



*Research article*

## **STEM education leadership and industry partnerships: Bridging the gap between educational institutions and industry**

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**Abstract:** In this research, we investigated how Science, Technology, Engineering, and Mathematics (STEM) educational programs meet the requirements of industries by studying STEM in Nigeria and South Africa. We examined how government entities, non-governmental organizations, and the industry collaborate to develop effective educational programs that connect academic institutions with industrial partners. As such, we employed a mixed-methods framework, collecting quantitative and qualitative information participants, including academics in the STEM domain, industry experts, and other education stakeholders. The research results demonstrated that neither country have the skills needed for practical problem solving and lack access to modern technologies and effective academic-industry partnerships. The comparative assessment showed that South Africa needs advanced cognitive and analytical skills, while Nigeria requires workers who have specialized technical abilities and domain-specific knowledge and can adapt from education to employment. Thus, we propose modernizing academic programs through real-world learning experiences that combine fields of study with improved industry partnerships and better resource distribution in areas with limited resources. The research findings demonstrated that Sub-Saharan African countries should improve their STEM education systems through industry partnerships to achieve Sustainable Development Goals (SDG) 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth).

**Keywords:** STEM, education, industry, curriculum, sustainable development goals (SDGs), training

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## 1. Introduction

STEM education is internationally recognized to be the driving force behind innovation, economic growth, and societal progress [1]. Countries with strong STEM education rank at the leading edge of technological innovation and industrialization, leading the world's competitive map [2]. In sub-Sahara countries, such as Nigeria and South Africa, education in STEM has immense capacity to address pressing socio-economic issues such as unemployment, poverty, and inequality [3]. These have, for a long time, hindered the nation's progress toward sustainable development. By instilling students with the skills to deal with the challenges of the Fourth Industrial Revolution, STEM education can empower both countries to unlock new opportunities, enhance innovation, and enhance their global ranking [4].

However, the success of STEM education largely depends on its applicability to the needs of industry. A well-structured STEM curriculum goes beyond theoretical studies, incorporating hands-on experience to enable accommodation in an ever-changing employment arena [5,6]. Collaboration with industry plays a central role in bridging the gap between training and the skills required by employers. These collaborations expose students to real applications of their learning in the real world, emerging technologies, and understanding working conditions [7]. They also provide educators with the avenue to integrate existing industry trends into curricula [8]. Although the advantages of such collaborations have been discerned, STEM education in Africa is not typically followed by the integration required to make students suitably prepared for the labor market. Moreover, the industry and schools operate in isolation with little interaction, to the extent that the curriculum taught aligns with the needs of employers. Isolation limits the application of the curriculum and prevents graduates from securing employment in high-demand fields. Additionally, through isolation, industry and academics miss the opportunity for collaboration and innovation, reducing the socio-economic value of STEM education.

In this study, we address such issues by examining the STEM education sector alignment in Nigeria and South Africa. The interest in the two Sub-Saharan African countries stems from the fact that they are among the top five countries in Africa for training students in STEM courses. We aim to determine how STEM courses align with the skills needed in the workplace, judging from respondents' perspectives, by employing a mixed-methods methodology to discover quantitative and qualitative findings. Moreover, we strive to determine whether the current education system provides students with skills that are suitable for industry needs and how the government and NGOs can facilitate the interaction between education leaders and industry players. We examine existing efforts to bridge the gap between education and industry, as well as applied research.

Our overall aim of the study is to probe into the adequacy of STEM training in the two sub-Sahara Africa countries and investigate the sufficiency of institution-industry partnership of STEM since curricula can draw strength from the institution-industry partnership. We aim to promote high-quality education and drive partnership between the education sector and industry, which matches Sustainable Development Goals (SDG) 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth).

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## 2. Literature review

### 2.1. Global and African perspectives on STEM education

STEM education is crucial for driving innovation, boosting competitiveness, and tackling global challenges [9]. Countries with strong STEM education systems, like the United States, Germany, and South Korea, consistently outperform others in technology, industry, and economic growth [2]. These countries have prioritized STEM education to ensure their workforce has the necessary skills to succeed in the digital economy and the emerging job market. Research indicates that effective STEM education systems produce skilled workers and promote socio-economic development. According to [2], countries that invest in STEM education tend to experience greater innovation, productivity, and economic success.

In developing countries, such as Nigeria and South Africa, governments increasingly recognize the significance of STEM education in addressing issues like high unemployment, poverty, and inequality [10]. The National Development Plan (NDP) emphasizes the need for developing a skilled workforce in key areas, especially in STEM fields, to boost economic growth and reduce socio-economic gaps [11]. Nevertheless, Nigeria and South Africa face considerable challenges in their education systems, including insufficient resources, outdated curricula, and a shortage of qualified teachers. Studies by Mushayikwa & Stephen (2022) [12] highlight that despite growing awareness of the need to prioritize STEM education, the school-industry partnership is not sufficient in the curriculum, except for three to six months of Students Industrial Work Experience Scheme (SIWES) in Nigeria and Work-integrated learning (WIL) programs in South Africa for STEM-related courses. When students go for SIWES and WIL, some engage in experience that is different from their studies owing to not being able to secure a place in their fields or prefer to work in a more convenient organization, thereby defeating the purpose of SIWES and WIL. The disconnect between classroom learning and industry needs often leads to a mismatch in the skills students acquire and those employers seek.

The Nigerian and South African STEM education industry relationship shows extreme differences, which are caused by rural challenges and the needs of underrepresented communities [13]. The two countries share systemic issues like outdated curricula, absence of collaboration with industries, and resource and opportunity imbalances [14]. The reports highlight the essential interventions of governments, businesses, and education systems in countering these challenges to develop a workforce that can fulfill the needs of the new economy [15].

Here, we focus on co-creation of curricula, investment in a rural STEM education infrastructure, and developing practical skills to bridge the gap between academia and industry. The two nations will create a more innovative and inclusive STEM ecosystem through better stakeholder partnership development and gender gap reduction [16,17]. The programs support SDG 4, which focuses on Quality Education, and Sustainable Development Goal (SDG) 8, which promotes Decent Work and Economic Growth [18]. The solution to these problems will lead to two benefits for Nigeria and South Africa because it will improve employability and economic productivity while creating sustainable socio-economic development [19].

STEM education partnerships with industry need operational partnerships and ecosystem development combined with institutional collaboration and labor market requirements to reach their maximum potential [20]. The study by [21] shows that multiple STEM ecosystem models, which

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exist in different forms, can develop according to the industrial structure and workforce requirements of each nation. The study shows that the Nigerian STEM education system in Africa display fundamental differences because of its operational systems and their treatment of rural communities and underrepresented student groups.

The two countries being studied share systemic issues like outdated curricula, absence of collaboration with industries, and resource and opportunity imbalances. The reports highlight the essential interventions of governments, businesses, and educational systems in countering these challenges to develop a workforce that can fulfill the needs of the new economy. We investigate three areas, which include co-creation of curricula, investment in rural STEM education infrastructure, and development of practical skills that serve as a bridge between academic institutions and industrial workplaces. Successful education-industry partnerships exist worldwide, which address the gaps between educational outcomes and industry needs. A prominent example is the collaboration between the Massachusetts Institute of Technology (MIT) and leading technology firms, resulting in a curriculum that merges academic rigor with industry-relevant skills [22,23]. The researchers in [24] stressed the successful implementation of industry and educational institutions in Germany, showing that the dual system adopted significantly contributed to Germany's low youth unemployment rate and high levels of innovation.

