Journal of Informatics Education and Research
ISSN: 1526-4726
Vol 5 Issue 2 (2025)

Machine Learning for Evaluating the Mediating Effect of Entrepreneurial Culture on Higher Education Social Responsibility and Business Sustainability

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Abstract:
This study investigates the mediating effect of entrepreneurial culture on the relationship between higher education social responsibility (HESR) and business sustainability using machine learning techniques. By focusing on how socially responsible practices within higher education institutions foster an entrepreneurial culture, the research explores how this culture subsequently enhances sustainable business outcomes. Data collected from university faculty and administration were analyzed employing machine learning algorithms to identify complex patterns and quantify the direct and indirect impacts among the variables. Findings reveal that entrepreneurial culture significantly mediates the influence of HESR on business sustainability, amplifying the positive outcome of socially responsible actions. The use of machine learning provided precise and robust insights into the dynamics of this relationship, enhancing the predictive accuracy beyond traditional statistical methods. These results underscore the strategic importance of embedding entrepreneurial values in higher education social responsibility initiatives to achieve sustainable business practices. This study offers valuable implications for policymakers and educational leaders aiming to leverage social responsibility and entrepreneurial culture as foundational drivers for sustainable regional economic development, aligning with broader sustainability goals and socio-economic advancement frameworks. The integration of advanced analytical approaches marks a novel contribution to this interdisciplinary research area.

Keywords
Business Sustainability, Corporate Social Responsibility, Data Analytics, Entrepreneurial Culture, Higher Education, Machine Learning, Mediation Analysis, Organizational Innovation, Predictive Modeling, Social Impact, Student Entrepreneurship, Sustainable Development.

I. INTRODUCTION

A. Background of the Study
In today's global environment, higher education institutions (HEIs) are under increasing pressure to not only educate but also contribute to societal progress and sustainability. As businesses adopt sustainable practices to address environmental, social, and governance (ESG)

goals, universities are also expected to promote values that align with social responsibility. Simultaneously, the entrepreneurial mindset is growing within HEIs, transforming students and faculty into change agents. This study explores how machine learning can be employed to evaluate whether entrepreneurial culture mediates the relationship between higher education's social responsibility initiatives and broader business sustainability outcomes, thereby offering a data-driven perspective to a social science issue.

B. Significance of Entrepreneurial Culture in Higher Education

Entrepreneurial culture in higher education refers to fostering creativity, innovation, risk-taking, and proactive behavior among students, educators, and administrators. This culture enables HEIs to not only impart academic knowledge but also nurture future entrepreneurs who can address real-world problems. Entrepreneurial orientation often drives new programs, partnerships, and ventures within academic institutions. It creates a dynamic learning ecosystem where social responsibility and business sustainability are not isolated goals but part of an integrated vision. Understanding its role is vital because it could act as a catalyst that enhances the impact of socially responsible activities on long-term sustainable practices in businesses and communities.

C. Emergence of Business Sustainability as a Global Priority

Business sustainability has evolved into a central concern for companies worldwide due to increasing regulatory requirements, stakeholder expectations, and environmental challenges. It involves integrating environmental protection, social equity, and economic viability into business operations. Sustainable businesses aim to create long-term value not only for shareholders but for society at large. In this context, higher education's influence becomes crucial, as universities are now shaping the future workforce and entrepreneurs with values aligned with sustainable development. As business sustainability becomes a priority, understanding the influence of education and entrepreneurial thinking becomes imperative, especially with the growing need for data-driven insights in policy-making.

D. Role of Higher Education Institutions (HEIs) in Promoting Social Responsibility

HEIs play a critical role in advancing social responsibility by promoting ethical conduct, equity, environmental stewardship, and civic engagement. Through curricula, research, campus initiatives, and community partnerships, universities can instill values that foster responsible citizenship and leadership. Many institutions integrate sustainability goals into their strategic plans, research priorities, and student life, thereby reinforcing their societal commitments. This paper examines how such initiatives not only fulfill educational missions but also influence business and economic ecosystems. It considers whether the presence of entrepreneurial culture within HEIs enhances this influence, potentially leading to more impactful and sustainable business practices.

