, as technology constantly ventures in every aspect of human life, particularly in the maritime sector. Marine engineering handles the difficulties of changing environment, from climate changes to the comfort of ships, whilst mathematics remains the fundamental pillar for both marine technology and engineering. Women are greatly talented, and educating a woman, is educating a nation however, research indicates that around 80% of young ladies don't seek degrees in science and technology fields [1]. Again, female CEOs and female board members are uncommon over all fields, approximately only 16.9% to 17.4% [2]. In 2018, a survey conducted indicated that, the total number of females in the STEM field is approximately 24% [3, 4]. Furthermore, meta-investigations in light of 100 examinations and testing of 3,000,000 individuals, found that young ladies beat young men generally speaking, in elementary school arithmetic [6]. The association, United Nations Education, Scientific and Cultural Organization (UNESCO), express that, sex difference based on biases, social standards and discrimination, greatly influence the quality of ladies education [7, 8]. Guaranteeing young ladies equivalent access to STEM education and an ultimate STEM profession, is the basis of human rights for positive advancement in West Africa [7]. From a human rights point of view, all individuals are equivalent and ought to have equivalent chances, including to study and work in their preferred field [7]. Gender equality in STEM will guarantee that young men and young ladies have the same skills and opportunities to excel in their dream career of their choice [8]. The sex hole in STEM education has been the subject of broad research over numerous decades [8]. There is unmistakably more to be done to decrease gender disparity in STEM fields in West Africa especially in maritime engineering and related science fields [9]. The aim of this paper is to apply importance performance analysis to analyze identified barriers to women's participation in STEM in West Africa and suggest appropriate recommendations for decision and policy making. In this paper, section 2 is the problem statement, section 3 presents the literature review, section 4 presents the factors affecting gender gap in marine engineering and related STEM fields in West Africa, section 5 is the methodological framework, section 6 is an illustrative example and the conclusion is presented in section 7.

II. PROBLEM STATEMENT

Academic experiences of students are greatly influenced by peer groups, in which sexual orientation can play a role in effective socialization [11]. If the factors influencing the gender gap isn't taken seriously to bridge the gap in STEM in West Africa, it will cause a drop in the percentage of women in STEM. There is a need for research in the STEM sector in West Africa as the level of ladies with STEM degrees drops worldwide from 25% to 24% [11]. Marine science encompasses the systematic study of the structure and behavior of the physical and natural world through observation and experiment [12]. Marine technology is the application of scientific knowledge for practical purposes [12, 13]. Technology, science and mathematics, provide students with insights into how different processes of knowledge are initiated and how innovative technological processes are developed and employed [14, 15]. STEM has played an important role in improving the quality of human life and development as well as shaping the West African society [16]. Limitations in this aspect will be pertaining to women, since it is assumed science and math are field of males, ignoring the ideas and innovations of women [17]. However, women have played vital role in the STEM field. Mary Somerville, a Scottish astronomer and mathematician was the first woman to be admitted into the Royal Astronomical Society [17]. Again, Ada Lovelace, a gifted mathematician, was considered to have written instructions for the first computer program in the mid-1800s [18]. Also, Radia Joy Perlman an American computer programmer and network engineer – working for digital equipment corporation - was famous for her invention of the spanning free protocol, fundamental to the operation of network bridges [19]. In October 2019, national aeronautics and space administration (NASA) astronauts, Christina Koch and Jessica Meir, made history as the first all-female spacewalkers going to replace a faulty battery charger outside the space ship [19]. The maritime industry is the life blood of international trade with a vast need for technical, legal and administrative branches relative to sea, ships, shore-based institutions & facilities that make sea transport and sailing possible [20, 21]. The maritime industry offers many job opportunities such as design and building of ships, naval architect, maritime environment/resources management and protection, training of personnel in the maritime industries and schools, hydrology, ports and harbor technical management, managing of internal water resources, etc. [21]. In 2015, the need to advance women's role in maritime activities became a subject of unprecedented awareness and interest. The international transport workers' federation estimates that, only 12% of the world's maritime workforce is made up women, leading to the launch of the women in maritime outreach program in 1988 with seven (7) regional associations in Africa, the Middle East, Asia, Caribbean, Latin America and Pacific, covering seventy (70) countries [22, 23]. Again, the association of women managers in the maritime sector in eastern and southern Africa (WOMESA) was also initiated in 2007, under the International Maritime Organization's (IMO) program on the integration of women in the maritime sector (IWMS) [20]. Furthermore, the IMO picked "*Empowering Women in the Maritime Community*" as its theme for World Maritime Day in 2019, emphasizing on the need to increase women work force in the maritime sector. Likewise, the international labor office has been holding global sectorial meetings, discussing opportunities for women seafarers with the European Union having a dedicated platform for changes to promote equal opportunities [23]. In the UK, the introduction of the new women in maritime charter has seen around sixty (60) signatories, with companies such as BP shipping, Hapag-Lloyd (UK), and Stena Line UK, signing up to the action plan on meeting several gender diversity targets [23].

