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Strengthening Inclusive Economic Development through Mango-Based Green Entrepreneurship: Cross-Border Mentoring of Women MSMEs in Indonesia and Malaysia

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Abstract

Women operating mango-based micro, small, and medium-sized enterprises (MSMEs) face challenges related to limited product diversification, access to finance, market reach, and adoption of sustainable production practices, which constrain their potential contribution to inclusive economic development. This study evaluated an integrated green entrepreneurship mentoring program implemented through an academic partnership between Indonesia and Malaysia. Using a participatory action research (PAR) approach, the study involved 25 purposively selected women entrepreneurs in North Sumatra, Indonesia, from May to October 2026. Participants completed 90 hours of training covering green entrepreneurship, mango processing, digital marketing, sustainable packaging, and financial literacy. Program outcomes were assessed through pre- and post-training competency assessments, direct observation, focus group discussions, document reviews, and participatory capacity scoring. Quantitative data were analyzed using descriptive statistics and normalized gain (N-gain) calculations. Mean competency scores increased from 40.3 to 72.4, corresponding to a moderate normalized gain of 0.54. The average number of product varieties increased from 1.6 to 4.2, while mango byproduct utilization rose from 12% to 76%. The proportion of participants holding formal business bank accounts increased from 40% to 92%, and marketplace participation reached 88%. The proportion of participants using nonrecyclable plastic packaging decreased from 88% to 28%. These findings suggested that integrated mentoring could support improvements in product innovation, financial inclusion, digital market participation, and environmentally sustainable business practices. The program demonstrated potential as an approach to strengthening women-led MSMEs and supporting inclusive regional economic development. However, the absence of a comparison group limited causal attribution, highlighting the need for longitudinal evaluation to determine whether the observed improvements translated into sustained business performance and environmental benefits.

INTRODUCTION

Micro, small, and medium-sized enterprises (MSMEs) constitute a fundamental component of the Indonesian economy. However, many continue to operate in low-value-added activities characterized by limited access to technology, financing, and markets (Tambunan, 2019). In North Sumatra (Sumatera Utara), these structural challenges are particularly evident in rural economies, where small enterprises generate employment but remain constrained by limited capital and inadequate managerial capabilities (Hasanah et al., 2025; Sembiring et al., 2024). Women play a significant role in these economic activities. The growth of women-led enterprises can generate broader socioeconomic benefits, including improvements in household nutrition, educational opportunities, and local consumption. Consequently, women's entrepreneurship is increasingly recognized as an important mechanism for promoting inclusive economic development rather than merely a specialized area of entrepreneurial activity (Brush et al., 2009; Kabeer, 1999; Welter, 2011).

Mango is an important horticultural commodity supporting the livelihoods of many women entrepreneurs. However, a substantial proportion of mango production is marketed as fresh fruit, limiting opportunities for value addition and reducing producers' participation in downstream economic activities. Furthermore, mango byproducts, including peels, seeds, and leaves, are frequently discarded despite their potential as sources of oils, dietary fiber, and bioactive compounds with commercial applications (Jahurul et al., 2015). The program's baseline assessment identified similar challenges among participating women entrepreneurs: 80% produced only one or two product varieties, 76% had never participated in green entrepreneurship training, only 40% maintained formal business bank accounts, and 88% used nonrecyclable plastic packaging. Comparable constraints have been documented among rice, chili, and smallholder agricultural producers in North Sumatra, where improvements in economic welfare are closely associated with opportunities to move beyond the sale of unprocessed agricultural commodities (Fadlan et al., 2024; Faried et al., 2022).

Green entrepreneurship offers a potential strategy for addressing these challenges by integrating economic value creation with environmental sustainability and resource efficiency. Enterprises pursuing both environmental and economic objectives may stimulate innovation in products, production processes, and business models (Demirel et al., 2019; Schaltegger & Wagner, 2011). The circular economy provides a complementary framework emphasizing resource efficiency, waste reduction, material reuse, and recycling to extend the productive life of resources (Geissdoerfer et al., 2017; Kirchherr et al., 2017). In North Sumatra, previous research conducted by the research team has demonstrated the potential of community-based waste management systems incorporating circular economy principles to influence production and consumption practices (Faried, Sembiring, Wardhani, & Hasanah, 2023). Related findings have also highlighted differences in innovation readiness among local industrial clusters, indicating the importance of context-specific entrepreneurial development strategies (Hasanah, Faried, & Sembiring, 2025).