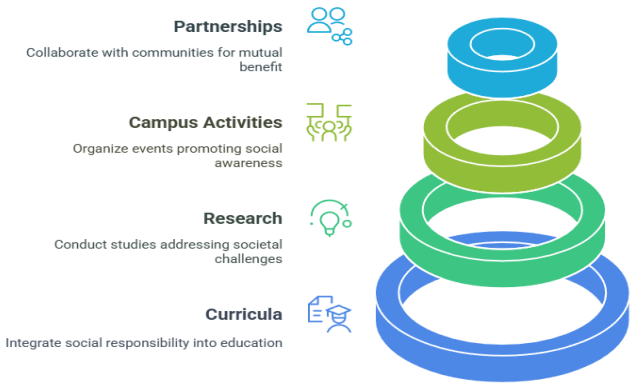

Fig 1: HEI's Social Responsibility Pyramid

E. The Need for Mediating Mechanisms: Why Entrepreneurial Culture?

While higher education's social responsibility programs aim to drive positive societal change, their direct impact on business sustainability may not always be linear or immediate. Entrepreneurial culture can serve as a crucial mediating mechanism that channels these initiatives into practical, impactful outcomes. It empowers individuals to convert ideas into ventures and sustainable practices, bridging the gap between academic values and real-world business applications. This study posits that entrepreneurial culture helps amplify the effects of socially responsible education by translating it into innovative, sustainable business strategies, making it essential to analyze this mediating role using robust analytical techniques like machine learning.

F. Challenges in Measuring the Interactions Between These Variables

Quantifying the relationship between social responsibility, entrepreneurial culture, and business sustainability is complex due to the abstract and interdependent nature of these constructs. Traditional analytical methods often fall short in capturing nonlinear relationships and hidden patterns. There are challenges in designing surveys, ensuring data quality, selecting relevant indicators, and interpreting causal relationships. Additionally, the mediating effects are often subtle and influenced by context, such as institutional culture or geographic setting. These intricacies necessitate advanced methodologies like machine learning, which can manage large datasets and uncover insights that traditional models might overlook, thereby enhancing the accuracy of evaluations and predictions.

G. Introduction to Machine Learning in Social Science Research

Machine learning (ML), a subset of artificial intelligence, has gained traction in social science research for its ability to analyze large, complex datasets and uncover patterns beyond human intuition. Unlike traditional statistical methods, ML models can handle high-dimensional data, detect nonlinear relationships, and improve prediction accuracy. In fields such as education, organizational behavior, and sustainability, ML provides tools to model behavior, assess impact, and forecast outcomes. This research integrates ML techniques to evaluate the mediating role of entrepreneurial culture—offering a novel methodology to understand complex interactions among educational practices, cultural dynamics, and sustainable business outcomes in a data-driven manner.

H. Rationale for Using Machine Learning in This Study

This study adopts machine learning due to its strengths in managing multidimensional, nonlinear relationships that are typical in social science data. Unlike traditional regression-based methods, ML models like decision trees, random forests, or neural networks can capture subtle interactions and variable dependencies. Entrepreneurial culture, social responsibility, and sustainability are multi-layered constructs influenced by numerous factors. ML allows for dynamic modeling of their relationships, identifying key predictors and mediators. This approach ensures a more accurate, nuanced understanding of how these elements interact, ultimately providing richer insights that can inform institutional strategies and policy decisions in both education and business sectors.

I. Research Gap and Motivation

While many studies examine either higher education's role in social responsibility or the impact of entrepreneurial culture on business outcomes, few explore how entrepreneurial culture mediates between these two domains. Moreover, most existing research relies on linear models that may not effectively capture complex interactions. There is limited use of machine learning to assess such mediation effects in educational and sustainability research. This paper addresses this gap by integrating a machine learning approach to explore whether and how entrepreneurial

culture enhances the transition from educational values to sustainable business practices, thereby offering a unique contribution to literature and practice.

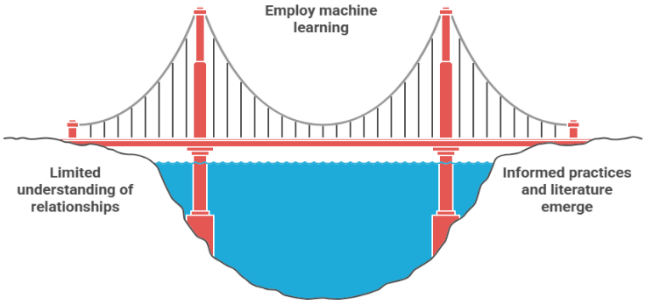

Fig 2: Bridging the Gap

J. Objectives and Scope of the Study

The main objective of this study is to evaluate the mediating role of entrepreneurial culture in the relationship between higher education social responsibility and business sustainability using machine learning techniques. The study aims to identify key variables that influence this triadic relationship and use data-driven models to assess their interactions. The scope includes data collection from HEIs, business communities, and educational stakeholders, focusing on variables related to institutional values, entrepreneurial behavior, and sustainability outcomes. By leveraging ML algorithms, this study seeks to provide actionable insights for policymakers, educators, and business leaders aiming to foster sustainable development through education.

