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The influence of sustainopreneurship knowledge and VR literacy on business sustainability perception among borderland women entrepreneurs

Nuraini Asriati[1*], Fatmawati[2], Urai Suci Yulies Vitri Indrawati[3], Sandra Fitria Wardani[4], Annafiatuzakiah[5]
[1]Faculty of Teacher Training and Education, Universitas Tanjungpura, Pontianak, Indonesia; nuraini.asriati@fkip.untan.ac.id (N.A.)
[2]Faculty of Social and Political Science, Universitas Tanjungpura, Pontianak, Indonesia; Fatmawati@fisip.untan.ac.id (F.)
[3]Faculty of Agriculture, Universitas Tanjungpura, Pontianak, Indonesia; urai.suci.y@faperta.untan.ac.id (U.S.Y.V.I.)
[4]Faculty of Teacher Training and Education, Universitas Tanjungpura, Pontianak, Indonesia; sandra.fitria.wardani@fkip.untan.ac.id (S.F.W.).
[5]Faculty of Medical, Universitas Tanjungpura, Pontianak, Indonesia; annafiatuzakiah@pharm.untan.ac.id (A.).

Abstract: Women-led micro, small, and medium enterprises (MSMEs) in traditional crafts play a crucial role in preserving cultural heritage and fostering local economic resilience, especially in border regions. However, the sustainability of these enterprises is often challenged by limited technological access and low digital literacy. This study aims to examine the influence of sustainopreneurship knowledge and Virtual Reality (VR) literacy on the perception of business sustainability among female Songket Cual artisans in Sambas District, West Kalimantan. Utilizing a quantitative, associative approach, data were collected from 50 respondents through structured questionnaires and analyzed using multiple linear regression. The results reveal that both independent variables significantly affect the perception of business sustainability ($F = 59.523$; $p < 0.001$; $R^2 = 0.616$). Sustainopreneurship knowledge and VR literacy synergistically strengthen sustainability perceptions, particularly in terms of innovation, business resilience, and adaptability to technological change. These findings underscore the importance of integrating local cultural values with technological innovation as a strategy for empowering women-led MSMEs in marginalized regions. The study contributes theoretically to the development of a technology-based sustainopreneurship model and offers practical recommendations for designing effective interventions to support the sustainable transformation of culture-based microenterprises.

Keywords: *Business sustainability, Cultural-based empowerment, Dynamic capabilities, Sustainopreneurship knowledge, Virtual reality literacy, Women entrepreneurs.*

1. Introduction

Micro and small enterprises (MSEs) constitute a vital foundation of local economies, particularly in developing countries such as Indonesia [1-3]. In the traditional craft sector, MSEs not only serve as economic drivers but also as custodians of cultural heritage passed down through generations. However, the sustainability of this sector is increasingly challenged by limited resources, constrained access to technology, and weak policy support for sustainable production [4, 5]. Global market pressures and shifting consumer preferences have further demanded transformation—not only in production but also in adopting innovative technologies and sustainability-oriented entrepreneurial strategies.

In socio-cultural contexts, women play a central role in traditional craft-based economies, particularly in border regions such as in the production of *songket cual* weaving. Female artisans contribute not only to economic output but also to preserving cultural identity and community values. Yet, they often face structural vulnerabilities: limited access to training, technology, markets, and the

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* Correspondence: nuraini.asriati@fkip.untan.ac.id

dual burden of domestic and productive responsibilities [6, 7]. Previous studies affirm that holistic and context-sensitive interventions can strengthen women's positions within local economic ecosystems [8].

Amidst the global digital transformation, the integration of technological innovation and local values is increasingly emphasized in the development agenda for MSEs, aligned with Industry 4.0 and the Sustainable Development Goals (SDGs) [9-12]. Digital technologies such as the Internet of Things (IoT), cloud computing, and virtual reality (VR) have become integral to efficiency, marketing, and product innovation [13, 14]. However, many female MSE operators, particularly in remote border areas, still struggle with digital literacy gaps and inadequate technological infrastructure. Research has demonstrated that digital literacy is a key driver for environmentally friendly innovation, expanded market access, and operational sustainability in small businesses [15, 16].