In Nigeria, partnerships between universities and industry are gradually emerging. For example, Covenant University, Nigeria, has teamed with Huawei to create Information and Communication Technology (ICT) training centers, giving students skills in telecommunications and cybersecurity [25]. Similarly, the Nigerian Content Development and Monitoring Board (NCDMB) collaborates with universities to improve STEM capabilities in the oil and gas sector, offering scholarships, internships, and research funding [26]. In South Africa, there are some successful small-scale initiatives, such as the partnership between the University of Cape Town (UCT) and renewable energy companies. UCT's Centre for Renewable and Sustainable Energy Studies collaborates with firms like Siemens and Enel Green Power to create research projects that contribute to sustainable energy solutions and provide students with real-world experience [27]. The UCT and renewable energy companies have formed a successful partnership that serves as one of several effective small-scale projects operating throughout South Africa. Through its research partnership with Siemens and Enel Green Power, UCT's Centre for Renewable and Sustainable Energy Studies develops sustainable energy solutions. The South African government created the National Skills Development Strategy (NSDS) to establish educational pathways that meet labor market requirements through partnerships between educational institutions and major industry sectors, including mining and agriculture and ICT [28].

The literature demonstrates two significant research gaps because STEM education research shows economic development links and successful education-industry partnerships; however, both fields need more research. Research in developed countries provides most findings, while developing countries like Nigeria and South Africa face unique challenges that remain undocumented in the literature. The studies showing that industry partnerships have achieved success did not provide a comprehensive examination of the long-term effects of these collaborations on graduates' career paths and the wider economy.

Also, literature often concentrates on either education or industry, with few researchers looking at the mutual relationship between them. More research is needed on how education providers can

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collaborate with industries to co-create curricula, design internships, and ensure that students develop the practical skills that employers value. Although the role of government and NGOs in supporting education-industry partnerships is acknowledged, there is limited evidence on how these stakeholders can effectively facilitate these partnerships in the Nigerian and South African contexts. Even though the significance of STEM education and industry collaboration is widely acknowledged, there is a considerable gap in understanding how these sectors can collaborate more effectively in both countries. Addressing these gaps is vital for building a workforce with the skills needed to meet 21st-century challenges and promote sustainable economic growth. The procedure used for data collection is discussed in the following sections.

### **3. Materials and methods**

#### **3.1. Study design**

In this study, we adopt a mixed-methods approach, blending quantitative and qualitative research methods to explore the connection between STEM education and industry needs in South Africa and Nigeria. This approach facilitates a thorough analysis of measurable aspects of the education-industry gap and the contextual factors influencing cooperation between these sectors. By integrating both methods, we aim to provide solid, evidence-based insights into how well STEM education aligns with workforce demands.

The quantitative aspect gathers large-scale data to identify trends, while the qualitative component offers insights that capture the varied experiences of stakeholders in education and industry. This mixed-methods approach enables data triangulation, where findings from one method can be verified and enriched by the other. This design enables us to determine how well STEM trainings match industry needs as well as the wider challenges in education-industry partnerships.

We include STEM Educators from tertiary institutions responsible for shaping the STEM curriculum and people from the industry. This group forms the largest section of the sample and was drawn from urban and rural areas across Nigeria and South Africa, with respondents covering a range of STEM disciplines. A total of 120 participants took part in the study, with 67 (55.8 %) from Nigeria and 53 (44.2%) from South Africa. There was a strong response rate compared to typical online surveys, and we examined their views on the alignment between STEM education and industry requirements. Industry Leaders included employers and executives from STEM-related fields, particularly in technology, engineering, and manufacturing. These individuals provided insights into the required skills in the workforce and how STEM education can better align with industry needs. The statistics for the proportion of responses by categories of responses are detailed in the Results section, sharing perspectives on initiatives to enhance STEM education and foster collaboration between schools and industry.

Data were collected with a well-structured questionnaire and semi-structured interview and are accessible online for the convenience of participants who prefer completing the survey online. Moreover, we used a quasi-experimental approach to address differences in engagement between active and non-active STEM participants, following methodologies used in another research [29].

The sample included a balanced representation from students, educators, industry leaders, and other education stakeholders, providing a multi-faceted view of the challenges and opportunities in STEM education and its alignment with workforce demands in Nigeria and South Africa.

### 3.2. Data collection

The data for this study were gathered from a structured questionnaire and semi-structured interviews. The questionnaire consisted of six sections, capturing participants' general background, perceptions about how STEM education aligns with industry needs, and the extent to which STEM education is adequate for skill development, as well as industry engagement and resource availability. The questionnaire also inquired about how successful STEM education is in preparing students for entering the workforce.

In addition to the survey, semi-structured interviews were conducted to gain richer insights into the participants' experiences and perspectives regarding the role of industry in STEM education and how partnerships might enhance the educational experience. Due to saturation, a total of 16 people were involved in the interview. The link to the interview is provided in the Appendix. This combination of quantitative surveys and qualitative interviews provided a comprehensive analysis, ensuring broad insights and rich, detailed perspectives on the alignment of STEM education with industry needs in both countries.

To ensure the research tool was dependable, a reliability analysis was conducted. Cronbach's alpha is provided in Eq. (1):

$$\alpha = \frac{k}{k-1} \left( 1 - \frac{\sum \sigma_i^2}{\sigma_T^2} \right) \quad (1)$$

where:

$k$  = number of items

$\sigma_i^2$  = variance of each item

$\sigma_T^2$  = total variance

The study reported:

Cronbach Alpha  $\approx$  0.8601 (High reliability)

Cronbach alpha was used to evaluate how consistently the items measured the intended concepts, and the result was 0.8601 for all 25 items. This score showed a very high level of internal consistency, meaning the instrument appropriately captures leadership styles, school culture, and resource management practices. A strong alpha value also indicates that the items work well together and produce stable results, which is important for drawing meaningful conclusions. This level of reliability strengthens confidence in the findings and aligns with standards reported in other research [30].

### 3.3. Ethical procedure

Before embarking on the study, the ethics procedure was followed with the ethics committee of the University where the research was conducted, and the documents provided included participants' information sheets, approval from the organizations where the study took place, informed consent from the participants, the survey instruments, and a detailed proposal. The process of ethical clearance started in May 2025, and the study did not start until it was finalized.

### 3.4. Data analysis

Quantitative data analysis was conducted utilizing SPSS software developed by International  
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Business Machines Corporation (IBM), version 30. The analysis encompassed descriptive statistics, including frequencies, means, and standard deviations, to encapsulate overall information and the feedback received from the questionnaires. To examine the relationship between the variables, Pearson's product-moment correlation was employed. Additionally, multinomial logistic regression was performed due to the categorical nature of the response variable. The qualitative part was conducted using Atlas.ti 9.

### 3.4.1. Logistic regression

The Logistic regression model is of the form:

$$f(x_i) = \ln\left(\frac{\tau_i}{1 - \tau_i}\right) = x_i\beta \quad (2)$$

Further solving gives

$$\tau_i = \frac{e^{x_i\beta}}{1 + e^{x_i\beta}} \quad (3)$$

The maximum likelihood function based on Eq (1) is given as

$$L = \sum_{i=1}^n y_i \log(\tau_i) + \sum_{i=1}^n (1 - y_i) \log(1 - \tau_i) \quad (4)$$

Taking partial derivative of (3), we have

$$\frac{\partial L}{\partial \beta} = \sum_{i=1}^n (y_i - \tau_i)x_i = 0 \quad (5)$$

The maximum likelihood estimate based on Eq. (3) would be computed based on iteratively reweighted least squares (IRLS). Details on the estimation of the parameters of logistic regression can be found in [31] and [32].

Interview data were thematically analyzed using atlas.ti 9, seeking patterns and repetition in responses. The following analyses contextualized the quantitative findings by exploring the factors and perceptions that underpin the use of online tools in teaching algebra.

The variables used for binary logistics included a dichotomy response variable Urban (0 = rural, 1 = urban).

