Journal of Engineering Education Transformations ,
Volume 39, No. 1 , July 2025 , ISSN 2349-2473, eISSN 2394-1707

10.16920/jeet/2025/v39i1/25122

Antecedents of Sustainable Development for Students Pursuing Career in STEM: The Mediating Role of STEM Education

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Abstract: Science, technology, engineering and mathematics (STEM) education possesses the capacity to shape the future by developing requisite knowledge and skills needed to find employment and effectively contribute to address the issues of the twenty-first century. It acts as the foundation of individual liberation and collective advancement in a dynamically changing society. This study attempts to delve into the association among skills and re-skills development (SRD), affinity to technology (AFT), outcomes-based education (OBE), and sustainable development (SD). The study also analyzes the mediating role of STEM education in this relationship. Cross-sectional data has been collected from 314 engineering graduates studying in universities in India. Hypotheses testing were done through the covariance-based structural equation modeling (CB-SEM) and mediation analysis was carried out using bootstrap estimation in SPSS AMOS software. The results suggest that SRD and AFT have a significant effect on STEM education and SD. Also, STEM education has a direct impact on SD. Mediation analysis suggests that STEM education has full mediation between the relationship of OBE and SD while partial mediation between AFT and SD. In light of the imminent fourth industrial revolution, it is imperative for sustainable global development that we fully grasp how STEM education can contribute to narrowing the performance gap at the university level and provide great potential for fostering sustainable living.

Keywords: Performance Gap; STEM Education; Sustainable Development Goals; 21st Century Skills.

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1. Introduction

Education is widely recognized as a tool for promoting individual empowerment, social progress and economic well-being (Abulibdeh et al., 2024). With the advent of the 21st century, employees witnessed several challenges such as globalization that advanced technology and the changing work ethic of the employers (Tushar & Sooraksa, 2023), have made it vital to promote STEM literacy among job-seekers (Relmasiraet al., 2023). Those countries that aim to nurture qualified manpower to be competitive in the international arena as well as to keep up with the fast changes in science and technology certainly consider STEM education as important. STEM education emphasizes learning beyond theories and methods. The STEM discipline requires students to participate in STEM activities, such as measurement and systems (Tan et al., 2023). The emergent field of STEM education which includes mathematics, science and technology are inviting much attention as it holds the promise to be a powerful transformative tool because of the enormous improvements it has brought to the standard of living and workplace efficiency. Student's interest in science is seen as one of the principal factors motivating them to understand the significance of sciences in their lives and to make a decision to choose a career and pursue science (Sheng et al., 2023).

Education is highly important for the Sustainable Development Goals (SDGs) program not only because it is one of the specific goals but also because it provides a base for the progress of the rest of SDG goals. STEM education assists students in mastering the competencies of the 21st century, as per the instruction of the Organization for Economic Cooperation and Development (OECD) in its Learning Framework-2030 (Abina et al., 2024). Education in STEM implies acquiring sight, broadening and critically assessing knowledge and using appropriate thinking and acting methods. Natural sciences, technology engineering, mathematics knowledge and skills are important to develop students' abilities to face global challenges (Binani et al., 2024).

It also provides a foundation for efforts aiming at resolving them based on well-founded information (Díaz & Lim, 2022). The World Economic Forum (WEF) highlighted that along with the STEM competencies; there should be social awareness (Weforum.org, 2024). WEF's underpinning intention was to bring up dual literacy students who are brought up both socially and academically. This has been accomplished by endowing students with insightfully known matters as well as competencies. Therefore, STEM in general, is pursuing and providing creative solutions to global issues precisely linked to the SDGs 2030 within the 21st century (AlAli et al., 2023). STEM education compliance with all the components such as “Modern World Comprehension", "Daily Life Skills", and "Ethics and Values" in conformity. STEM learning helps students acquire competencies in communicating, solving problems, creativity, being entrepreneurial and working in teams in the 21st century era (Bhatnagar, 2020). This is particularly suitable for the solution needed for SDGs 2030 (Ramezanzade et al., 2021). Also, the current study suggests STEM as a beneficial catalyst to build the community. STEM investigates several innovative inventions keeping in mind that intelligence is the foundation of every country's existence (Krishnan & Deshpande, 2021).