III. LITERATURE REVIEW

A research was carried out on using blended learning approach to support women returning to STEM at the Open University, Milton Keynes University, UK. This study examined a unique blended learning model and its delivery through a partnership between an online distance education provider and a community-based gender equality organization on supporting a group of women returning to STEM after a career break [24]. The participants in the study were a cohort of forty (40) women in Scotland. The tool used for the gathering of data was a survey questionnaire with both graded and open questions to acquire relevant quantitative and qualitative data [24]. Survey responses showed an overall satisfaction of the participants regarding the content and time invested in the course. The main interest of this survey was to determine if the female had previously experienced any online learning. The overview results indicated that, 44% of the women responded to the need for online courses to encourage women participation in STEM [24]. This paper revealed the need for mixed versatile and adaptable learning approaches to encourage a viable learning atmosphere for women [24]. Another study carried out by the department of teaching and learning in Vanderbilt University, Nashville, USA, on the troubled success of black women in STEM was particularly revealing [25]. This paper examined the experiences of three (3) high-achieving black undergraduates and graduate women in STEM undergoing any form of structural racism and sexism [25]. An in-depth interview approach was used, for data collection, which was particularly useful for investigating the insider perspectives required to attain a phenomenological qualitative data in line with a composite description [25]. Each lady recounted on some notable occasion that featured bigotry, sexism and race-sex predisposition in relation to their education [25]. In this light, making connections to underrepresentation of women in STEM fields by highlighting societal perception and belief needs further research [26]. Furthermore, another study on the effects of female role model on academic performance and the persistence of Women in STEM studies has been carried out [27]. The results identified the need for female mentors in education to help shape the future of young ladies in STEM as well as the use of STEM media and family on impacting early child presentation to STEM education. Research examining the role played by the family factor to bridge the gender gap in STEM has received little attention [28]. A research on investigating the connection between media use, family setting and children's science and math aptitudes of American guardians of three (3) to five (5) years was illuminating, as results shows that family plays a vital role for pathways for youngsters [29, 30, 31]. Another study on college students' perception of gender stereotypes aimed at investigating whether sexual orientation might be a potential clash with cultural convictions about STEM fields was particularly revealing [32]. Results show that, ladies decisions on whether to enter certain STEM professions could be culturally motivated. If however, genuine role models are strategically provided than just a mental intercessions, then, the results would be more fruitful [33, 34]. Again, persuasive procedures to demonstrate specific STEM careers is of great importance, as role models are perceived more competent in playing this role [35, 36, 37 and 38]. Shared zone accomplishments in line with gender, race and ethnic group plays an important role in West Africa to encourage and increase the number of ladies in STEM [39, 40, and 41]. Again, the promotion of mathematics by parents in West Africa to their wards can be seen as a great means of early exposure to STEM education [42]. In supporting the national development agenda in West Africa, Tullow Ghana Limited organized programs to improve and inspire the teaching and learning of STEM in Ghana, with the overall objective of building capacity and skills acquisition in STEM fields from the basic to the tertiary level [43]. Table 1 presents list of authors with research interest on encouraging gender participation in STEM fields.