Covariates were: (i) Skills, (ii) ind\_prof., (iii) focus, (iv) fit, and (v) expertise. Variables (i) to (v) in full can be expressed as:

- (i) The current STEM curriculum aligns well with the skills needed in the workforce.
- (ii) Consultations of industry professionals during the development of a STEM curriculum.
- (iii) Clear focus on teaching practical skills in STEM education.
- (iv) Employers find that STEM graduates are well-prepared for entry-level positions in the industry.
- (v) The skills taught in STEM programs meet the technological advancements in the industry.

Substituting variables into Eq. (2) gives:

$$\tau_i(X) = \frac{e^{(\beta_0 + Skills \beta_1 + Ind\_Prof \beta_2 + focu \beta_3 + fit \beta_4 + experti se \beta_5)}}{1 + e^{(\beta_0 + Skills \beta_1 + Ind\_Prof \beta_2 + focu \beta_3 + fit \beta_4 + expertise \beta_5)}} \quad (6)$$

### 3.5. Justification for the methodology

We selected the mixed-methods approach because it enabled us to examine how STEM education connects with industry requirements. The quantitative data showed statistical proof about how STEM curriculum standards matched or did not match industry needs. This combination enabled the triangulation of data, which enabled us to verify and enrich our quantitative results using qualitative data.

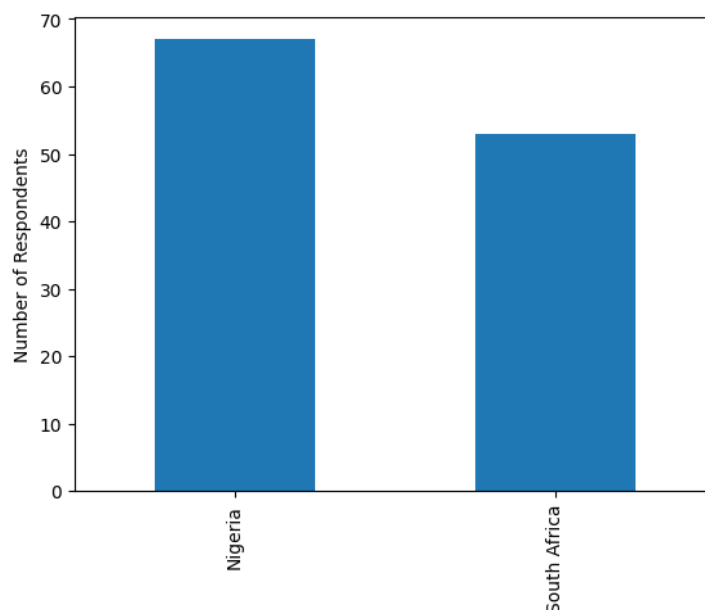
The thematic analysis of the qualitative data enabled us to investigate all contextual elements that create the education-industry gap. We need quantitative data and qualitative information to accomplish our goals, which will help improve STEM education in Nigeria and South Africa by better matching educational programs with industry requirements.

## 4. Results

In this part of the research, we provide an overview of our findings. We look at STEM education and its link to industry relevance, with 67 (55.8%) of respondents from Nigeria and 53 (44.2%) from South Africa. Our findings come from quantitative and qualitative analyses, each providing insights into demographic data of the respondents, perceptions of STEM education relevancy, and overarching system challenges faced in relation to education and industry. Together, the findings also revealed some urgent gaps in STEM education, thus giving rise to a conversation around how to best leverage the findings to enhance collaboration between education and industry, as well as curriculum development and skills development in Nigeria and South Africa.

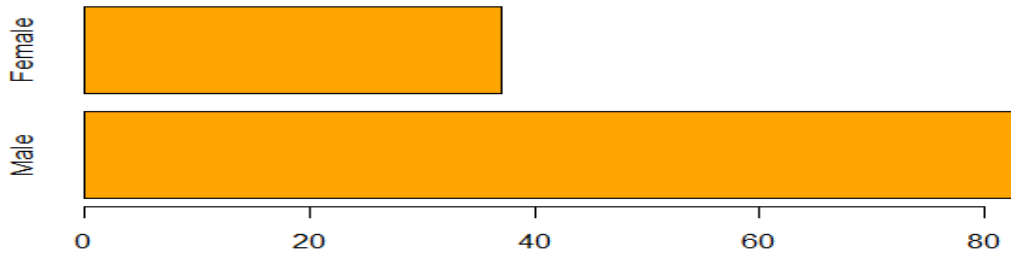
### 4.1. Demographic statistics

Demographic data can be found in Figures 1 to 6, including respondents' profiles and, by extension, the relevance to the study on STEM education and industry relevance.



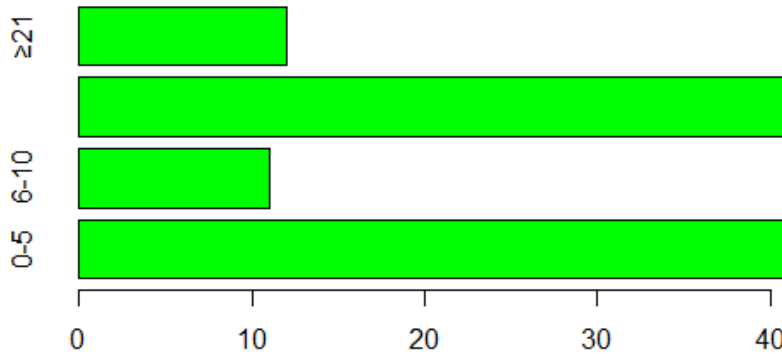
**Figure 1.** Distribution of respondents by country.

Figure 1 shows that the sample was obtained from 120 people who participated in the study, showing that 67 people were from Nigeria and 53 people were from South Africa, making up 55.8% and 44.2% of the sample, respectively. This created a moderately balanced sample that researchers could use to study cross-country differences.



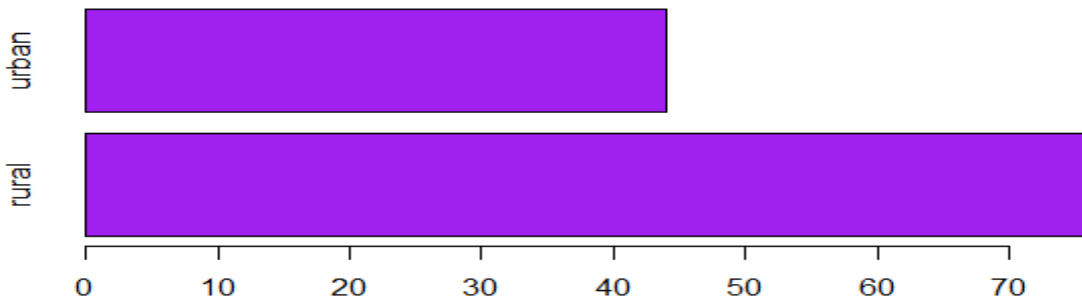
**Figure 2.** Gender.

Figure 2 represents the gender mix of the respondents. The number of Male respondents (83) was greater than the number of female respondents (37). Through a percentage count, this represented a disparity of 69.2% to 30.8%. The trends (the percentage of men to women respondents) were consistent with observed trends of men and women who enter STEM related fields.



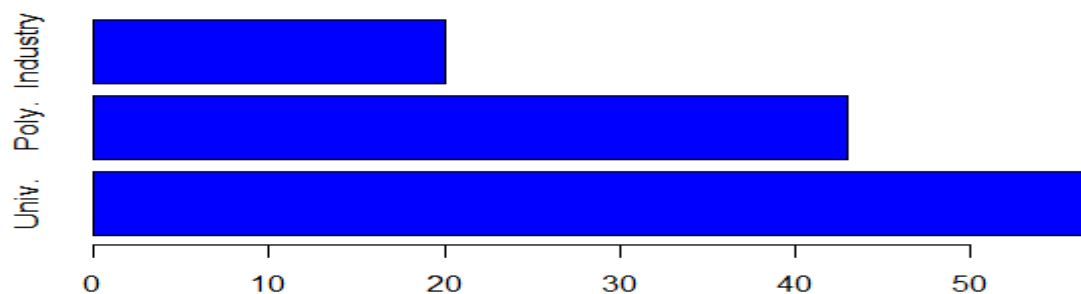
**Figure 3.** Year of experience.