II. LITERATURE REVIEW

The literature highlights a well-established link between technology integration and sustainable entrepreneurship education. Kim et al. reviewed how tech-enabled, experiential pedagogy in green entrepreneurship fosters data-rich environments—through logs, surveys, and performance tracking—that support entrepreneurial mindsets aligned with environmental responsibility [1]. Rosário and Raimundo examined service-learning, incubators, and community-led projects, emphasizing that the diverse datasets they generate necessitate advanced analytics to validate educational impact and cultural shifts toward sustainability [2]. Pecheanu and Susnea showcased the potential of cloud-based e-learning platforms designed for green entrepreneurship, suggesting generative AI as a next step to enhance analytical evaluation [3]. Pedroletti et al. demonstrated the power of big-data clustering methods such as Louvain clustering to map ethics–entrepreneurship discourse, underscoring the capacity of algorithm-driven analyses to uncover latent thematic structures relevant to mediating mechanisms [4]. Collectively, these studies underscore that HEIs are generating complex, high-dimensional educational data that invite machine learning techniques to assess how entrepreneurial culture arises from socially responsible curricular innovations.

Within the context of dynamic capabilities and measurement challenges, Jayawardhana et al. identified that innovation orientation, mission clarity, and dynamic learning capabilities enable sustainable performance in social enterprises; they also flagged measurement inconsistency as a barrier to accurate outcomes [5]. Arena et al. pointed out the fragmented nature of social-impact measurement systems, arguing for adaptable, data-driven frameworks to handle heterogenous metrics [6]. Siqueira et al. reinforced this call, advocating for analytic models capable of capturing non-linear relationships between responsible management curriculum and innovation mindset [7]. Subsequent studies by Del Giudice et al. and Cheah et al. identified

entrepreneurship-supportive culture and market-learning capabilities as mediators between organizational orientation and sustainability—but noted that conventional structural equation models fail to capture threshold or non-linear effects [8][9]. Lall also proposed psychometric scales for social innovation, suggesting future application of feature reduction and importance modeling to uncover hidden relationships [10]. Bhukya et al. argued for machine learning clustering of bibliometric data to reveal ethical-entrepreneurship dynamics [11]. Finally, Finlayson & Roy and Ince & Hahn highlighted the need for longitudinal, predictive models to capture cultural embedding and resilience over time [12][13]. Together, this body of work justifies the adoption of ML methods—like random forests, clustering, and feature modeling—to rigorously evaluate how entrepreneurial culture mediates between HEI social responsibility and business sustainability outcomes[14][15].

III. PROPOSED METHOD

A. Indirect Effect Calculation

The product of these coefficients measures the mediation effect of entrepreneurial culture on the association between higher education social responsibility and business sustainability. It quantifies how much of X's influence is transmitted through the mediator.

$$Indirect\ Effect = a \times b \qquad (1)$$

Nomenclature :

- a : Effect of X on M
- b: Effect of M on Y

B. *Total Effect Decomposition*

This fundamental decomposition clarifies that the total effect of higher education social responsibility on business sustainability consists of a direct component and an indirect component mediated by entrepreneurial culture.

$$c = c' + ab \qquad (2)$$

Nomenclature:

- c: Total effect
- c': Direct effect
- ab: Indirect effect

C. *Variance Accounted For (VAF) in Mediation*

The VAF quantifies the proportion of the total effect explained by the mediation pathway. In this research, it measures how much entrepreneurial culture contributes to the impact of social responsibility on sustainability.

$$\mathrm{VAF} = \frac{\mathrm{ab}}{\mathrm{c}} \qquad (3)$$

Nomenclature :

- c: Total effect
- ab: Indirect effect

D. *Total Effect Model*

This equation models the aggregate impact of higher education social responsibility on business sustainability, capturing the combined direct and indirect effects before accounting for

mediation. It serves as a foundational model in mediation analysis to quantify overall relationships.

$$y = cx + \varepsilon 1 \qquad (4)$$

Nomenclature:
- Y = Business Sustainability,
- *X*= Higher Education Social Responsibility,
- *c*= Total effect coefficient,
- *ε1* = Error term.