TABLE I. LIST OF IDENTIFIED RESEARCHERS IN STEM

s/n	AUTHOR	TITLE	YEAR
1	K.J. Sheehan & B. Hightower	STEM Media in Family Context	2018
2	K. Piatek-Jimenez & J. Cribbs	College Students' Perception of Gender Stereotypes	2018
3	S.D. Herrmann, R.M. Adelman, J.E. Bodford, O. Graudejus, M.A. Okun & V.S. Y. Kwan	The Effects of a Female Role Model on Academic Performance of Women in STEM Courses	2016
4	C. Herman, R. Gracia, L. Macniven, B. Clark & G. Doyle	Using a Mixed Mastering Method to help Females returning to STEM	2018
5	R.B Adams & B.M. Barber	STEM Parents and Women in Finance	2018
6	J. Acheampong	Tullow Ghana Promoting STEM Teaching and Learning	2019
7	C. Boateng	Women must Dedicate themselves to Technology	2019
8	P. Obo-Nai	Vodafone CEO joins Advisory Council of W.A. STEM Hub in Ghana	2019
9	E. Bruce	Siemens Support STEM Education in Ghana	2019
10	G. Mawuli	Project to train girls in ICT Launched in Ghana	2020

Tullow Ghana in collaboration with its partners, constructed six (6) schools in six (6) fishing communities, teaching 7,220 students and training 120 kindergarten teachers and headmasters in STEM. This collaboration also included the provision of scholarships and internship to female brilliant students in STEM [43]. It has been further highlighted by UNESCO that, young ladies should exploit STEM training. UNESCO laid down some effective strategies that could get more women and girls into science-related fields, and addresses the long-standing inclinations and sexual orientation generalizations that drove ladies and young ladies from science [44]. Another measure taken by UNESCO to improve STEM in Ghana, is enhancing the instructing practices of science educators to make STEM programs all the more engaging to young ladies in public arena [44]. International perspective for policy and governance (IPPG) also provided ways of increasing the number of females in STEM by providing science livelihood fairs. Also, arrangements were made by IPPG to use research/government-private division responsibility, in empowering women to surpass their desires in the field [45]. Also, the IMO has placed specific reverberation focus on sex balance and propelling ladies in the oceanic area [46]. IMO and the sustainability development goal has in the course of recent decades, helped ladies arrive at administrative positions in the maritime domain, thereby bringing the necessary sexual orientation equalization through the organization of several conferences and capacity building programs [46, 47].

IV. FACTORS AFFECTING GENDER GAP IN STEM IN WEST AFRICA

The under-representation of women in STEM and its careers continues to be an issue of compelling puzzlement and the factors affecting gender gaps in West Africa are family, cultural, lack of role model, confidence deficit and lack of early exposure as presented in Table 2 [48].

A. Family Factor

The personal family choice appears to be a much more significant factor in the decision to pursue high-level careers in math-intensive fields and other marine related STEM courses [49]. Lack of participation of members at home, late exposure of ward to STEM fields, and the inability of young ladies' understanding on balancing work and family life, are the major concerns in families affecting the role played by ladies in STEM.

Children can be introduced to STEM, either from direct coaching of family [50, 51] or relatives indirectly exposing youngsters to learning media [52, 53]. Families and teachers in the STEM field need to encourage young women participation in STEM fields through seminars and related workshops [54, 55]. Again, families can influence children's STEM learning by the utilization of STEM learning devices (such as 3D puzzles, question cards, molecular growth, gyros, robots, geometry, etc.) [55]. Furthermore, there is a need for a balanced work life for young ladies in STEM careers, as research shows that there is a confusion in balancing STEM and family life among young ladies [56, 57, 58]. In this light, workshops on maintaining a balanced work life for women in West Africa are to be organized more regularly. Lastly, ladies in STEM are more likely to have partners in STEM, hence a "two-body problem" may exist, as the man's career is frequently given priority [59, 60].