A. Global perspectives in STEM

From a global perspective, STEM education considers a wide range of factors, their implications and their acceptance worldwide. Firstly, STEM education ensures consideration of diversity and inclusion in multiple STEM fields. The diversity includes backgrounds, gender types, minorities and people belonging to different social and economic strata, marginalized communities, demographic diversity and racial diversity. Secondly, STEM education emphasizes interdisciplinary domains such as the environment, healthcare management and emerging technology. It should consider cultural beliefs, values and cultural diversity while conducting research and development activities and curriculum design. STEM education considers international collaborations with scientists, technologists and engineers to work in collaboration with the expertise of other countries (Mekala et al., 2020). Furthermore, it considers ethics in research, and technological advancements and is framed in diverse cultural and social forms across borders. STEM education makes its unique mark as it further addresses various global issues such as environmental changes, contagious diseases, energy conservation and food security. STEM education prepares a pool of experts to tackle these issues through scientific, technological, engineering and mathematical solutions.

2. Materials And Methods

A. Visual representation of literature review

To identify various research subtopics through a visual, systematic and structured literature review is being conducted using various AI-based research tools. The use of such tools gives a wider picture of the research and thus identifies various major and minor research terms. The tools used for the visual literature review are Vosviewer, Carrot2, Open Knowledge maps and citation gecko.

Carrot2 is an open-source engine that supports five different languages English, French, German, Italian and Spanish and supports documents from eight countries- Austria, France, Germany, Great Britain, Lichtenstein, Italy, Spain, and Switzerland. The document clusters are formed and represented pictorially. The size of the cluster shape is directly proportional to the significance of the research concept. The visual representations are indicated in Fig. 1 generated when the search keyword was 'STEM Education'.

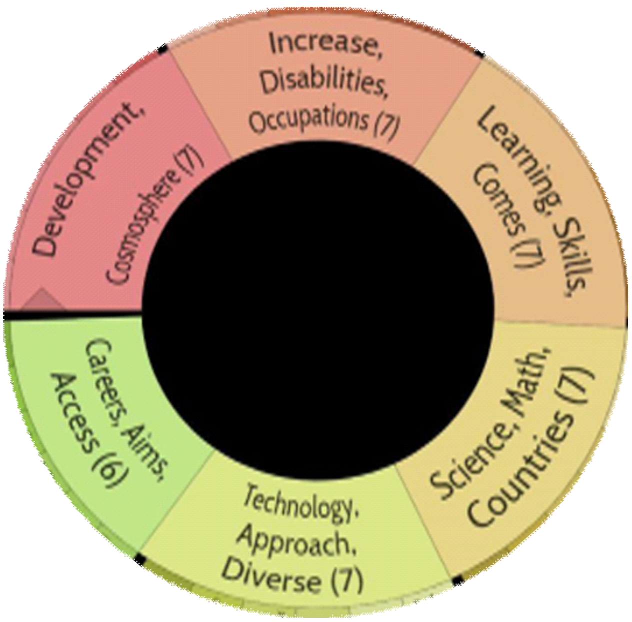

Fig. 1 : Pie Chart Search Term 'Stem Education' in Carrot2

As shown in Fig.1, the significant research topics are 'careers', 'aims', 'technology', 'approach', 'diverse', 'science', 'maths', 'learning', 'skills', 'disabilities' and 'occupations'. The minor research topics are 'internationalization of STEM education', 'college of education', 'science education', 'racial diversity' and 'discrimination in STEM fields', 'C-STEM center', 'CK-12 foundation', 'STEM learning' and 'current trends in STEM education'. The above visualization provides direction about various research topics which need to be explored for the current literature review.

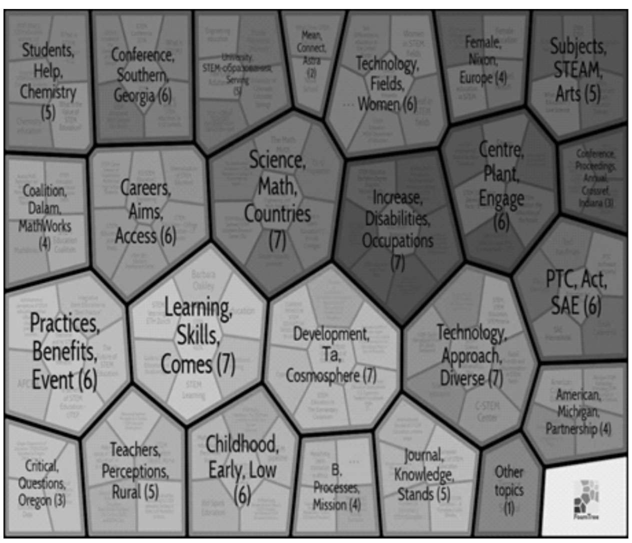

Fig. 2:Treemapsearch Term 'Stem Education' in Carrot2

As shown in Fig.2, the significant research topics are careers, aims, technology, approach, diversity, science, maths, learning, skills, and STEM inclusion with individuals having disabilities and occupations.