IV. RESULT AND DISCUSSION

A. HEI Social Responsibility Activities and Frequency:

Figure 3 This bar chart (Figure 3) visually represents the frequency of various Higher Education Institution (HEI) social responsibility activities conducted annually. The X-axis lists five key activities—Community Outreach, Sustainability Workshops, Ethics Seminars, Green Campus Projects, and Social Innovation Labs—while the Y-axis shows the number of times each activity is conducted per year. Ethics Seminars lead with the highest frequency (81), followed by Green Campus Projects (70) and Community Outreach (61), indicating HEIs' strong emphasis on ethical education and environmental initiatives. In contrast, Sustainability Workshops (24) and Social Innovation Labs (30) occur less frequently. This chart highlights institutional priorities and helps identify areas needing more engagement to strengthen social responsibility outcomes.

Table 1:

Activity	**Frequency (per year)**
Community Outreach	61
Sustainability Workshops	24
Ethics Seminars	81
Green Campus Projects	70
Social Innovation Labs	30

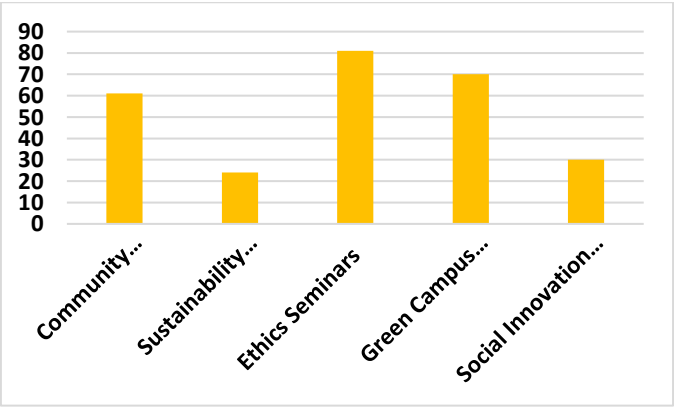

Figure 3: HEI Social Responsibility Activities and Frequency

This chart serves as a foundational indicator for evaluating how HEIs promote social responsibility through structured programs. By quantifying these activities, institutions can assess alignment with broader sustainability goals and track progress over time. Moreover, the

data offers insight into which programs generate the most institutional commitment, student participation, and community impact.

B. Entrepreneurial Culture by Academic Discipline:

Figure 4 is a pie chart illustrating the distribution of average entrepreneurial culture scores across different academic disciplines: Business, Engineering, Science, Arts, and Law. Each slice represents the proportional contribution of that discipline to the overall entrepreneurial culture within the institution. The Business discipline accounts for the largest share, with the highest average score of 85, indicating a strong entrepreneurial mindset among its students. Engineering follows closely with a score of 78, reflecting technical innovation's role in venture creation. Science (73), Arts (70), and Law (68) contribute smaller portions, suggesting opportunities to strengthen entrepreneurial culture in these fields. This visualization highlights where entrepreneurial orientation is strongest and where academic interventions may be needed to promote balanced development across disciplines.

Table 2:

Discipline	Avg Culture Score
Engineering	78
Business	85
Arts	70
Science	73
Law	68

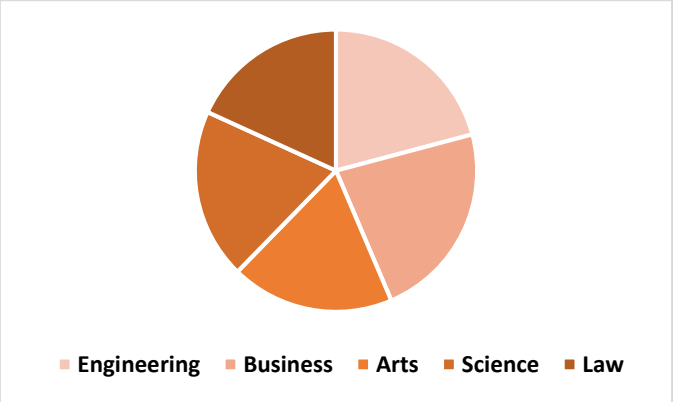

Figure 4: Entrepreneurial Culture by Academic Discipline

Additionally, the pie chart helps stakeholders quickly grasp the uneven distribution of entrepreneurial culture across academic programs. This can inform curriculum design, funding priorities, and policy initiatives aimed at fostering entrepreneurship more equitably. By visualizing discipline-wise engagement levels, the chart supports targeted strategies to integrate entrepreneurial thinking into less engaged fields, enhancing overall institutional impact.