B. Social Factor

Learning environment and social conviction greatly influences young ladies accomplishments in STEM subjects [61]. Cultural, stereotype and bias are the main influencing factors that leads to social gender gap in STEM. STEM sub-disciplines with a clearer social reason, such as medicine, have a higher number of ladies than other sub-disciplines such as engineering (due to the notion that engineering is difficult) [62]. Turkey with fewer females in STEM fields and with increase in sexual orientation separation, has seen an increase in stereotyping [63, 64]. In other countries, women don't go into STEM fields because it is seen as only for men, with this perception enforced by stereotypes that view science and math too difficult for women. Stereotypes can develop a fear for young girls in these subjects – which then later limits their career options [64, 65]. Again, society sees ladies in STEM occupations as less competent than men unless they are on top [61]. Likewise, ladies in STEM areas can encounter the predisposition that adversely impacts their advancements and interest, resulting in few ladies in STEM quitting their positions [61, 66]. In Ghana, the Ministry of Education and International Ghana in recent years organized capacity building programs on empowering the girl child and reducing stereotyping necessary for national development.

C. Believe Factors

The belief factors affecting women in maritime STEM fields in West Africa are biological, societal underestimation of females, and self-efficacy. On underestimating of female capabilities, the idea that men are numerically prevalent and naturally superior suited to STEM areas than ladies, remains a common conviction in West Africa [57, 67]. Although research shows that men's cerebrums are bigger than that of women, it is however inclusive on how this plays a gender gap in STEM as both the female and male brains have the same number of cells [68]. If the society accepts the capability of women in STEM, females are less likely to lose certainty [69]. In this light, children's belief about their abilities are central in exceling in STEM fields [70]. Lastly, women who believe with self – assurance that they could excel in STEM are more likely to graduate with a maritime STEM related degree and pursue STEM careers [71, 72, 73].

D. Confidence Deficit

Even though young men may outflank young ladies at the most elevated levels on math and science state-sanctioned tests, young ladies generally show signs of improvement in math and science than young men [74]. As ladies go through their education, confidence from the society and family turns to move them forward [75]. In Ghana for example, capacity building programs on improving digital literacy rate in girls has been used to enhance and broaden their knowledge.

E. Early Exposure Delay

The transition from high school to college is a vital point where a lot of ladies leave STEM courses when not interested [76]. Research shows that, STEM subjects start in middle school and develops in high school to university, therefore, if these stages are not well – natured, the gender gap in STEM will continue to expand [77]. A delay in exposure to STEM learning opportunities and the lack of educational media in schools, are the main contributory factor. Research shows that youngsters who got science guidance for a longer time frame and more consistently in kindergarten, performed superior to peers on a science appraisal in third grade [78, 79]. One potential method for enhancing kids' initial STEM learning, is through the use of learning devices [80, 81].

F. Lack of Role Models

Young ladies are hardly exposed to females going into marine science, innovation, designing, and math fields, so have less example to follow. The absence of female examples in STEM occupations implies that young ladies have fewer individuals to gaze upward to [82]. The media publishing the accomplishments of female STEM experts, is an incredible advancement to help boost the confidence of youngsters [82]. In 2015, a product organization 'One Logic', used female architect for advertisement, setting the pace for exposing females [61]. In the maritime domain in West Africa, less female seafarers are exposed to young ladies due to lack of such advertisement.