Fig. 3 shows another AI-based tool Citation gecko - a GUI (graphical user interface) to generate associations within various research papers where the papers are related to the term 'seed papers'. The visual representations created when the search keyword was 'STEM education' and related research articles are considered as 'seed papers'. The results were created of seed papers, clusters of seed papers as shown in Fig. 4 and related papers. The visualizations are given below:

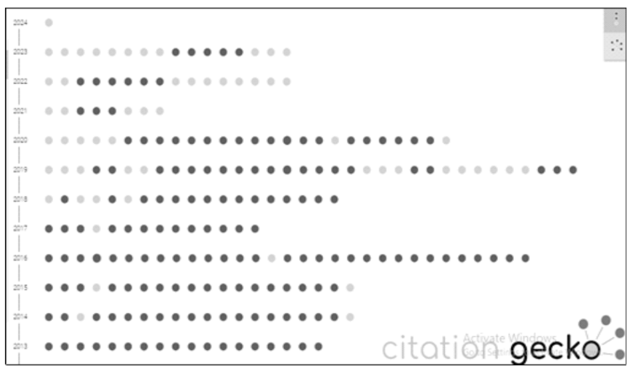

Fig. 3 : List of Seed Papers Generated With the Keyword 'Stem Education' From Citation Gecko

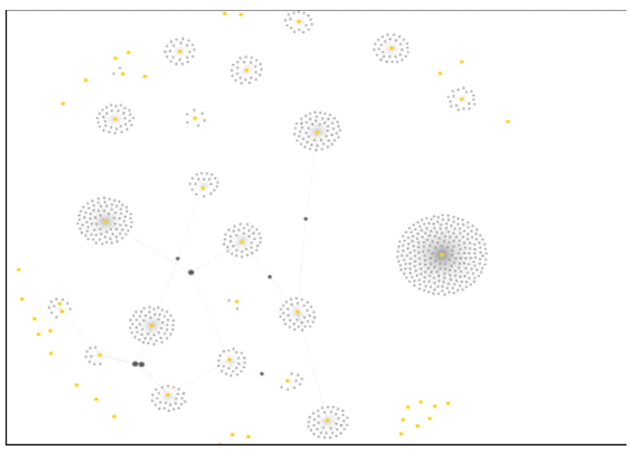

Fig. 4 : Cluster Of Seed Papers Generated With the Keyword 'stem Education' From Citation Gecko

As shown in Fig. 4, the centers of the cluster are the seed papers surrounded by citing the seed paper shown in yellow color. It is noted that the seed papers are surrounded by many other papers in most of the cases; however, in many cases, the seed papers do not have any relationship with other papers or seed papers.

Bibliometric analysis is a quantitative data analysis related to the subject or domain under study (Gupta et al., 2024; Kumar et al., 2022; Kumar & Mundi, 2022; Perannagari & Gupta, 2022; Sahni & Kaurav, 2023; Vessal & Anand, 2022). Bibliometric analysis is performed using various steps. Firstly, the research database is determined. For this study, the IEEE explore database is considered as it provides a wide-ranging range of topics on engineering, science, and technology. It consists of books, journals, standards, open-access articles, and conference proceedings. Secondly, an 'advanced search' is being performed throughout 2018 to 2023. The key terms considered are as follows: 'STEM education', 'skills', 'employability' and 'outcome-based education'. To gain wider dimensions of STEM education, 'full text and metadata' are searched. Later, the data was exported from IEEE explore in .csv format and fetched by VosViewer software.

The total link strength (TLS) is automatically provided by VOS viewer upon mapping the research activity. In the current study, the authors developed a structured and systematic search resulting in categorical data. Visualization is generated with five different clusters as shown, these clusters have a 'number of items' and are arranged in alphabetical order as revealed in Table 1.

Table I : Keyword Cluster and its Description

Cluster number	Cluster color	No. of items	Percentage of Items in the Cluster (%)	Name of items arranged in ascending order
1	Red	54	28.87	Artificial intelligence, capability, computer, computing, ICT, software development, software engineering,
2	Green	41	21.92	Computer science, fourth industrial revolution, skills, soft skills,
3	Blue	34	18.18	Academia, communication skills, Sustainable development, sustainable development goal, technical skills
4	Yellowish Green	34	18.18	Employment, entrepreneurship, SDGs
5	Purple	24	12.83	Creativity, critical thinking, digital transformation, digital technology, transversal skills

Source: Author's Compilation

As shown in Table 1, the keywords generated are in order with the hypothesis created. The terms such as Artificial intelligence, capability, computer, computing, ICT, software development, software engineering (shown in red color cluster), Computer science, fourth industrial revolution (green color cluster) and digital technology (purple color cluster) discuss various technology trends i.e. it shows 'affinity to technology'. The second keyword is 'skill/re-skilling' and it is aptly reflected in the keyword's soft skills, technical skills and transversal skills. To accomplish SDG4, Sustainable development for education promotes inclusive, equitable quality education for everyone and encourages lifelong learning. Outcome-based education is depicted by various outcomes such as Creativity, critical thinking, Employment, entrepreneurship and digital transformation (Kumar et al., 2022.