Based on Figure 3, in terms of professional experience, 49 (40.8%) had 0-5 years of work experience, representing early career, 48 (40.0%) had 11-20 years of work experience, representing mid-career, while senior professionals with over 21 years of experience constituted only 12 (10.0%), while those with 6-11 years represented 11 (9.2%) of the respondents.



**Figure 4.** Settlement type.

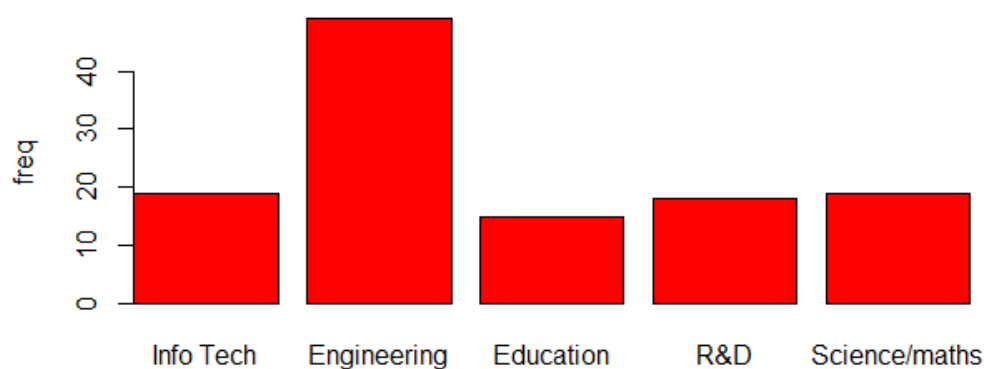
From Figure 4, most respondents were from urban areas 76 (63.3%), while rural representation was lower 44 (36.7%), potentially highlighting disparities in access to STEM opportunities and infrastructure between urban and rural settings.



**Figure 5.** Organization type.

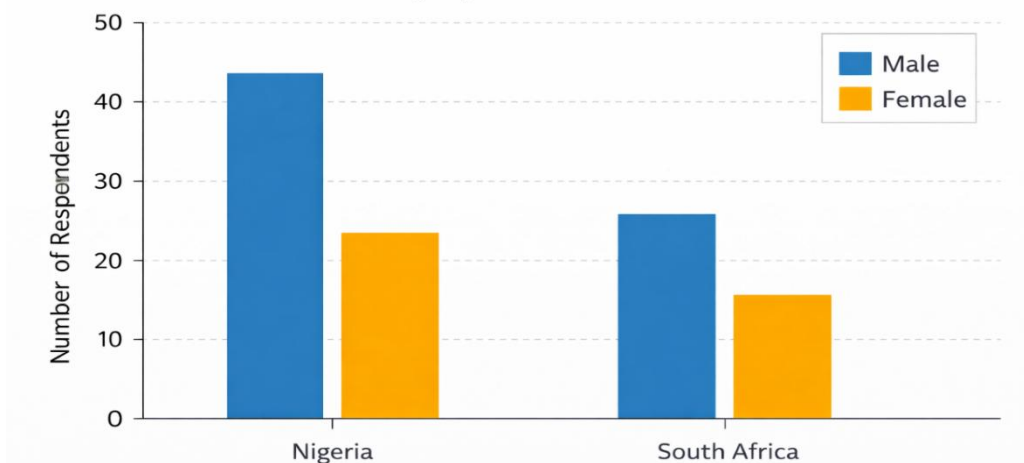
From Figure 5, the distribution in Figure 4 could be summarized as: 57 (47.5%) of the participants in the university were either a student, technologist, or lecturer, 43 (35.8%) worked in the polytechnic, while 20 (16.7%) were in the industry.

Overall, demographic data provided a diverse pool of perspectives, albeit with a strong academic and urban representation, which may have influenced the interpretation of findings related to STEM education and its alignment with industry needs.



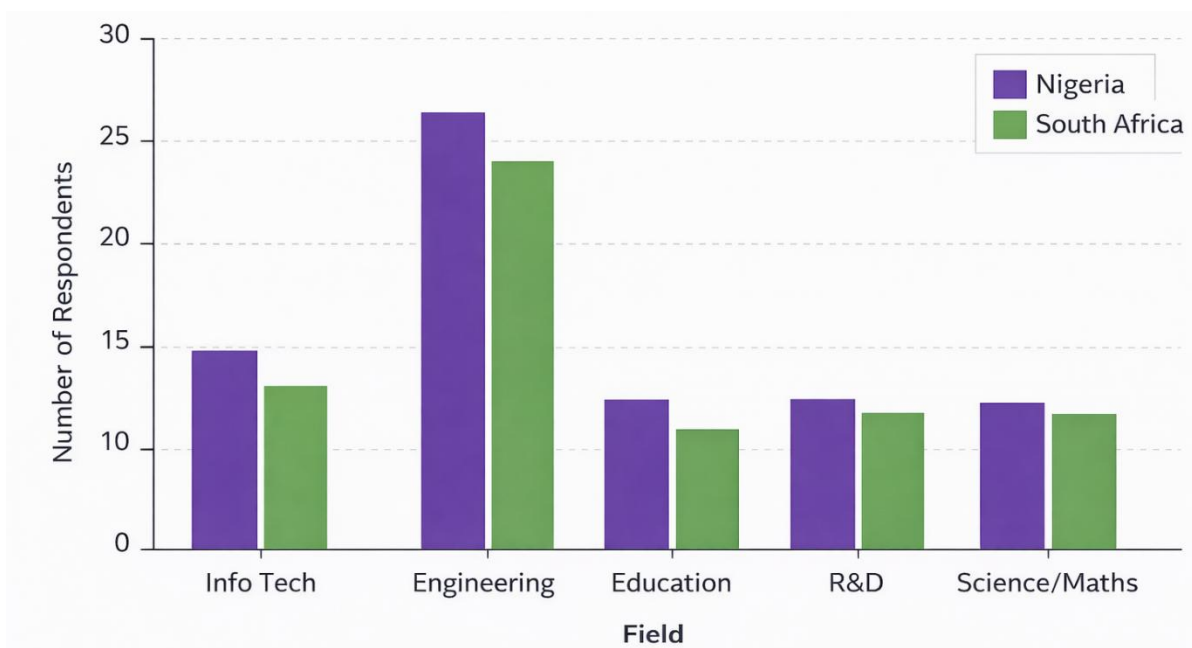
**Figure 6.** Field.

From Figure 6, Engineering was the dominant field of expertise, with 49 (40.8%), followed by a relatively even distribution across Information Technology, with 19 (15.8%), Science/Mathematics, Research/Development, and Education were both 15 (12.5%) and 18 (15.8%), respectively. This indicated a strong technical and scientific foundation among respondents, which is critical for evaluating STEM-industry alignment. The respondents in Research/Development came to 18 (15.0%).



**Figure 7.** Distribution of gender by country.

Figure 7 shows that, in Nigeria, males accounted for about 46 (68.7%) and females 21 (31.3%), while in South Africa, males were about 37 (69.8%) and females 16 (30.2%). In both countries, male respondents dominated the sample. Moreover, male participants made up 69.2% of the study group while female participants made up 30.8% of the study group.