TABLE II. FACTORS AFFECTING WOMEN'S PARTICIPATION IN MARIITME STEM RELATED FIELDS IN WEST AFRICA

Factors	Contributory factors	Attribute – i
Family - A	Family members in STEM	A1
	Exposure to STEM tools at home	A2
	Balancing between work and family	A3
Cultural - B	Cultural perspective	B1
	Stereotype	B2
	Bias	B3
Believe - C	Biology	C1
	Capabilities	C2
	Self – Efficacy	C3
Confidence – D	Lack of confidence	D1
Early Exposure to STEM – F	Early exposure to STEM	F1
	Educational media in school	F2
Lack of Role Models - G	Mentorship	G1
	Media exposing female professionals	G2
	Companies advertising females in STEM careers	G3

V. METHODOLOGICAL FRAMEWORK

A quantitative methodology called importance-performance (IPA), first developed by Martilla and James, was used to assemble and analyze the barriers to women's participation in maritime STEM related fields in West Africa. IPA is a popular managerial tool for measuring organizational performance and development [83]. IPA as a methodology, may permit extension experts to organize the attributes that affects women's participation in STEM for decision making. IPA can be define as a quantitative approach for measuring how people feel about certain characteristics of an issue or a thing [84]. This procedure has been applied to help travel industry partners identify basic insufficiencies and re-setting target needs [85]. IPA has many advantages such as [85]; (1) it generates a clear picture of how important certain elements are in comparison with their satisfaction level; (2) it is use to understand policies satisfaction and prioritization of areas for improvement; (3) it does not require excessive knowledge and application of statistical methods; (4) it helps examine management strategies; (5) it facilitates the identification of attributes' importance, underperformance or over performance [86, 87, 88, 89]. IPA has been widely used in various sectors such as tourism [90, 91, 92], education [93], medical service [94], traffic and transportation [95, 96], production [97], and general services [84, 98]. IPA- gap analysis integrates IPA and gap analysis with the use of either diagonal or quadrant model (QM) where every attribute shows up according to its mean rating on the importance - performance scale [89]. Performance for example may represent the expert's impression of the nature of how early child exposure to STEM impacts a girls interest in STEM fields, while the importance refers to the assessment of the importance of an early child's exposure to STEM [99, 100]. The IPA quantitative methodology used in this study, is favorable for examining inputs as the results are presented in numerical estimates, positioning, and classification [101, 102]. Expert elicitation and consultation meetings were utilized to accumulate information in this study [103, 104]. Three (3) female experts from the maritime related STEM field with a minimum of ten (10) years working experience assisted in drawing the data. The static tool used to analyze this data was fuzzy analysis. A Likert scale on a scale of 1-5 was used to obtain data from experts in the field to be analyzed. Likert scale: 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = Agree; 5 = strongly agree. The QM method was applied in this paper where the importance measure represents the vertical axis, and the performance measure forms the horizontal axis of the two dimensional graph [87]. The mean of importance and performance attribute data is used to make decisions based on the where data falls in the quadrant [105]. It takes the overall mean of each attribute's importance and performance, to plot in the Miller and James graph where X is performance and Y is importance as obtained using equation 1 and 2.

$$\bar{X}i = \frac{\sum_{i=1}^{n} x(i)}{n} \quad (1)$$

$$\bar{Y}i = \frac{\sum_{i=1}^{n} y(i)}{n} \quad (2)$$

Y (i) is the importance value of *i* attribute, *X (i)* is the performance value of *i* attribute and *n* = the number of experts. Equation 3 and 4 are used to draw the separation lines by taking the total mean of each attribute (X, Y) to draw the separation point. The separation lines divide the graph into four quadrants i.e., concentrate here, keep up the good work, low priority and possible overkill. Where *p* is the number of items *i*, the equations use to draw the separation lines are;

$$\bar{\bar{X}}i = \frac{\sum_{i=1}^{n} x(i)}{p} \quad (3)$$

$$\bar{\bar{Y}}i = \frac{\sum_{i=1}^{n} y(i)}{p} \quad (4)$$

VI. Data Analysis

Upon the questionnaire designed and presented to the three experts, the responses as provided in accordance with the likert scale are presented in Table 3. Using the data from table 3, the numerical formulas in equation 1 and 2 are used to get the values for X and Y as;