3. Theoretical Framework And Hypotheses Development

A. Background theories

Diffusion of innovation theory offers a new lens for examining the appeal and rapid spread of new ideas, technologies, or other innovations. The theory demonstrates a widespread fascination with STEM education that resonates among learners both national and international while unveiling communication channels' role in transmitting new ideas from one individual or group to another. According to DOI, technology is a crucial tool that reduces the degree of ambiguity in the cause-effect relationships to achieve the intended results (Oke & Fernandes, 2020). Technology affinity in programs of STEM plays an important role as catalysts for change that promote sustainable development. The problem-solving process is mostly guided by Vygotsky's theory. It contains culturally relevant materials and offers a cognitive tool for people's behaviors (Newman & Latifi, 2021). With these students address concrete issues they experience daily and can find a new and better practical solution.

B. Research hypotheses and model development

STEM education links theoretical knowledge of science and mathematics to real-life applications, thus providing solutions to current and future problems of the people (Sulai & Sulai, 2020). Cognitively, these skills go beyond traditional domains of education. Project-based learning is a pedagogical approach where students pertain their classroom knowledge in a real-life context that focuses on experiential learning and practical application of theory (Sánchez-Muñoz et al., 2022) and helps to promote a more positive attitude towards STEM careers (Shulga et al., 2023). Meta-cognitive skills, Collaborative learning, interdisciplinary curriculum and real-world applications are examples of effective mechanisms for developing and internally reinforcing STEM skills (Abu Khurma et al. 2022). Critical thinking, problem solving, creativity and innovation are the cornerstone foundation blocks of advanced skills in STEM (Weng et al. 2023). The integration of these competencies into educational curricula exemplifies how students can manage complex problems effectively thereby embracing the holistic approach to learning.

H1: Skills & Re-Skills Development (SRD) has a positive impact on Sustainable Development (SD)

The affinity to technology approach depicts that technology is a powerful mechanisms for achieving sustainable goals when used in conjunction with the 'STEM for Sustainability'. Technology can be a great support to emphasize social sensitivity and STEM competency. STEM education makes students better aware of how things work and enhances their usage of technologies (Mittal et al., 2022). Globally, there have been changes in several sectors due to developments in technology that enhance their operational procedures and offer additional job opportunities. It is done to create skilled human resources who possess a sense of societal accountability required for utilizing technical knowledge (Goulart et al., 2022). Technology helps to develop social consciousness together with science and innovations (Oliveira& De Souza, 2022). Swift technological transformation has allowed for sustainability transitions with capacities to identify it and fully address its ability, promoting people, especially those considered weak or marginalized while ensuring inclusion and equality (Lyra & Lehtimäki, 2023).

H2: Affinity to Technology (AFT) has a positive impact on Sustainable Development (SD)

STEM education builds a connection between business and education. It equips students with 21st-century skills as they can also pursue their careers in businesses towards entrepreneurship or innovation (Amalu et al., 2023). Collaborative schemes such as STEM mentorship programs or projects sponsored by industries are some important strategies through which students acquire practical experiences and an understanding of industry standards (DeCoito & Briona, 2023). Additionally, it also provides a connection with the professional world across various communities and businesses that help to maintain the vitality of sustainable development and cultivate talents with sustainable development capacity (Ramasamy et al., 2024). Apart from this apprenticeships and work-based learning allow individuals to improve their skills in close alignment with employers' requirements (Hansen et al., 2024). Enhancing the transition from school to the workplace can be accomplished by combining study and work. Thus, STEM as an outcome-based education emphasizes the need to invest in human resources through training and equipping learners with the requisite knowledge and skill sets relevant for future careers.

H3: Outcome-based Education (OBE) has a positive impact on Sustainable Development (SD)

A unified integrated STEM curriculum comprises a cohesive system of various disciplines with a strong collaborative connection to life.STEM education includes a curriculum that becomes more and more specialized at higher educational levels, preparing students for careers that prepare them for the challenges of the modern world. The curriculum is essentially outcome-based and closely aligned with industry requirements, so curriculum tied with the future changes. STEM education is one of the perfect ways to help the community transition from traditional employment to sustainable methods of learning that are not limited to temporary solutions (Peters et al., 2024). They can provide a solid foundation, which can be modified to meet the changes and requirements of several businesses. Technology usage, community engagement and program accessibility are the three-corner stone of STEM education (Chan, 2023). It also fosters effective industry-academic partnerships to offer skill-based and outcome-based education through skill-readiness programmes. STEM education involves the use of sustainable methods and system approaches to innovative pressing human needs.