**Figure 8.** Distribution of field by country.

Figure 8 shows that engineering recorded the highest proportion of respondents in both countries, with Nigeria having 26 (33.8%) and South Africa 24 (34.3%). Information Technology followed with 15 (19.5%) in Nigeria and 13 (18.6%) in South Africa. Education, R&D, and Science/Maths showed equal distributions within each country. In Nigeria, each field had 12 (15.6%), while in South Africa, each recorded 11 (15.7%).

## 4.2. Empirical analysis based on our objectives

**Objective 1:** Determine the relationship between STEM training and industry needs based on settlement

To determine the relationship between stem training and industry needs based on settlement, we conducted the binary logistic regression discussed in section 3 and presented in Table 1.

**Table 1.** Variables in the equation (Step 0).

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Constant	0.547	0.189	8.324	1	0.004**	1.727

The constant was significant ( $p = 0.004$ ), indicating a meaningful baseline for urban settlements. The odds ratio ( $\text{Exp}(B) = 1.727$ ) suggested that urban settlements were 1.727 times more likely to be predicted over rural settlements in the absence of additional variables. This reinforces the urban bias in perceptions of STEM training effectiveness. The classification table is presented in Table 2.

**Table 2.** Classification table (Step 1).

Observed	Predicted Settlement	Percentage Correct
Rural	Rural: 9 / Urban: 35	20.5%
Urban	Rural: 4 / Urban: 72	94.7%
<b>Overall Percentage</b>		<b>67.5%</b>

With additional variables in Step 1, the model's overall accuracy improved slightly to 67.5%. However, rural classification remained poor (20.5% accuracy), while urban classification remained high (94.7%). This imbalance suggested that STEM training perceptions are better modeled for urban respondents than rural ones, likely reflecting underlying inequalities in access to quality STEM education. The estimation of the relationship between the response variable and covariate is given in Table 3

**Table 3.** Variables in the equation (Step 1).

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Skills	0.105	.241	.191	1	0.662	1.111
Ind_Prof.	-0.378	0.248	2.321	1	0.128	0.685
Focus	-0.542	0.272	3.971	1	0.046	0.582
Fit	-0.082	0.241	0.117	1	0.732	0.921
Expertise	0.231	0.228	1.028	1	0.311	1.260
Constant	2.985	1.125	7.037	1	0.008	19.783

The variable "Focus" was the only significant variable ( $p = 0.046$ ). The coefficient was -0.542, indicating a negative relationship between the type of settlement and the level of attention given to STEM education. As the number of STEM involvement increased from rural to urban, the focus on teaching practical skills in STEM reduced. This may be because of the belief that the urban

population has a fair share of STEM education already. The odds ratio ( $\text{Exp}(B) = 0.582$ ) suggested a 41.8% reduction in the likelihood of perceiving STEM training as effective, considering the focus on technical skills acquired by the trainee. The constant ( $p = 0.008$ ) was significant, showing strong baseline odds ( $\text{Exp}(B) = 19.783$ ) for urban settlements.

**Objective 2:** Impact of training and resources on graduates' outcomes

**Table 4.** Model summary for regression.

Model	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	Std. Error
<b>Model 1</b>	0.738	0.544	0.524	0.535

The regression model explained 54.4% of the variance in perceptions of educational adequacy ( $R^2 = 0.544$ ). The adjusted  $R^2$  (0.524) indicated that the predictors (FSP1–FSP5) provide strong explanatory power. A small standard error (0.535) suggested that the model's predictions are precise.

**Table 5.** ANOVA for regression.

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	38.927	5	7.785	27.197	<0.001**
Residual	32.633	114	0.286		
Total	71.560	119			

The ANOVA confirmed that the regression model was highly significant ( $F = 27.197$ ,  $p < 0.001$ ), meaning the predictors collectively explain a substantial portion of the variance in perceptions of educational adequacy. The low residual mean square (0.286) further indicated a well-fitting model.

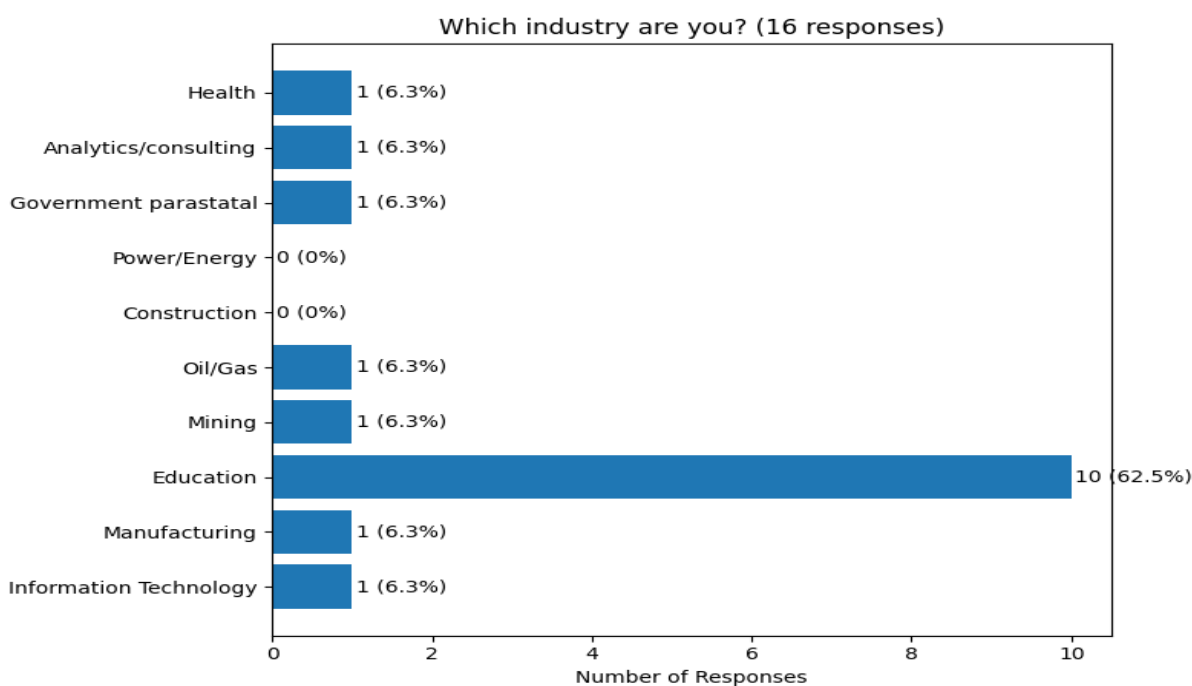
**Table 6.** Regression coefficients.

Variable	B	Std. Error	Beta	t	Sig.
<b>FSP1</b>	0.165	0.062	0.238	2.676	0.009**
<b>FSP5</b>	0.338	0.066	0.439	5.129	<0.001**

FSP1 (Practical Training) and FSP5 (Resources) were significant positive predictors of perceived educational adequacy, with FSP1 ( $p = 0.009$ ) showing that a one-unit increase led to a 16.5% improvement, while FSP5 ( $p < 0.001$ ,  $\text{Beta} = 0.439$ ) emerged as the strongest predictor, highlighting that resource availability had the largest impact on improving perceptions and educational outcomes.