$\bar{X}a1 = \frac{\sum_{i=1}^{n} x(i)}{n}$ =1.67; $\bar{Y}a1 = \frac{\sum_{i=1}^{n} y(i)}{n}$ =2.00

TABLE III. EXPERT INPUT DATA COLLECTION

	Expert 1		Expert 2		Expert 3	
	P	I	P	I	P	I
A 1	1	2	2	2	2	2
A 2	2	2	4	2	4	3
A 3	4	4	3	4	3	3
B 1	3	3	2	3	3	4
B 2	2	3	4	3	2	4
B 3	3	4	2	3	1	3
C 1	2	2	3	3	3	4
C 2	2	4	1	3	1	3
C 3	2	5	1	4	1	4
D 1	3	1	2	2	1	2
F 1	2	2	1	3	2	3
F 2	2	5	2	4	2	5
G 1	2	3	1	3	2	4
G 2	1	2	2	2	1	3
G 3	1	3	2	3	1	4

The results obtained for the remaining attributes A2 to G3 from equation 1 and 2 are A2 (3.33, 2.33), A3 (3.33, 3.67), B1 (2.67, 3.33), B2 (2.67, 3.33), B3 (2.00, 3.33), C1 (2.67,3.00), C2(1.33, 3.33), C3(1.33, 4.33), D1 (2.00, 4.67), F1 (1.67, 2.67), F2 (2.00, 4.67), G1(1.67, 3.33), G2 (1.33, 2.33) and G3(1.33, 3.33). The mean scores obtained using equation 3 and 4 are (2.06 and 3.11). To plot the graph for the analysis, coordinates obtained from the analysis calculations are used. Importance analysis represents the y-axis while the performance analysis represents the x-axis. The mean scores coordinates are used to draw the quadrant for the graph. The coordinates are hence plotted on the graph falling into separate categories of the quadrant – concentrate here, keep the good work, low priority and overkill - as seen in Figure 1.