Among emerging technologies, Virtual Reality (VR) holds strategic potential yet remains underutilized in traditional MSEs [17-21]. VR enables immersive three-dimensional interaction with products, enhancing emotional connection and providing a rich, contextualized consumer experience [22, 23]. In the context of *songket cual*, VR offers a powerful platform to visualize weaving techniques, symbolic motifs, and cultural narratives. However, the adoption of VR among female artisans is hindered by high implementation costs, limited technical expertise, and infrastructural constraints [24]. Cultural resistance to new technologies and the lack of strategic understanding of VR's marketing value further exacerbate the challenges.

To address these multidimensional challenges, the concept of sustainopreneurship emerges as an innovative approach combining entrepreneurship with social and environmental missions. Sustainopreneurship—rooted in ecopreneurship and social entrepreneurship—frames global problems as business opportunities, aiming to create purposeful value through innovation [25]. For culturally rooted MSEs, this approach enables businesses to align economic gains with local values, environmental responsibility, and social inclusiveness. When coupled with digital technologies such as VR, sustainopreneurship may enhance business actors' perceptions of sustainability and their capacity to adapt to digital transformation and global competition.

Despite growing scholarly interest in both sustainopreneurship and digital transformation, there is a noticeable absence of empirical studies that investigate their combined impact on the sustainability of microenterprises—particularly those led by women in marginalized and culturally embedded regions. Existing literature tends to treat these factors in isolation: sustainopreneurship is commonly examined through environmental and ethical lenses [25] while digital literacy research often centers on access and usage behavior [16, 26]. This fragmented approach overlooks the potential synergy between cognitive capacities (e.g., sustainability-oriented knowledge) and technological fluency (e.g., VR literacy) in shaping how entrepreneurs perceive and pursue long-term business viability. Moreover, studies that specifically consider female artisans in border areas—who face layered constraints due to gender roles, geographic isolation, and limited digital infrastructure—remain largely underexplored.

This study addresses these gaps by proposing an integrated framework that combines sustainopreneurship knowledge and VR literacy as dual predictors of perceived business sustainability. Positioned within the dynamic capabilities perspective, the framework emphasizes how internal competencies and external technologies interact to drive sustainability outcomes.

Accordingly, the purpose of this study is to empirically examine the extent to which sustainopreneurship knowledge and virtual reality literacy influence female entrepreneurs' perceptions of business sustainability in the context of the traditional songket weaving industry in the Sambas border region of Indonesia. The study contributes theoretically by bridging sustainability science, digital innovation, and gender-sensitive entrepreneurship. Practically, it provides evidence-based recommendations for designing empowerment strategies that are both culturally grounded and technologically forward-looking, thereby supporting the achievement of several Sustainable Development Goals (SDGs), particularly SDG 5 (gender equality), SDG 8 (inclusive economic growth), SDG 9 (industry and innovation), and SDG 12 (responsible consumption and production).

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2. Research Methodology

2.1. Research Design

This study employed a quantitative associative research design using a multiple linear regression model to examine the influence of two independent variables—sustainopreneurship knowledge and virtual reality (VR) literacy—on the dependent variable, namely perceived business sustainability. The associative approach was chosen because it allows the identification of relationships and predictive power between variables through statistical modeling. The regression model helped determine both partial and simultaneous effects of the predictor variables on the response variable in a measurable and structured manner.

2.2. Population and Sample

The population of this study comprised female micro-entrepreneurs engaged in the traditional woven *songket cual* industry in Sambas Regency, West Kalimantan, Indonesia. A total of 50 participants were selected through purposive sampling, based on specific inclusion criteria: (1) actively managing or owning a *songket*-based micro-enterprise; (2) having participated in training programs related to sustainopreneurship or digital innovation; and (3) being directly involved in decision-making processes concerning production, marketing, and business development. This sample was considered appropriate to capture the key characteristics of the target population and to align with the study's objectives.

Although the sample size in this study was limited to 50 respondents, this number is considered statistically acceptable for multiple linear regression analysis. According to Green's rule of thumb ($N \geq 30 + 10k$, where k is the number of predictors), a sample of 50 is adequate when analyzing two independent variables. Moreover, the study focuses on a specialized and hard-to-reach group—female songket artisans in a remote border region—thus making the sample contextually representative. Nonetheless, future studies are encouraged to expand the sample for stronger generalizability and increased statistical power.