Furthermore, it also helps to react more precisely in the matter of educational demand changes, innovation advancements, workforce skills and knowledge gaps (Kayyali, 2024).

H4: STEM education has a positive impact on Sustainable Development

H4a-c: STEM education positively mediates the relationship between Skills & Re-skills Development (H4a), (ii) Affinity to Technology, (H4b), (iii) Outcome-based Education (H4c) and Sustainable Development.

A research model is proposed encompassing all hypotheses is shown in Fig. 5.

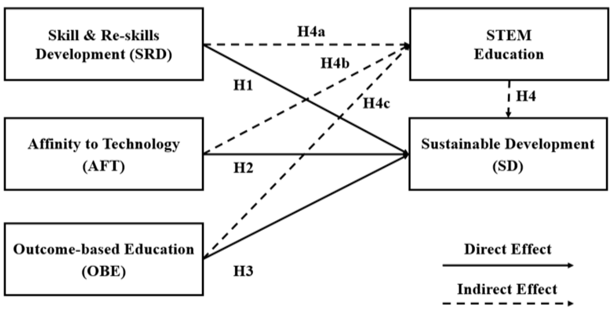

Fig. 5 : Research Model (Source: Author's compilation)

4. Research Methodology

A. Measurement instruments

The measurement instruments for each variable were borrowed from the existing literature. The questionnaire items were adapted and modified for the current context. In the literature, authors have developed the scales for skills & re-skills development (Christensen, 2021), affinity to technology (Franke et al., 2019), outcome-based education (Athayde, 2009), STEM education (Wan et al., 2022), and sustainable development (Biasutti&Frate, 2017).

B. Data collection

The questionnaire items were split into two sections; first, respondents' demographic profile, and second, the students' perception of STEM education. We drew our sample from the population of undergraduate students enrolled on their careers in STEM disciplines. A purposive sampling method was used. The respondents were B.Tech students studying in private universities enrolled in the academic years 2019-2023. The respondents were 314 in numbers among them male consisted of 218 in number whereas the female students were 96. The questionnaire consists of 28 items in the 7-point Likert scale.

C. Analysis and findings

Reliability analysis is performed to check the item's internal consistency of respective constructs. Using SPSS software, the reliability is computed in terms of Cronbach's alpha values (α). The α values for each construct i.e. Skills & Re-skills Development (SRD), Affinity to Technology (AFT), Outcome-based Education (OBE), Sustainable Development (SD) and STEM education are 0.755, 0.765, 0.793, 0.898 and 0.728, respectively. The Cronbach Alpha (α) value of more than 0.7 shows a good sign of reliability. For some constructs, the (α) value improved after deleting some items. After deleting SRD1, the α value increased to 0.770. Similarly, after deleting STEM1, the α value increased to 0.766 (refer to Table 2). Therefore, SRD1 and STEM1 were removed from further analysis for better reliability of constructs.

In survey research, common method bias is one of the concerns which need to be checked. In this paper, a single factor accounts for 31% of the total variance explained which is lower than the suggested value of 50%, which shows that there is no concern of common method bias in this study. Further, exploratory factor analysis (EFA) is performed to find out the underlying structure among the variables using the principal component method and varimax rotation. Initially, the KMO test is done to check the sample adequacy to perform the EFA. KMO test shows a value of 0.879 which is above the suggested threshold value of 0.80. EFA results in a five factors structure i.e., SD, AFT, SRD, OBE and STEM among 25 items. Table 3 represents the factor loading of each variable and the eigen value and explains the variance of each factor.

Using confirmatory factor analysis (CFA), the measurement model is tested for model fit and construct validity i.e., convergent and discriminant validity. Table 4 shows the model fit values for both the initial and final measurement models. The initial measurement model represents all the items from the EFA and the final measurement model (refer to Fig. 6) represents the final items (AFT1, AFT4, AFT5, SRD4, SRD5, SRD6 and STEM4 are deleted from further analysis) to measure the constructs in the model. Model fit indices are within the suggested cut-off values (refer to Table 4). Table 5 suggests a good convergent validity among all constructs as all AVE values are greater than the suggested value of 0.5. Table 5 shows the diagonal values (correlation with the same construct) for each construct are greater than the inter-correlation values which shows a good sign of discriminant validity among constructs. The reliability of the construct for the measurement model is analyzed with the help of composite reliability (CR) values and CR values for each construct are above 0.70 which confirms the good reliability of items to measure respective constructs.