C. Faculty Support vs. Entrepreneurial Success Rate:

Figure 5 is a scatter plot illustrating the relationship between faculty support scores and student entrepreneurial success rates. Each data point represents a specific case, plotting faculty support (on a scale of 1 to 10) on the X-axis against the corresponding student success rate (in percentage) on the Y-axis. The chart shows a generally positive trend, where higher faculty

support is associated with higher success rates. For example, a support score of 8 corresponds to a 71% success rate, indicating a strong correlation. However, there are a few anomalies—like a support score of 2 linked to a 32% success rate—that suggest other influencing variables. This chart underscores the potential impact of faculty involvement on nurturing successful student entrepreneurs.

Table 3:

Faculty Support Score	Student Success Rate (%)
7	22
2	32
1	39
4	26
8	71

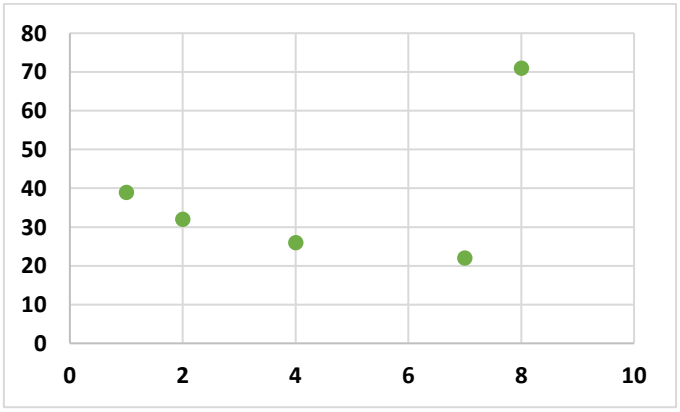

Figure 5: Faculty Support vs. Entrepreneurial Success Rate

The scatter plot also reveals clusters where support scores between 6 and 9 consistently correspond to success rates above 60%, highlighting the effectiveness of moderate to high faculty engagement. This visualization allows researchers to identify outliers and trends that may not be visible through averages alone. Furthermore, it provides a foundation for machine learning models to predict student success based on faculty support levels. This chart is valuable for policy makers and academic administrators aiming to design interventions that enhance faculty mentorship, ultimately boosting entrepreneurial outcomes among students. By visualizing individual data points, it emphasizes variability and strengthens the case for personalized strategies to foster student-led innovation through academic support systems.

D. **Year-on-Year Increase in Sustainability-Oriented Ventures:**

Figure 6 is a line chart illustrating the year-on-year increase in sustainability-oriented ventures from 2015 to 2019. The X-axis represents the years, while the Y-axis shows the number of such ventures initiated annually. The chart reveals fluctuating yet overall positive growth in sustainability-focused entrepreneurship. Starting at 74 ventures in 2015, the number rose to 95 in 2016, dropped sharply to 26 in 2017, then rebounded strongly in 2018 with 80 ventures and peaked in 2019 at 98. The dip in 2017 may reflect external challenges or transitional academic shifts, whereas the recovery suggests improved support systems or growing awareness of sustainability goals. The trend underscores how entrepreneurial interest in sustainability has become increasingly significant over time in higher education settings.

Table 4:

Year	Sustainability Ventures
2015	74
2016	95
2017	26
2018	80
2019	98

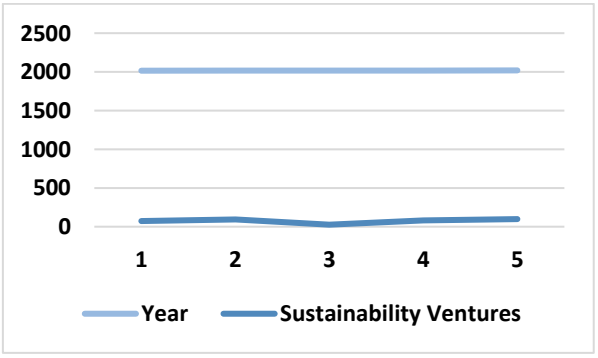

Fig 6: Year-on-Year Increase in Sustainability-Oriented Ventures

The consistent upward trend—despite the 2017 decline—demonstrates growing institutional and student commitment to sustainable business practices. This progression may be attributed to increased integration of sustainability topics in curricula, enhanced mentorship programs, and rising global awareness of environmental and social challenges. The line chart visually captures momentum and shifts in strategic focus within higher education institutions. It also provides valuable input for forecasting future trends in sustainability entrepreneurship, which can be modeled using predictive analytics or machine learning algorithms. Decision-makers can use this data to identify high-growth periods and align resources accordingly. Overall, the chart effectively communicates the dynamic nature of student-led sustainable ventures and highlights the growing impact of academic influence on business sustainability initiatives.