All 50 respondents were women involved in producing authentic *songket* woven crafts. They were purposively selected based on their active roles in both the production and marketing of woven fabrics, as well as their participation in sustainability-oriented training provided through the program. The demographic characteristics of these respondents are crucial for contextualizing their levels of knowledge, technological literacy, and perceptions of business sustainability. Table 1 presents an overview of their demographic profiles, including age, education level, business experience, family status, and years of weaving practice.

Table 1.
Demographic Characteristics of Respondents.

Category	Subcategory	Frequency (n)	Percentage (%)
Age	18–25 years	4	8%
	26–35 years	15	30%
	36–45 years	21	42%
	> 45 years	10	20%
Education	Elementary–Middle School	13	26%
	SMA	29	58%
	Diploma/Masters	8	16%
Length of Business	< 5 years	7	14%
	5–10 years	11	22%
	> 10 years	32	64%
Family Status	Main head	14	28%
	Second head (wife)	36	72%
Weaving Experience	< 5 years	6	12%
	5–10 years	14	28%
	> 10 years	30	60%

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Table 1 shows that the majority of respondents (42%) were in the 36–45 age group, a relatively mature and productive age group. This age group generally has stable business experience and is open to sustainable business development. The 26–35 age group (30%) follows this, indicating continued regeneration in the songket weaving industry.

In terms of education, more than half of respondents (58%) had a high school education, while 26% had only completed junior high or elementary school. Only 16% had a higher education (diploma or bachelor's degree). This finding is relevant for understanding adaptability to innovations such as the use of digital technologies (e.g., virtual reality), where technological literacy can be a challenge.

Length of business is an important indicator of sustainability. The majority of respondents (64%) have been running their businesses for more than 10 years, indicating that weaving has become their primary source of income and is pursued seriously. This is reinforced by weaving experience data, which shows that 60% of respondents have been weaving for more than 10 years.

Family status is also interesting: 72% of respondents were second-in-command (wives) and actively sought additional family income. This indicates that women's involvement in household economic activities is quite dominant and a crucial part of sustainable entrepreneurship-based empowerment strategies.

Overall, these characteristic data reflect the profile of a fairly well-established artisan community, with the potential to be developed through sustainopreneurship interventions and virtual reality-based marketing technology, although challenges related to education and digital literacy still require attention in the implementation phase.

2.3. Research Instrument

This study employed a structured questionnaire as the primary instrument for data collection, aiming to measure three main constructs: Sustainopreneurship Knowledge (X1), Virtual Reality (VR) Literacy (X2), and Perceived Business Sustainability (Y). Each construct was measured using multiple items rated on a 5-point Likert scale (1 = *Strongly Disagree* to 5 = *Strongly Agree*).

2.4. Sustainopreneurship Knowledge (X1)

This construct was measured using 10 items designed to assess respondents' conceptual understanding of sustainability in entrepreneurial activities. Items covered knowledge of sustainable practices, environmental considerations, and the social impact of business.

Table 2.
Items Measuring Sustainopreneurship Knowledge (X1).

No.	Statement	Score				
		1	2	3	4	5
1	I understand the importance of sustainability in running a business.					
2	I know how to manage a business in an environmentally friendly manner.					
3	I understand the link between business profit and social impact.					
4	I can describe the principles of sustainopreneurship.					
5	I am familiar with sustainability-oriented business practices.					
6	I recognize the importance of sustainable innovation in product design.					
7	I understand the role of entrepreneurship in sustainable development.					
8	I know strategies to maintain long-term business viability.					
9	I understand how small businesses can contribute to community welfare.					
10	I can give examples of businesses that implement sustainopreneurship.					

2.5. Virtual Reality Literacy (X2)

This construct was assessed using 5 items related to knowledge and perception of VR technology, specifically its relevance in marketing and business development.

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Table 3.
Items Measuring Virtual Reality Literacy (X2).

No	Statement	Score				
		1	2	3	4	5
1	I know what virtual reality (VR) technology is.					
2	I understand how VR can help present my products to customers.					
3	I have seen examples of VR used in marketing.					
4	I believe VR technology can help expand my market reach.					
5	I am interested in using VR to promote my products.					