Table 6 shows the testing of the hypothesis (refer to Fig. 7) and all the hypotheses i.e., H1, H2 and H4 except H3 are supported using p-value 0f 0.5. Table 7 demonstrates the mediation analysis based on the indirect effect using the bootstrap estimation method in SPSS AMOS software. From the results, Hypothesis H4b and H4c are supported with partial mediation and full mediation respectively while hypothesis H4a is rejected with no mediating effect.

Table II :
Reliability Analysis (Cronbach's Alpha)

Constructs	Cronbach's Alpha	Improved Cronbach's Alpha (if items deleted)
SD	0.898	-
AFT	0.765	-
SRD	0.755	0.770 (if SRD1 deleted)
OBE	0.793	-
STEM	0.728	0.766 (if STEM1 deleted)

Table III :
Eigen Values, Explained Variance And Factor Loadings

	Factors				
	SD	AFT	SRD	OBE	STEM
Eigen Value	7.8	2.1	1.8	1.5	1.2
Total Explained Variance	59.10%				
Explained Variance	31.50%	8.60%	7.40%	6.30%	5.10%
SD1	0.728				
SD2	0.689				
SD3	0.668				
SD4	0.834				
SD5	0.831				
SD6	0.828				
AFT1		0.566			
AFT2		0.730			
AFT3		0.769			
AFT4		0.611			
AFT5		0.646			
SRD2			0.732		
SRD3			0.707		
SRD4			0.600		
SRD5			0.539		
SRD6			0.706		
SRD7			0.554		
OBE1				0.803	
OBE2				0.739	
OBE3		0.425		0.458	
OBE4				0.734	
STEM2					0.694
STEM3					0.785
STEM4					0.735
STEM5		0.421			0.584

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Note: Factor loadings less than 0.40 are not shown in the table.

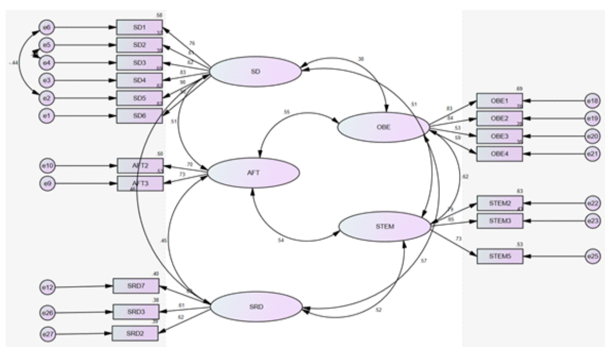

Fig. 6 : Cfa Measurement Model With Values

Table IV :
Model Fit Indices

Model Goodness of Fit indices	Cut-off values (Source: Guptaetal., 2020)	Final measurement model	Initial measurement model
χ2/ df	< 3	2.297	2.463
RMSEA	< 0.08	0.064	0.068
GFI	> 0.90	0.916	0.861
AGFI	> 0.80	0.880	0.829
NFI	> 0.90	0.900	0.821
CFI	> 0.90	0.940	0.884

Table V :
Factor Correlation Matrix, Composite Reliability (cr) And Average Variance Explained (ave)

	CR	AVE	*OBE*	*SD*	*AFT*	*SRD*	*STEM*
OBE	0.799	0.508	**0.713**				
SD	0.901	0.609	0.384	**0.781**			
AFT	0.710	0.514	0.551	0.509	**0.717**		
SRD	0.703	0.502	0.571	0.460	0.454	**0.708**	
STEM	0.770	0.529	0.616	0.511	0.543	0.519	**0.727**

Note: Diagonal values (bold) show the square root of the AVE

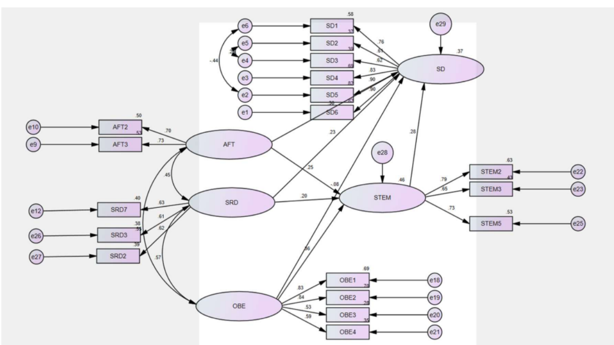

Fig. 7 : Structural Model With Values

Table VI :
Hypotheses Testing

Dependent Variable	<---	Independent Variable	Estimate	P Label	Results
STEM	<---	AFT	0.354	0.005**	Supported
STEM	<---	SRD	0.313	0.136**	Supported
STEM	<---	OBE	0.405	0.000***	Supported
SD	<---	SRD	0.485	0.013**	H1 Supported
SD	<---	AFT	0.563	0.001**	H2 Supported
SD	<---	OBE	0.124	0.357 (ns)	H3 Rejected
SD	<---	STEM	0.382	0.002**	H4 Supported