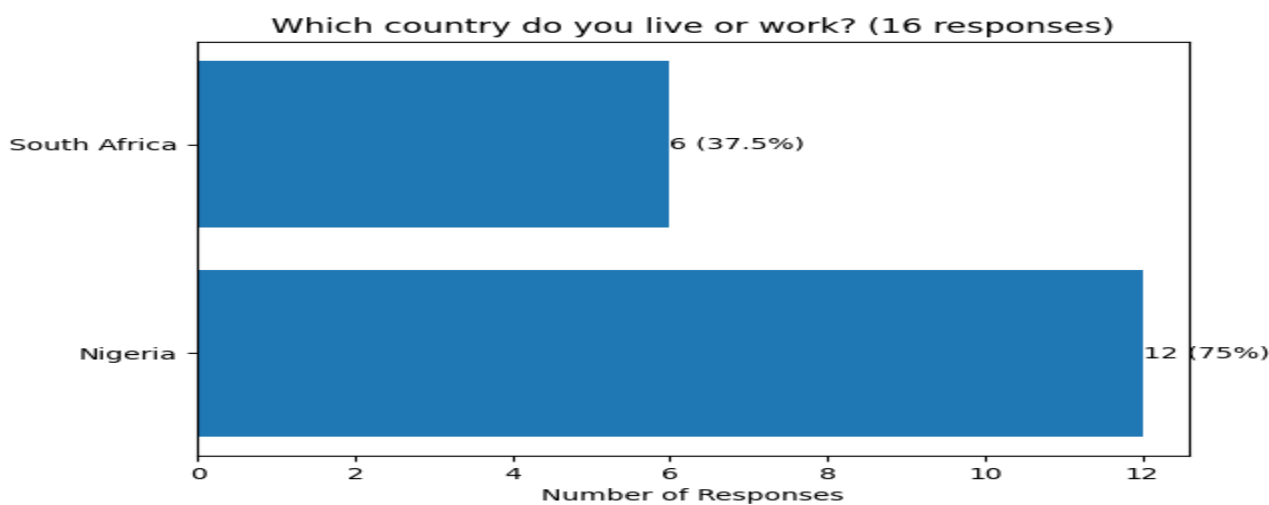
### 4.3. Qualitative analysis

The opinions of 16 respondents consisting of educators in STEM subjects, industry leaders, and education stakeholders regarding gaps, barriers, and best practices in the field of STEM education are presented. The responses were thematically grouped into four key areas: missing skills, barriers to student equipping, government and NGO contributions, and successful education-industry initiatives.



**Figure 9.** Response mix of the interviewer.

Figure 9 shows the distribution of the 16 participants who were involved in interviews from different industries. The education sector received the most responses because 10 participants (62.5%) came from that field, and each of the other sectors, Information Technology, Manufacturing, Mining, Oil/Gas, Government Parastatal, Analytics/Consulting, and Health, had 1 participant (6.3%) responding to the survey. The interviewees selected for the study, according to their requirements, reflected our method of selecting participants through purposeful sampling. We investigated STEM Education Leadership and Industry Partnerships, meaning educational leaders and practitioners received priority because they work as key staff members who develop curricula, manage educational institutions, and build partnerships.



**Figure 10.** Distribution of respondents in both countries.

We selected only a few essential industry experts who would share their insights about workforce demands and required skills and challenges during collaboration. Our results demonstrated an educational institution and industry connection that required resolution through investigative work. Table 11 provides the thematic analysis related to missing skills in the current STEM Curriculum.

The diagram displays which country interviewees live in or where they work. Nigeria recorded 12 responses (75%), while South Africa recorded 6 responses (37.5%). The total number of responses (18) exceeded the number of participants (16) because 2 interviewees selected both Nigeria and South Africa. Some participants maintained professional activities that extended between two countries through their academic research, their consultancy work, and their institutional partnerships, which involved both countries. The dual affiliation of participants showed how African STEM education and industry collaboration have developed into a transnational framework.

Our study benefitted from this research distribution because it enabled us to examine leadership practices and partnership models across regions. The two countries shared research links that connect their higher education systems with their industrial development.

The study received enhanced comparative and contextual depth through multiple-country affiliations, which some interviewees exhibited.

i. Missing skills in the current STEM curriculum

**Table 7.** Thematic analysis of missing skills in the current STEM curriculum.

Theme	Second-Level Codes	First-Level Codes
Practical Problem-Solving Skills	Coding and Programming	“The curriculum is deficient in fundamental programming and analytical problem-solving instruction.”
	Data Analysis Skills	“Students require familiarity with data analysis tools to successfully analyze and resolve real-world issues.”
Industry-Specific Knowledge	Emerging Technologies, Sector Trends	“Students are not exposed to advancements in AI, renewable energy, or automation trends.”
	Environmental Sustainability Knowledge	“There is a lack of attention on environmental sustainability techniques and green technologies.”
Soft Skills	Communication, Teamwork, Adaptability	“Graduates frequently lack collaborative competencies and proficient communication skills essential in contemporary companies.”
Hands-On Technical Skills	Laboratory Work, Technical Expertise	“STEM education lacks adequate laboratory work and industry-specific technical training.”
Exposure to Real-World Practices	Internships, Industry Projects	“Internships and projects with real industries are absent, resulting in students being unprepared for professional responsibilities.”

The interview consisted of 11 questions. Questions 7-9 of the interview directly helped us determine the strength of the relationship between the curriculum and industry partnership. This analysis revealed that the STEM curricula poorly prepare graduates for emerging industries. Moreover, the respondents recognized the complete absence of real and practical skills for problem-solving, like coding, programming, industry-specific and knowledge for most contemporary disciplines related to artificial intelligence, renewable energies, and environmental sustainability.

Soft skills, including but not limited to teamwork, flexibility, and resilience skills, were the gaps addressed, along with other hands-on skills in technical training.

ii. Barriers to equipping STEM students

**Table 8.** Thematic analysis of barriers to equipping STEM students.

Theme	Second-Level Codes	First-Level Codes
Outdated Curriculum	Theoretical Focus	“The curriculum focuses on theory and does not reflect current industry standards.”
	Limited Interdisciplinary Learning	“STEM programs hardly incorporate interdisciplinary approaches, limiting broader problem-solving abilities.”
Lack of Collaboration	Education-Industry Disconnect	“Institutions hardly engage with industries to align teaching with practical needs.”
Limited Real-World Exposure	Missing Internships, Industry Visits	“Students lack access to internships or real-world settings to apply their knowledge.”
Insufficient Resources	Infrastructure, Technology	“The lack of modern lab equipment and tools hinders effective STEM teaching.”
Inadequate Training Programs	Industry-Relevant Workshops	“There are few industry-relevant training workshops to prepare students for specific job requirements.”

The systemic barrier prevents the delivery of effective STEM educational programs. The three major barriers existed because the curriculum design used outdated methods, the program required students to study theoretical material without gaining practical skills, and the program lacked sufficient resources needed for effective operation, which included laboratory equipment and necessary infrastructure. Furthermore, students face difficulties with problem-solving during their learning process because they need to understand multiple fields of study, which their educational program does not provide.

One educator expressed his sorrow about the situation because he believed that students would enter the job market unprepared when their educational institutions failed to establish proper connections with industrial partners. The first person mentioned how "chronically underfunded" rural schools face resource shortages, which make it difficult for students to access STEM education.

Educational institutions can achieve their goals after they create two systems, which involve building educational facilities and establishing connections between schools and industries, as well as implementing teaching methods that combine different fields of study.

iii. The role of the government and NGOs

Table 9 shows that the role of governments and NGOs emerged as very important in the bridging of gaps between STEM education and the needs of industry. Indeed, respondents highlighted some initiatives such as policy development that promotes industry-education partnership, increased funding for STEM programs, and professional training workshops for educators. NGOs were noted to contribute to sustainability awareness and integrating green technology into curricula.

**Table 9.** Thematic analysis of government and NGO contributions.

Theme	Second-Level Codes	First-Level Codes
Policy Development	Industry-Education Collaboration	“Governments need to create policies encouraging industry-academia partnerships for curriculum alignment.”
Increased Funding	STEM Resource Allocation	“More funding is needed to equip labs and facilitate modern STEM programs.”
Business Incentives	Internships, Training Opportunities	“Incentives for businesses to offer internships can bridge gaps in real-world experience.”
Trend Integration	Curricular Updates, Emerging Trends	“Incorporating trends like AI, robotics, and renewable energy into the curriculum is essential.”
	Sustainability and Green Tech	“NGOs play a role in promoting sustainability and green technology awareness in STEM programs.”
Educator Development	Professional Training, Workshops	“Educators need training programs to stay updated with industry changes and teach practical skills.”