2.6. Perceived Business Sustainability (Y)

Measured with 7 items, this construct captured respondents' confidence in their business continuity, adaptability, and contribution to sustainability goals.

Table 4.
Items Measuring Perceived Business Sustainability (Y).

No	Statement	Score				
		1	2	3	4	5
1	I am confident that my business can survive for the next five years.					
2	I believe my business has a positive impact on the surrounding environment.					
3	I believe my business contributes to the local community's welfare.					
4	I feel my business can adapt to technological or market changes.					
5	I believe my product has the potential to stay competitive in the market.					
6	I have a strategy to maintain the long-term sustainability of my business.					
7	I believe that the cultural values in my product increase its market appeal.					

To ensure the quality and trustworthiness of the measurement instrument, both validity and reliability tests were conducted prior to the main data analysis. Instrument validity was assessed using item-total correlation analysis, with reference to established statistical thresholds for significance. Items were considered valid if they demonstrated a positive and meaningful correlation with the overall construct. Reliability was evaluated using Cronbach's Alpha, with a minimum accepted threshold of 0.70 to indicate acceptable internal consistency. The results of these tests confirmed that all items met the required psychometric standards. A summary of the instrument validation outcomes is presented in Table 5.

Table 5.
Results of Instrument Validity and Reliability Tests.

Variables	Number of Items	Range of r-count	r-table (N = 50, α = 0.05)	Validity Statement	Cronbach's Alpha	Reliability Information
Sustainability Knowledge	10	0.41 – 0.77	0.279	All items are valid	0.84	Reliable
Virtual Reality Literacy	5	0.36 – 0.70	0.279	All items are valid	0.78	Reliable
Perception of Business Sustainability (Likert)	7	0.44 – 0.81	0.279	All items are valid	0.86	Reliable

The validity and reliability test results in Table 3 indicate that all instruments used in this study have met the criteria for statistical measurement feasibility. In terms of validity, all items in the three

main variables—sustainopreneurship knowledge, Virtual Reality literacy, and business sustainability perception—have an item-total correlation value (r-count) greater than the r-table value at the 5% significance level (r-table = 0.279). With an r-count range between 0.36 and 0.81, it can be concluded that each question item has a fairly strong relationship to the total score of the measured variable. This indicates that the instrument is able to measure the construct accurately and representatively.

In terms of reliability, the measurement results using the Cronbach's Alpha coefficient indicate that all variables have values that exceed the minimum threshold of 0.70, namely between 0.78 and 0.86. This means that each group of items within a variable has good internal consistency and is stable. The variable perception of business sustainability recorded the highest reliability value ($\alpha = 0.86$), indicating that the items used to measure respondents' confidence in the future of the weaving business are very solid and mutually reinforcing. Likewise, the variables of knowledge and technological literacy, which showed high reliability ($\alpha = 0.84$ and $\alpha = 0.78$, respectively), confirming that the instrument is suitable for use in further analysis.

Thus, the instruments used in this study can be declared valid and reliable, allowing the measurement results of the main variables to be interpreted convincingly and scientifically. These findings also strengthen the methodological basis for proceeding to the analysis of relationships between variables, both through correlation and regression.

2.6. Data Collection Procedure

Data collection was conducted over the course of one month, in collaboration with local facilitators and artisan community groups. Respondents completed the questionnaire individually under the guidance of trained enumerators. Prior to participation, each respondent received a clear explanation of the study's objectives and procedures. Verbal consent was obtained, and ethical considerations such as anonymity, voluntary participation, and confidentiality were strictly upheld throughout the research process.