Table VII :
Mediation Analysis

Path (X to M to Y)	Direct effect (X to Y)	Indirect effect (X to Y)	Results
SRD to STEM to SD	0.485 (ns)	0.119 (ns)	No mediation (H4a not supported)
AFT to STEM to SD	0.563**	0.135**	Partial mediation (H4b supported)
OBE to STEM to SD	0.124 (ns)	0.154**	Full mediation (H4c supported)

P value = ** < 0.05; ns = 'not significant'

Note: 'X', 'M'and 'Y' represent independent, mediator and dependent variables respectively

5. Discussion

The core intention of the research paper was to examine the association between STEM education and sustainable development in the context of students pursuing careers in STEM. The results show that three independent factors, such as skills & re-skills development (SRD), affinity to technology (AFT), and outcomes-based education (OBE) have a direct and significant association with sustainable development (SD). The outcomes of the present study are uniform and supported by the earlier research conducted. The results regarding skills& re-skills development are reliable to the studies conducted earlier and thus confirm hypothesis 1. Hypothesis 1 depicts that to enhance sustainable development the students should understand the two effective STEM learning approaches which are project-based learning and problem-based learning (Abulibdeh et al., 2024). In project-based learning, students are pushed to come up with ideas that are technically sound and imaginative, which promotes critical and creative thinking in them. With problem-based learning, students can add new skills and information by working with a facilitator to solve a challenging problem that has no right or wrong answer. STEM education also supports group work. It acknowledges the significance of the social aspect of learning (Thyssen et al., 2023; Chiu et al., 2015). People's skills were seen as a "vital national asset" in the study done by (Sheng et al., 2023). Additionally, they asserted that sufficient investment in this specific asset is necessary to tackle the problems of the twenty-first century, which include sustainable employment, a fairer and more inclusive society, and a competitive and productive economy (Tan et al., 2023). Individuals' skills extend beyond their professional lives. They fulfil important societal functions as well. To create a more equitable and inclusive society, young people must graduate from high school or college prepared for the workforce. To help students deal with the challenges of society, it is essential to shift the focus from simply identifying the problems that are common to all disciplines and then providing students with opportunities to understand the issues through rich, engaging and powerful experiences thereby linking them with the disciplines of STEM.

Similarly, the findings of hypothesis 2 states that affinity to technology has a positive relationship with sustainable development are also consistent with previous studies. STEM education drives innovations across disciplines, making use of computational power to accelerate discoveries and finding creative ways to work across disciplinary silos to solve big challenges. The interdisciplinary nature of STEM education provides the necessary tools for students to address a wide range of problems (AlAli et al., 2023). Our everyday lives are marked by both rapid technical breakthroughs and societal shifts. The finding of hypothesis 3 posited that outcome-based education has a significant association with sustainable development as STEM-related occupations and innovations continue to proliferate and expand upon the quality of life. It became crucial in the 21st century, to raise individuals who are critical thinkers, and entrepreneurs; capable of solving problems creatively, and having innovation and research capabilities (Sangeeta &Tandon, 2021).

The results obtained from hypothesis 4c associated with mediation analysis suggest that STEM has a full mediation between the relationship between OBE and SD. The growing interest in outcome-based learning among academics, industry, and accrediting organizations is a proof of its significance in higher education. Employer demand will be one of the main factors pushing graduates with sustainability literacy. Companies are under increasing pressure to monitor and report on their environmental and social performance in addition to their financial success due to the growing interest in responsible corporate behavior. Given the increasing international awareness of STEM education, several research and scholarship works have recently been conducted to respond to this call (Takeuchi et al., 2020). Continuous monitoring and understanding of the current and future landscape of the scholarship in the STEM field is essential to let it develop and be well positioned. The funding distribution for STEM education reflects growing recognition of a systemic approach to change. The global strategies and initiatives for STEM education at the school level will prove thereby as one of the most important ways to lower academic differences, especially among girls and women (Ramezanzade et al., 2021). Further, the current research study helps in deciphering the OBE elements that affect the career selection, for students, pursuing STEM. It focuses on evaluating the efficacy of instructional strategies and student performance at various levels. It provides a teaching and learning methodology that is focused on the needs of the learner and is made to achieve predefined goals and objectives. On the other hand it overemphasizes quantifiable outputs and preset outcomes at the expense of other crucial facets of education. By OBE, learning may be reduced to something that is concrete, measurable, and observable. STEM education could potentially solve these issues and concerns by promoting the adoption of research-based solutions by students.