**Table 10.** Thematic analysis of successful education-industry initiatives.

Theme	Second-Level Codes	First-Level Codes
Industry-Sponsored Programs	Internships, Work-Study Programs	“Programs like Siemens’ internships allow students to gain hands-on industry experience.”
Government-Funded Projects	Curricula and Resource Development	“National funding initiatives have modernized curricula in some sectors like ICT and renewable energy.”
Public-Private Partnerships	STEM Education Support	“Partnerships with companies like Enel Green Power have created research opportunities for students.”
Collaborative Research	University-Industry Engagement	“Research projects between universities and industries foster innovation and skill development.”
National Initiatives	STEM Inclusion, Rural Focus	“Programs aimed at STEM participation in underrepresented communities are improving access.”
	Digital Skill Development	“Initiatives focusing on coding bootcamps and digital skill acquisition are bridging technological gaps.”

This was summarized to describe successful examples of collaboration between education providers and the workforce, including internships sponsored by industry, renewable energy projects funded by government grants, and public-private partnerships where work-related learning opportunities are available. More transformational examples included work to improve STEM inclusion among underrepresented communities.

One respondent described the positive outcome of a Siemens-sponsored internship program that had improved student employability because they learned through practice and had more opportunities for work exploration. Another respondent mentioned that this could be enhanced again through collaboration with institutions that conduct research with the industry.

#### 4.4. Comparative analysis between Nigeria and South Africa

**Table 11.** Analysis based on STEM and industry partnership.

Theme		Nigeria % (Freq)	South Africa % (Freq)	Key Difference
Missing STEM Skills Required by Industry	Practical problem solving	41.8 (28)	62.7 (33)	SA much stronger
	Hands-on technical skills	55.2 (37)	51.0 (27)	Nigeria is stronger
	Industry-specific knowledge	46.3 (31)	35.3 (19)	Nigeria stronger
	Industrial exposure	44.8 (30)	41.2 (22)	Very close
	Soft skills	26.9 (18)	31.4 (17)	SA slightly higher
Barriers to equipping STEM Students	Outdated curriculum vs industry needs	36 (53.7%)	32 (60.4%)	Very high concern both countries
	Weak industry–education collaboration	34 (50.7%)	30 (56.6%)	Shared structural barrier
	Limited real-world exposure / internships	33 (49.3%)	29 (54.7%)	Workforce transition gap
	Insufficient hands-on learning resources	28 (41.8%)	25 (47.2%)	Infrastructure challenge
Preferred Government/NGO Interventions	Industry–education collaboration policies	39 (58.2%)	34 (64.2%)	Strongest shared priority
	Increase STEM funding	31 (46.3%)	28 (52.8%)	Major shared intervention
	Industry-integrated curriculum programs	29 (43.3%)	27 (50.9%)	Curriculum modernization priority
	Educator professional development	30 (44.8%)	25 (47.2%)	Workforce capability strategy
	Full multi-policy intervention package	21 (31.3%)	18 (34.0%)	System-wide reform support
Existing Successful Partnership Models	Industry internships / work-study	35 (52.2%)	30 (56.6%)	Most recognized success model
	Public–private STEM partnerships	18 (26.9%)	16 (30.2%)	Strong structural support model
	Government / NGO curriculum alignment programs	15 (22.4%)	13 (24.5%)	Policy-driven alignment
	University–industry research collaboration	12 (17.9%)	14 (26.4%)	SA more research-driven
	National STEM inclusion initiatives	10 (14.9%)	11 (20.8%)	Social equity programs similar

Table 15 presents a quantitative assessment, which shows how Nigeria and South Africa differ regarding their STEM educational leadership and their industry partnerships. These serve as methods to connect educational institutions with industrial sectors.

## 4.5. Highlights from the results

The results show that there are two pathways for STEM ecosystem development, which exhibit similarities and differences across four areas, including skill gaps, systemic barriers, intervention preferences, and partnership models.

### 4.5.1. *Missing STEM workforce skills: Cognitive–technical orientation divide*

The research results show that respondents from different backgrounds view STEM workforce shortages in different ways. South African respondents reported significantly greater concern for practical problem-solving skills (62.7%) compared to Nigeria (41.8%). Moreover, South Africa's STEM labor market requirements demand advanced cognitive abilities, analytical skills, and adaptive problem-solving skills, which professionals need to work in advanced industrial sectors.

Nigerian respondents displayed greater concern for three areas, including industry-specific knowledge (46.3%), hands-on technical skills (55.2%), and industrial exposure (59.7%). The Nigerian STEM ecosystem continues to prioritize basic technical skill development together with skills needed for transition to professional work environments. The finding demonstrates that developing industrial economies require basic operational skills before they can develop advanced analytical capabilities for their workforce.

The Resource Dependence Theory explains this pattern through the existence of knowledge infrastructure and innovation ecosystems, which organizations use to access resources. Research and industrial innovation systems in South Africa create a demand for cognitive and innovation-oriented STEM skills because they serve as established systems, while Nigeria needs technically skilled graduates who can immediately work in its expanding industrial sectors.

The Institutional Theory explains South Africa's stronger cognitive STEM skill requirements because of its institutional development and its educational programs, which match international knowledge economy standards. Nigeria's technical focus shows how institutions transformed their education systems to meet local workplace requirements.

### 4.5.2. *Systemic barriers: Structural convergence with complexity differentiation*

The two nations show complete consensus about the major obstacles that prevent successful STEM cooperation between academic institutions and industry. The situation shows full agreement, which indicates that all educational institutions face fundamental issues that prevent them from meeting industry requirements. The situation shows complete agreement between the two nations about their need to establish joint partnerships with different stakeholder groups. We found that South Africa needs better systems to manage stakeholder participation, while Nigeria needs to improve its ability to coordinate between governmental, academic, and business organizations. Furthermore, the South African respondents tended to focus their answers on specific areas that needed institutional changes, which included curriculum updates and new methods of working together.

### 4.5.3. *Government and NGO intervention preferences: System reform vs policy optimization*

The intervention preference patterns reveal nuanced differences in perceived policy needs.

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Nigerian respondents demonstrated stronger support for comprehensive multi-policy intervention frameworks that simultaneously address funding expansion, curriculum redesign, educator training, policy reform, and industry incentives. This suggests a perceived need for systemic STEM ecosystem transformation rather than isolated policy improvements.

South African respondents demonstrated stronger prioritization of direct industry–education collaboration policies and targeted funding expansion. This pattern suggests that foundational institutional and policy structures may exist, with current needs focusing on policy optimization and scaling rather than systemic restructuring.

This finding supports the Institutional Theory, suggesting that South Africa may be in a phase of institutional consolidation and refinement, while Nigeria may be in a phase of institutional system building and expansion. Moreover, the intervention preference patterns show distinct differences between actual policy requirements, which people consider to be necessary. The Nigerian participants preferred to support complete multi-policy solutions that would fund educational development while updating curricula, training teachers, changing policies, and providing industry-based incentives. The data indicates that people need to transform the STEM ecosystem instead of implementing single policy changes.

The South African participants showed a greater preference for developing policies that establish direct links between industry and educational institutions and for developing financial support systems. The organizational and policy frameworks of the foundation exist, so the present requirements must be met through better policies and mode of operation expansion instead of major organizational changes. South African institutional development operates at a stage of institutional consolidation according to the Institutional Theory, while Nigeria develops its institutional system by building and expanding activities.