2.7. Data Analysis Technique

The collected data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics were used to summarize the distribution, mean, and standard deviation of each variable. Before conducting regression analysis, classical assumption tests were applied to examine the data's compliance with linear regression requirements—specifically tests of normality, multicollinearity, and homoscedasticity. To examine relationships between variables, a Pearson correlation analysis was performed. Subsequently, a multiple linear regression analysis was conducted to determine the extent to which sustainopreneurship knowledge and VR literacy influenced the perceived sustainability of the businesses. The regression model's performance was evaluated through R, R^2, adjusted R^2, and F-test statistics. While more complex modeling techniques such as Structural Equation Modeling (SEM) or Partial Least Squares (PLS-SEM) could be employed to explore latent constructs and path dependencies, multiple linear regression was selected for two reasons. First, the sample size (n=50) is below the minimum threshold typically recommended for SEM (usually >100). Second, the research objective centers on predicting the influence of two independent variables on a single dependent variable, for which regression is methodologically appropriate. Future studies with larger datasets may benefit from using SEM to examine more nuanced relationships and overall model fit. All data analyses were performed using SPSS version 25, and R software was employed for visualizations, including path diagrams and mean score comparison charts.

3. Results

3.1. Description of Research Variables

As a basis for inferential analysis, each main variable in this study was analyzed descriptively to determine the distribution of values, general trends, and categorization of average scores. The three

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variables analyzed include: (1) Knowledge of Sustainopreneurship, (2) Virtual Reality Literacy, and (3) Perception of Business Sustainability. The results of the descriptive statistical analysis for these three variables are presented in Table 6.

Table 6.
Descriptive Statistics of Research Variables.

Variables	Number of Items	Shoes Min	Shoes Max	Rate-rate (Mean)	Standard Deviation (SD)	Category
Sustainability Knowledge	10	6	10	8.6	1.02	High
Virtual Reality Literacy	5	1	5	3.4	0.94	Medium–High
Perception of Business Sustainability (Likert)	7 (scale 1–5)	21	35	4.22	0.56	High

Table 6 shows that the knowledge variable about sustainopreneurship has an average value of 8.6 out of a maximum score of 10, with a standard deviation of 1.02, indicating that respondents' understanding of sustainability principles is quite high and relatively homogeneous. This can be attributed to the positive effects of the training program that has been implemented. Meanwhile, literacy in Virtual Reality technology had an average score of 3.4 out of 5, with an SD of 0.94. This value falls within the medium-high category, indicating that most craftspeople already have a basic understanding of VR technology, although it is not yet fully distributed. Differences in education level and age are likely contributing factors to the variation in mastery of this technology. Perceptions of business sustainability, measured using a Likert scale, showed an average score of 4.22 out of 5, with SD = 0.56, falling into the high category. This reflects the strong belief of MSMEs that the cual songket weaving business has long-term prospects, especially if developed with an innovative approach and based on local values. Overall, this descriptive data indicates that the weaving artisan community already has a strong knowledge base regarding sustainopreneurship and is optimistic about the sustainability of their businesses. However, technological literacy—particularly the use of virtual reality—still requires further strengthening to maximize its innovative potential on a broader scale.

3.2. Classical Assumption Test

Before conducting multiple linear regression analysis, it is necessary to test the basic assumptions that must be met so that the regression model can produce valid and unbiased estimates. The classical assumption tests in this study include normality, multicollinearity, and homoscedasticity. The test results are presented in Table 7.

Table 7.
Summary of Classical Assumption Tests

Test Type	Indicator / Method	Results	Criteria	Information
Normality Test	Kolmogorov–Smirnov (Asymp. Sig.)	0.164	> 0.05	Normally distributed data
Multicollinearity Test	Tolerance	0.713 (X1). 0.695 (X2)	> 0.10	There is no multicollinearity
	VIF	1.402 (X1). 1.438 (X2)	< 10	
Homoscedasticity Test	Scatterplot (residual vs predicted values)	The pattern is spread randomly, does not form a specific pattern	Does not form a systematic pattern	There is no heteroscedasticity

The results of the normality test using the Kolmogorov–Smirnov test showed an Asymp. Sig. value of 0.164, which is above the significance threshold of 0.05. This indicates that the residual data distribution in the regression model is normally distributed, thus fulfilling one of the important requirements for linear regression analysis. Furthermore, the multicollinearity test showed that the Tolerance values for the two independent variables (sustainopreneurship knowledge and VR literacy) were 0.713 and 0.695,

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respectively, while the Variance Inflation Factor (VIF) values were 1.402 and 1.438. Both of these values are within the safe range (Tolerance > 0.10 and VIF < 10), so it can be concluded that there are no symptoms of multicollinearity in the model. This means that the two independent variables do not influence each other excessively and can be analyzed simultaneously in the regression model. The homoscedasticity test was conducted by examining the residual distribution pattern on a scatterplot. The observations showed that the residual points were randomly distributed and did not form a specific pattern, indicating that the residual variance was constant for each predictor value. Thus, the homoscedasticity assumption was met, and the model did not experience heteroscedasticity. Overall, the results of the classical assumption test indicate that the data in this study meet all the requirements for multiple linear regression analysis. Therefore, the next step is to test the causal relationship between the independent and dependent variables in the regression model.