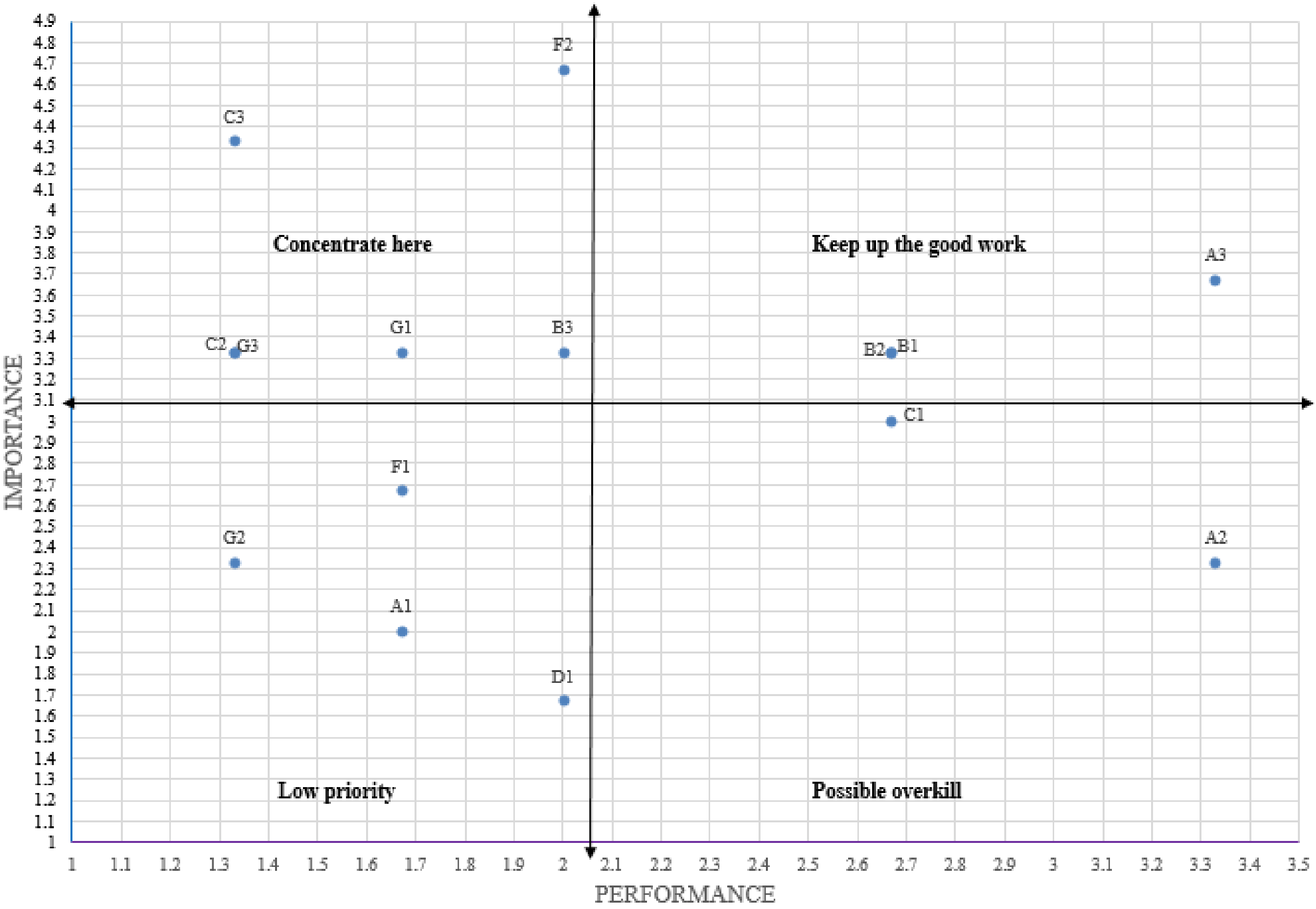

Figure 1. Important performance representation of result

The results on keeping the good work quadrant i.e., high importance and high performance (A3, B1, B2) shows the attributes with greatest strength. The areas to concentrate on - (B3, C2, C3, G1, G3, and F2) - represents high importance and low performance. These attributes are of top priority requiring immediate corrective measures. The low priority areas - (A1, D1, G2, and F1) - have low importance/low performance and represents no danger to the framework. Areas of possible overkill - (C1, A2) - have low importance and high performance. These elements have no impact on the total system and resources can be reallocated to other attributes

VII. Discussions & Conclusion

Linguistic inputs from three (3) female experts in maritime related STEM fields were consulted for this study, where IPA was used to process the input data numerically into graphical representation. Literature review reveals that a lot of interrelated factors greatly affects women's participation in maritime related STEM fields and a quantitative analysis to prioritize the barriers limiting the participation of women in STEM fields remains an area of continuous research in West Africa. The areas to improve interventions as indicated by the result of this study are confidence, belief, early media exposure of ward to STEM fields and lack of women role models. In this light, though qualified, women may lack confidence in their ability to excel in STEM careers and to correct this troubling trend in West Africa, it is crucial that educators and parents in West Africa, provide young females with hands-on STEM experiences and exposure to inspiring women role models in maritime related STEM fields. Again, early exposure of girls to STEM fields will help build confidence in STEM subjects and beyond. Also, there is a strong demand for qualified teachers and the need for a holistic and integrated women in STEM participation policies in West Africa. It is believed that having more women in STEM fields will bring about sustainable development in West Africa necessary for faster economic growth. Therefore, empowering girls and women to enter STEM fields of study and careers through workshops, conferences and seminars remains imperative. Policies have to be in place to enhance the awareness of maritime STEM education through media advertisements whereby, women already in maritime related STEM fields can participate in media discussions. Lastly, the need to strengthen the capacity of West African countries to deliver gender – responsive STEM education remains of great importance in the region.

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