#### ***4.5.4. Partnership models: Research integration vs workforce transition orientation***

The partnership model analysis shows two distinct structural differences between the two ecosystems. Nigerian respondents most frequently identified public–private STEM partnerships and government/NGO curriculum alignment programs, suggesting reliance on externally coordinated collaboration mechanisms to drive STEM integration outcomes. South African respondents most often selected industry-sponsored internships and government-university research collaboration models, which demonstrate stronger institutional partnerships for industrial cooperation and paths to research commercialization. Additionally, South Africa establishes superior internal academic resource exchange systems with industries according to the Resource Dependence Theory, while Nigeria depends on external partnership systems for STEM resource acquisition and knowledge sharing.

## **5. Discussion**

The predictive model in Table 3 shows higher representation accuracy among respondents from urban areas (100%) compared to respondents in rural areas, indicating that solutions should be designed to solve the difficulties that rural STEM education experiences. The results indicate that urban areas show high baseline conformity with industry standards because urban areas demonstrate a strong preference for industry partnerships. The results demonstrate that Nigerian and South African rural communities require policy measures that will provide them equal access to

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industry-based STEM education programs.

These results agree with the literature on STEM education challenges in Africa [33]. The research study demonstrates that institutions and industries lack an established partnership framework [13,14]. This study confirms the need for industry partnerships to develop curricula and eliminate workforce shortages according to earlier research [17,20]. Additionally, our results show that rural participants expressed high levels of dissatisfaction. Moreover, there were extreme gender imbalances, creating a need for both countries to develop solutions that will create equal results.

### **5.1. Implications of the study**

Nigerian and South African policymakers must develop frameworks that facilitate the collaboration of education providers and business stakeholders. The policies should establish incentives that support curriculum co-creation while enabling feedback loops and providing resources for internships and apprenticeships, which will help students bridge the gap between theoretical knowledge and practical experience. The rural community problems require immediate solutions because governments must invest in developing STEM frameworks, educating teachers, and creating industry partnerships for their local economic development. The training program requires students to utilize technological tools, advanced laboratory equipment, and practical learning experiences. Additionally, the new school curriculum requires industry partners to provide input that will help students develop practical skills, understand technologies, and skills needed for ICT, renewable energy, and engineering fields.

Both nations need to establish programs that enable their industries to participate in STEM education through internship opportunities, mentorship programs, and research funding, which will support applied research that develops skills needed by the workforce. Technical schools and universities can partner with industry leaders to develop educational programs that will prepare students for the requirements of the Fourth Industrial Revolution. The STEM participation rates show a 69.2% male and 30.8% female distribution, which requires organizations to take deliberate steps that will increase female participation rates. The workforce in South Africa and Nigeria can become more diverse through scholarships, mentorship, and outreach programs, which will create better opportunities for underrepresented groups. Moreover, students need to develop their skills through practical training, which includes hands-on learning experiences, because this training will help them succeed in technology-based industries.

#### ***5.1.1. Integrated interpretation: Parallel but distinct STEM ecosystem evolution pathways***

The combined findings indicate that Nigeria and South Africa have developed their STEM ecosystems through separate pathways, which do not follow a single development continuum. South Africa exhibits characteristics of a knowledge-based STEM ecosystem through its research performance, which supports advanced scientific endeavors. The country pays particular attention to teaching cognitive and analytical skills required for STEM disciplines. Additionally, the country displays research partnerships because of its strong connections between academic institutions and business enterprises. The country has established formal procedures that enable businesses to work together with educational institutions through methods of collaboration.

The country displays its capability-expansion STEM system through three major elements. The

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elements are technical skill development orientation, workforce transition through industry exposure, and reliance on externally coordinated partnerships. Moreover, the country requires its workforce to possess technical abilities and needs its workforce to gain practical experience through industry exposure programs. The organization depends on multiple external partners to handle its partnership activities with various stakeholders. As such, the two nations demonstrate strong similarities because they both identify industry partnerships as the main method to connect STEM education with workforce requirements.

### ***5.1.2. Policy and leadership implications for STEM education systems***

The results indicate that STEM education leadership practices need to be developed according to educational environments. South Africa should direct its leadership efforts toward developing STEM education programs that require innovative teaching methods and research commercialization processes, and that need university expertise to become part of their educational programs. The Nigerian leadership needs to focus on developing technical skills through structured industry training programs and building STEM facilities at all professional educational institutions. The two nations need to establish better national systems for governing STEM education because multi-organization STEM leadership functions as the primary method to connect educational institutions with businesses throughout Sub-Saharan Africa.

## **6. Conclusions**

The research shows that STEM education systems in Nigeria and South Africa need to address two factors of resource and infrastructure inequality that create educational barriers in rural regions and for underrepresented student populations. The two countries share systemic issues like outdated curricula, absence of collaboration with industries, and resource and opportunity imbalances. The reports show that governments and businesses, together with educational institutions, must perform crucial tasks to solve problems so they can create a workforce that meets the demands of the emerging economy. Here, we focus on co-creation of curricula, investment in a rural STEM education infrastructure, and developing practical skills to bridge the gap between academia and industry. The two nations can create a more innovative and inclusive STEM ecosystem through better stakeholder collaboration and gender gap reduction.

The programs of these educational institutions support SDG 4, which focuses on Quality Education, and SDG 8, which promotes Decent Work and Economic Growth. The solution to these problems will enhance employment opportunities and economic efficiency while fostering sustainable economic progress in Nigeria and South Africa. The United Nations [34] stated that developing technical and vocational skills is essential for countries to achieve sustained economic growth and increase their capacity to drive innovation.

The research shows that STEM education partnerships with industry need to establish operational partnerships and institutional partnerships, which develop workplace relationships and work through educational systems to meet market needs. The findings show that multiple STEM ecosystem models, which exist in different forms, can develop according to the industrial structure and workforce requirements of each nation.

STEM education alignment with industry needs requires concerted collaboration from policymakers, educators, and industry experts. This coordination will assist both nations to develop

capable talent to spearhead innovation, fight unemployment, and contribute toward enhancing global competitiveness in the 21st century. We recommend that cross-country STEM curricula should be visited and analyzed with respect to the alignment with industrial needs to complement the survey.

### Author contributions

Dr. Olumide Sunday Adesina: Conceptualization, Methodology, Resources, Formal Analysis, Software, Data Curation, Writing – Original Draft, Visualization, Questionnaire design and Administration.

Prof. Lawrence Ogechukwu Obokoh: Conceptualization, Validation, Resources, Writing – Review & Editing, Questionnaire design and Administration, and Supervision.

### Use of Generative-AI tools declaration

During the preparation of this work, the author(s) utilized AI tools such as ChatGPT to assist in identifying relevant existing studies in literature. Additionally, Grammarly (sometimes referred to as AI) was employed for language refinement, and the manuscript was made as grammatically error-free as possible. The author(s) declare that they reviewed and edited the final output as needed and take full responsibility for the content of the published article.

### Conflict of interest

The author declares that there is no conflict of interest with respect to the manuscript

### Ethics declaration

The ethics procedure was duly followed as detailed in the manuscript.

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## Appendix

### Survey Links

- (i) Interview: <https://forms.gle/wgJYMuYB2qRTSz41A>
- (ii) Questionnaire: <https://forms.gle/u4aiCdaejHbeM7VE9>

## Author's biography

**Dr. Olumide Sunday Adesina** is a Senior STEM Faculty with over twenty years of experience in teaching Mathematics, Statistics, and Data Science courses. He holds a Bachelor of Science in Data Science from the University of London, a Bachelor of Science in Mathematics from the University of Ilorin, an MBA from Ladoke Akintola University of Technology, Ogbomoso, a master's degree in Statistics from the University of Lagos, and a PhD in Statistics from Olabisi Onabanjo University, Ogun State. His research interests span computational statistics, machine learning, and deep learning, with strong applications in health, finance, and other data-driven domains. He is a fellow of the Royal Statistical Society in London. He has published over 60 scholarly articles, book chapters, and conference papers in reputable outlets.

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