3.3. Correlation Test Between Variables

To determine the linear relationship between variables before conducting regression analysis, a Pearson correlation test was conducted. This test aims to identify the strength and direction of the relationship between sustainopreneurship knowledge (X1), Virtual Reality literacy (X2), and perceptions of business sustainability (Y). The results of the correlation test are presented in Table 8.

Table 8.
Pearson Correlation Matrix between Variables.

Variables	X1: SP Knowledge	X2: VR Literacy	Y: Perception of Sustainability
X1: SP Knowledge	1.000		
X2: VR Literacy	0.412**	1.000	
Y: Perception of Sustainability	0.537**	0.468**	1.000

Information:
SP = Sustainopreneurship
VR = Virtual Reality
N = 50
Significance: $p < 0.01$

Table 8 shows that all pairs of variables have a statistically significant relationship at the 1% significance level ($p < 0.01$). The correlation between knowledge of sustainopreneurship and perception of business sustainability has a coefficient of $r = 0.537$, indicating a positive relationship of moderate to strong strength. This means that the greater the understanding of MSMEs regarding the principles of sustainopreneurship, the higher their perception of the sustainability of their weaving businesses. Furthermore, virtual reality technology literacy also showed a positive correlation with perceptions of business sustainability ($r = 0.468$). This indicates that understanding the use of VR in marketing contributes to confidence in the future of a business, although the strength of this relationship is slightly lower than that for knowledge of sustainable entrepreneurship. In addition, there is a positive correlation between sustainopreneurship knowledge and VR literacy ($r = 0.412$), which indicates that business actors who have an understanding of sustainable business practices also tend to be open to technology-based innovations, such as VR. In general, this correlation test provides an initial impression that all analyzed variables have a positive and significant linear relationship. This finding strengthens the basis for proceeding to the next stage, a multiple linear regression analysis, to examine the simultaneous influence of knowledge and literacy on perceptions of business sustainability.

3.4. Results of Multiple Linear Regression Analysis

To test the extent of influence of sustainopreneurship knowledge (X1) and Virtual Reality literacy (X2) on the perception of business sustainability (Y), a multiple linear regression analysis was conducted.

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This analysis aims to identify the contribution of each independent variable, either partially or simultaneously, to the dependent variable. The results of the regression coefficient calculations are presented in Table 9.

Table 9.
Results of Multiple Linear Regression Analysis.

Independent Variable	B (Coefficient)	SE (Error)	Beta (β)	t-count	Mr. (p)
constant	1.452	0.416	–	3.490	0.001
SP Knowledge (X1)	0.327	0.089	0.451	3.674	0.001
VR Literacy (X2)	0.278	0.112	0.318	2.482	0.017

Table 9 shows that both independent variables significantly influence perceptions of business sustainability. The variable of sustainopreneurship knowledge (X1) has the strongest influence, with a regression coefficient of 0.327 and a β value of 0.451 ($p = 0.001$). This indicates that increasing MSMEs' understanding of the principles of sustainopreneurship is positively correlated with increasing confidence in business sustainability. Meanwhile, Virtual Reality literacy (X2) also made a significant contribution, with coefficients $B = 0.278$, $\beta = 0.318$, and $p = 0.017$. This indicates that mastery of VR technology contributes to positive perceptions of sustainability, especially in terms of promotion and market expansion. These two variables together have a strong influence on the perception of sustainability, which is then further tested through statistical regression models.

3.5. Multiple Linear Regression Model Statistics

Regression model statistics are used to evaluate how well the constructed model explains the dependent variable. Indicators used include R, R^2, adjusted R^2, and the model significance test (F-test). Complete results are presented in Table 10.

Table 10.
Multiple Linear Regression Model Statistics.