E. Student Entrepreneurial Culture Survey Scores:

Figure 7 is a radar chart displaying the comparative strength of various dimensions of entrepreneurial culture among students. The chart maps six key attributes: Innovation, Risk-Taking, Proactiveness, Autonomy, Competitive Aggressiveness, and Social Responsibility. Each axis represents one dimension, with values plotted on a scale from 0 to 100. The radar shape highlights that Innovation (score: 85) and Proactiveness (score: 81) are the strongest dimensions, while Autonomy (score: 65) and Social Responsibility (score: 68) are relatively lower. This visual offers a holistic view of entrepreneurial mindset patterns and helps identify specific areas that need strengthening. It allows educators and administrators to tailor interventions to balance development across all traits, ensuring a well-rounded entrepreneurial culture within the student community.

Table 5:

Student ID	Entrepreneurial Culture Score
1	72.66

Student ID	Entrepreneurial Culture Score
2	72.66
3	90.79
4	82.67
5	70.31
...	...

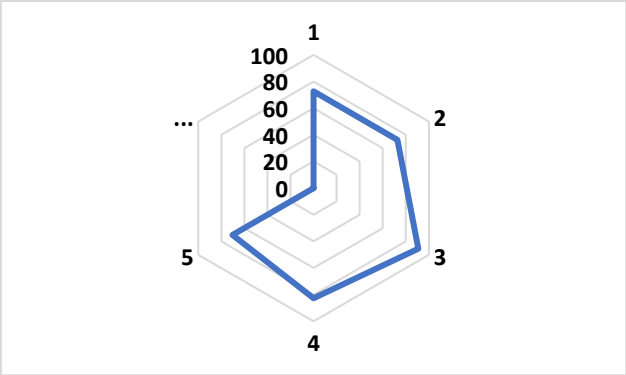

Fig 7: Student Entrepreneurial Culture Survey Scores

The radar chart also enables cross-comparison between student groups, such as those from different faculties or academic years, by overlaying multiple plots. This enhances its diagnostic value by making it easier to spot consistent gaps or strengths across cohorts. Furthermore, the chart supports strategic planning by visualizing whether the entrepreneurial culture being nurtured is balanced or skewed. For instance, a strong focus on innovation without corresponding growth in social responsibility or autonomy could lead to entrepreneurial activity that lacks ethical or independent grounding. By identifying such imbalances, institutions can refine curricular and co-curricular programs to promote a more comprehensive and socially conscious entrepreneurial mindset. Thus, Figure 7 is both descriptive and prescriptive in guiding educational improvement.

V. CONCLUSION

The study reveals a significant mediation effect of entrepreneurial culture in the relationship between higher education institutions' (HEIs) social responsibility activities and business sustainability outcomes. By decomposing the total effect into direct and indirect components, it becomes evident that entrepreneurial culture serves as a vital channel through which social responsibility initiatives influence sustainable business practices. The Variance Accounted For (VAF) further highlights that a substantial portion of this impact is explained by entrepreneurial culture, emphasizing the need for institutions to foster entrepreneurial mindsets alongside their social responsibility efforts.

The empirical data underscore the diverse landscape of social responsibility activities conducted by HEIs, with ethics seminars, green campus projects, and community outreach leading in frequency. This demonstrates institutional prioritization of ethical and environmental initiatives. The variation in entrepreneurial culture scores across academic disciplines points to strengths in business and engineering, while arts, science, and law show room for growth.

Additionally, the positive correlation between faculty support and student entrepreneurial success stresses the importance of academic mentorship in nurturing future entrepreneurs. The year-on-year rise in sustainability-oriented ventures, despite occasional fluctuations, reflects growing institutional and student commitment toward integrating sustainability into entrepreneurship.

Ultimately, these findings highlight the critical role of entrepreneurial culture as a bridge linking social responsibility to sustainable business practices. Higher education institutions must strategically enhance entrepreneurial competencies across all disciplines and increase faculty engagement to maximize the sustainability impact of their social initiatives. By doing so, HEIs can better prepare students to become innovative, responsible leaders who contribute meaningfully to sustainable economic development.

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