Hypothesis 4a and 4b show that STEM has a partial mediation between SRD and AFT. Previous research also mentioned that although a lot has been achieved in terms of establishing successful STEM learning and teaching environments, there is still a dearth of knowledge on how the results might be incorporated into extensive reform initiatives. It has been discovered that besides, graduates often have the preconceived idea that a career in science is very challenging and demanding (Subasman & Aliyyah, 2023). The theoretical knowledge just taught cannot be verified or mastered in greater depth over time, while students' hands-on skills remain unchanged. On the other hand, hardware updates cannot keep up, limiting the development of students' hands-on practical skills. Having this concern in mind most universities are now committed to building laboratories and increasing hardware investment. Mittal et al. (2019) highlight the significance of apprenticeships that help increase optimism in learners as well as the importance of STEM employment. Of course, STEM education cannot be separated from STEM employment; it serves as one of the foundational motivating factors for the STEM learner to energize and employ for their Brighter Future. Many studies focus on STEM education as a profitable investment, and its return on intellectual development should not be overlooked.

Finally, hypothesis 4 shows that the 'STEM for Sustainability' approach ensure that appropriate technological advancements are incorporated into the learning environment under the direction of educators who are knowledgeable about how contemporary technology might impact education and how to utilize it to improve context and enrich students' learning experiences. STEM education is vital to ensure that the nation's workforce is up-skilled to become the trailblazer of positive transformation in the world (Weng et al. 2023). With this strategy, the future change maker learns to leverage technical innovation to assist halt or reverse climate change.

Conclusion And Implications

The current study demonstrated how outcomes-based education through STEM provides a sustainable teaching model which facilitates students in pursuing in-depth computer science studies and developing their overall competence (Capraro et al., 2016). With the advent of the digital education era, new expectations for talent development are apparent. The results show that outcome-based education in STEM permits students to master computer science knowledge and skills at all stages, enhance their teamwork and innovation skills, achieve long-term growth as well as increase their marketability. Expansions in STEM education careers and university programs pave the way for new generations to further expand the fields of STEM in hope of building a strong foundation for the future. Interest in science and technology is not limited by national boundaries. Each country should engage its universities, teacher training institutions, schools and vocational training centers to find out how best to integrate or modify the STEM curriculum through some sort of partnership arrangement with other countries (Malhotra et al., 2020; Barakabitze et al., 2019).

In recent years, there has been a rapid expansion of interest in STEM education across the globe that has been supported by businesses, policymakers and nongovernmental actors in the creation of a robust and competent academic system. This creates an active exchange of knowledge and a fountain of innovations. Education for sustainable development promotes transitions in the knowledge, skills, concerns and appreciation of diverse citizens to create a more sustainable and enriched society (Kopnina, 2020). From another perspective, STEM consists not only of the content, processes and ways of thinking of each disciplinary field involved but also includes inter-subject aspects. It strives to better the conditions for current and future generations to meet their needs using a balanced and integrated approach to sustainable development. Community engagement programs through the auto trans-blending of classroom formal education and the realities of local environments can make STEM education more accessible and life applicable (Trott& Weinberg, 2020). New technologies always bring about changes in teaching methodologies and educational approaches. Teachers need to be up to date on the latest technology tools because the younger generation is growing up in a technologically savvy society. To adapt to changing pedagogical approaches, embrace new teaching strategies, and satisfy students' diverse learning needs, educators need to maintain up-to-date knowledge and skills. This ensures that academic institutions successfully embrace change while preserving their competitive advantage. To fully utilize the benefits that STEM education brings, more attention should be placed on secondary education institutions where developing cognitive and intellectual skills can be grown and nurtured.

Limitations And Future Research

The study is rich in valuable information and insights that provide the reader with immense scope to explore the topic from various perspectives. However, despite the richness of the topic, there are certain limitations. The finding of the research is not applicable universally, as it is centered on Indian students. Due to the existence of diverse cultural beliefs, economic challenges and regulatory norms, the findings of the study might vary considerably over other nations. These variations hold the ability to influence students' perception and involvement with STEM education, development of skills and technological advancement, thus impacting the results observed in the course of the study. Adopting a cross-sectional approach to collect data from the participants holds other limitations, by not providing comprehensive knowledge, in terms of skill development over time. The study might not restore the ongoing changes and dynamics within these particular domains and, thus, is unable to shed light on the long-term effect of STEM education in developing skills.

The future study shall include students from various nations with diversified cultures to analyze the shift in behavioral patterns in terms of the adoption of the STEM education system. This will help to understand their perceived behavior and craft an effective conclusion. Conducting the study over various time frames through panel data will help the researchers to evaluate the extent of the research work, with the impact of broadening technology and change in social dynamics. In this respect, the study opened the way for numerous opportunities required to be explored in the upcoming research.

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