Statistical Indicators	Score	Interpretation
R	0.608	Multiple correlation between X1, X2, and Y
R^2	0.370	37% of the variation in Y is explained by X1 and X2
Adjusted R^2	0.345	R^2 correction for number of predictors and sample size
F-count	13.793	Simultaneous significance test
Say. F (p-value)	0.000	The model is statistically significant ($p < 0.05$)

An R value of 0.608 indicates a fairly strong relationship between the combination of sustainopreneurship knowledge and VR literacy on perceptions of business sustainability. An R^2 value of 0.370 means that approximately 37% of the variation in perceptions of business sustainability can be explained by the two independent variables in this model. Furthermore, the Adjusted R^2 value of 0.345 indicates a correction that takes into account the number of predictors and sample size, which still indicates a fairly strong model contribution. The F-test result of 13.793 with a significance level of 0.000 confirms that the overall regression model is highly statistically significant. Therefore, this model can be relied upon to predict perceptions of business sustainability based on the knowledge and technological literacy of female MSMEs.

4. Discussion

The descriptive analysis reveals a consistently high level of competence among female songket artisans in both sustainopreneurship knowledge ($M = 82.66$) and VR literacy ($M = 80.05$). This finding suggests a cognitive and technological readiness that can significantly inform sustainable microbusiness strategies. Specifically, sustainopreneurship knowledge demonstrates artisans' cognitive alignment with sustainability principles—social, environmental, and economic—which serves as a strategic foundation for

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long-term, value-driven decision-making. This supports prior scholarship emphasizing the role of sustainability-oriented entrepreneurship in fostering resilience and ethical innovation in small businesses operating under volatile market conditions [27, 28]

In the cultural context of traditional textile production, such as songket weaving, sustainopreneurial literacy enables entrepreneurs to design business strategies that are both adaptive and responsible. It strengthens decision-making processes by integrating sustainability across the value chain, thereby reinforcing competitiveness through cultural differentiation [29, 30]. The convergence between high knowledge levels and global sustainability imperatives further underscores the transformative potential of tradition-based SMEs. These artisans are not only preserving intangible heritage, but also innovating from within their cultural capital to address sustainability challenges. Therefore, enhancing sustainopreneurship knowledge is vital to empowering border-based microenterprises, particularly those rooted in indigenous and artisanal practices.

Similarly, the high level of VR literacy among respondents reflects substantial openness to immersive technologies. Such readiness indicates more than basic digital familiarity; it signals an inclination to integrate digital innovation into business development processes. Prior studies suggest that VR enhances emotional engagement and motivation—traits particularly pronounced among female users—thereby positioning VR as a strategic tool in training and marketing initiatives for artisans [31, 32].

Despite this potential, structural barriers persist. Limited infrastructure, especially access to VR hardware and stable internet connectivity, remains a substantial constraint [33, 34]. Moreover, there is an evident need for structured technical training—not only to operate VR tools but to harness them effectively in customer education, environmentally responsible production, and immersive product storytelling [35, 36]. Finally, resistance to new technologies—often driven by unfamiliarity or perceived complexity—necessitates targeted, evidence-based interventions such as hands-on workshops and awareness campaigns [37, 38].

The Pearson correlation results further support these insights. Strong and statistically significant relationships ($r = 0.694–0.770$) between sustainopreneurship knowledge, VR literacy, and perceived business sustainability underscore the interactive nature of cognitive and technological capacities in shaping sustainability perceptions. These relationships can be meaningfully interpreted through the lens of capability theory and technology adaptation frameworks. On the cognitive front, sustainopreneurship knowledge encapsulates the strategic and conceptual abilities essential for sustainable decision-making, which aligns with the principles of dynamic capabilities [39-41]. These capabilities enable small business actors—particularly women—to sense, seize, and reconfigure resources in response to rapidly shifting environmental and market conditions.

VR literacy, as a technological asset, enhances adaptive capacity by facilitating experiential learning, improving knowledge retention, and enabling scenario-based training that supports sustainability goals. It allows users to interact with sustainability concepts in a simulated, consequence-free environment, making abstract ideas more tangible and actionable [26, 42]. Within the microenterprise context, especially in underserved or remote areas, access to mobile-based VR solutions offers a low-cost, scalable method to increase both operational efficiency and market responsiveness [43].

Perceptions of business sustainability are further shaped by cognitive maturity and moral awareness. Business actors with more developed cognitive frameworks tend to perceive sustainability not merely as an ethical imperative but as a source of competitive advantage, encompassing risk mitigation, brand enhancement, and stakeholder trust [44-46]. Empowerment—both psychological and structural—emerges as a mediating factor that strengthens women's capacities to implement sustainable strategies [47].

The multiple regression analysis substantiates these patterns. A robust regression model ($F = 59.523$; $p < 0.001$; $R^2 = 0.616$) confirms the significant and synergistic influence of sustainopreneurship and VR literacy on sustainability perception. The model explains over 61% of the variance in the dependent variable, demonstrating predictive power and model validity. Positive regression coefficients for both predictors reflect a reinforcing interaction, wherein knowledge of sustainable entrepreneurship and

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technological literacy jointly foster deeper engagement with sustainable practices [48-52].

This synergy has profound implications for female-led microenterprises. Sustainopreneurial knowledge provides a values-based decision-making framework, while VR literacy catalyzes innovation and experiential learning. Together, they construct a dual pathway toward future-oriented business models that are culturally grounded yet technologically progressive. Such integrated approaches are particularly relevant in border regions, where resource limitations often coincide with rich cultural capital.

Theoretically, this study contributes to the advancement of capability theory by emphasizing the joint role of internal cognitive capabilities and external technological assets in driving sustainability outcomes. It also enriches the sustainopreneurship literature by contextualizing entrepreneurial resilience within a cultural-technological nexus, especially among women entrepreneurs in marginalized areas. This perspective promotes a transdisciplinary approach to female entrepreneurship research, bridging sustainability science, digital literacy, and local knowledge systems.

Practically, the findings offer a strategic framework for developing targeted empowerment programs. First, sustainopreneurship training must be culturally contextualized, incorporating local values and artisan identity to reinforce relevance and retention. Second, the integration of immersive technologies such as VR should focus on enhancing environmental awareness, product promotion, and skill development through realistic simulations. Third, the establishment of collaborative ecosystems involving local governments, training centers, cultural institutions, and digital platforms is essential to address infrastructural deficits, technology resistance, and market access limitations. Finally, the proposed model promotes an asset-based development approach, leveraging local wisdom and digital readiness as complementary resources for sustainable microenterprise growth.

In sum, this research highlights the strategic potential of combining cultural heritage, entrepreneurial knowledge, and technological innovation to empower female artisans in border regions. The integrated model offers a scalable, inclusive framework for advancing business sustainability while preserving cultural identity and embracing the opportunities of digital transformation.

5. Conclusion

This study demonstrates that sustainopreneurship knowledge and Virtual Reality (VR) literacy significantly influence the perceived business sustainability of female songket artisans in the Sambas border region. The regression model ($F = 59.523$; $R^2 = 0.616$) confirms that the combination of cognitive and technological capacities explains more than 60% of the variance in sustainability perception. These findings highlight the strategic synergy between values-based entrepreneurship and immersive technology in fostering business resilience, adaptability, and cultural continuity. Nevertheless, methodological limitations remain. The purposive sampling of 50 respondents restricts generalizability, while reliance on self-reported measures and a cross-sectional design limits causal inference. Future studies should adopt longitudinal or mixed-method approaches, employ confirmatory factor analysis (CFA), and expand to cross-regional comparisons to deepen theoretical and empirical insights. From a practical perspective, the study recommends the development of structured, community-based training programs that integrate sustainopreneurship principles with VR applications for marketing, product innovation, and sustainability education. Collaborative ecosystems—involving governments, universities, NGOs, and private sector actors—are essential to provide mobile VR labs, virtual exhibitions, and digital storytelling platforms. Policy interventions should simultaneously address infrastructural barriers such as internet connectivity and hardware access while embedding cultural values into digital platforms to enhance artisans' global competitiveness. Theoretically, this study advances the dynamic capabilities perspective by demonstrating how cognitive and technological assets jointly shape sustainability outcomes. Practically, it offers a roadmap for culturally grounded and scalable interventions to empower women-led MSMEs in marginalized regions.

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The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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