Two additional factors have been consistently identified as important enablers of MSME development: digital capabilities and financial inclusion. Digital technologies can enhance the

marketing capabilities and market accessibility of rural MSMEs (Fadlan, Yusuf, & Pernanda, 2023), while branding strategies have been positively perceived by women entrepreneurs (Fadlan et al., 2023; Losi & Fadlan, 2022). Furthermore, brand experience has been asso ciated with sustainable rural tourism development rooted in local cultural values (Surya, Mesra, & Kadir, 2024). Financial capabilities represent another essential dimension of enterprise development. Financial literacy and inclusion have been associated with improved MSME performance (Sari, Sari, Pohan, & Syahputri, 2023), while digital financial literacy can facilitate the adoption of digital payment systems (Sari & Sari, 2025). Systematic financial recordkeeping may also improve enterprises' access to formal financing (Sembiring et al., 2023). Nevertheless, evidence suggests that access to credit alone does not necessarily produce substantial improvements in business income (Banerjee, Karlan, & Zinman, 2015). This finding underscores the importance of integrating financial access with entrepreneurial skills development and market opportunities (Lusardi & Mitchell, 2014).

Despite these contributions, three research gaps remain relevant to the development of integrated entrepreneurship interventions. First, previous studies have frequently examined individual dimensions of MSME development, including income determinants, partnership arrangements, digitalization, and financial reporting, rather than addressing the interconnected barriers experienced by a specific group of entrepreneurs (Sembiring, Faried, Hasanah, & Ginting, 2024; Wasila, Ramadhan, & Sembiring, 2024). Second, relatively limited attention has been directed toward integrated interventions for women entrepreneurs working with specific horticultural commodities, although commodity-specific processing knowledge is essential for transforming agricultural byproducts into marketable products (Jahurul et al., 2015; Lubis et al., 2025). Third, the application of cross-border mentoring models to women-led horticultural enterprises remains insufficiently explored. Previous collaborations between Universitas Pembangunan Panca Budi (UNPAB) and Malaysian institutions focused primarily on coastal communities in Pulau Ketam, addressing digital branding, digital financial services, and public–private partnerships in renewable energy development (Faried et al., 2025; Sari, Faried, Tuan Husain, & Ginting, 2025; Sari, Faried, Sianipar, Ibrahim, & Nuraisyah, 2026). These earlier studies did not specifically evaluate an integrated mentoring intervention targeting women-led mango enterprises through a structured pretest–posttest assessment (Schaltegger & Wagner, 2011; Wasila et al., 2024) .

The selection of a Malaysian institutional partner was based on the relevance of regional agricultural expertise and opportunities for collaborative knowledge exchange. Perlis has an established mango cultivation and processing sector, while Politeknik Tuanku Syed Sirajuddin (PTSS) contributes practical expertise in postharvest handling, product quality standards, and regional market networks. Integrating this expertise with the agricultural production potential of North Sumatra provided opportunities for reciprocal learning and collaborative capacity development rather than unidirectional knowledge transfer. Previous collaborations between UNPAB and Malaysian partners have emphasized transparent governance, shared institutional responsibilities, and community participation as important elements of sustainable partnerships

(Faried et al., 2025; Sari, Faried, Sianipar, et al., 2026). Similar participatory principles have informed the research team's community engagement initiatives in several North Sumatran villages, including Pematang Serai and Klambir V Kebun (Hasanah et al., 2024; Lubis, 2024).

The novelty of this study was reflected in four interconnected features, as summarized in Figure 1. First, the intervention integrated five dimensions of entrepreneurial capacity development: production, human capital, finance, market access, and environmental sustainability. Second, the program promoted comprehensive mango utilization through processing practices intended to minimize agricultural waste and generate value-added products. Third, the intervention was implemented through a cross-border mentoring partnership between UNPAB and PTSS in Perlis, Malaysia, facilitating collaborative knowledge exchange and entrepreneurial capacity building. Fourth, program outcomes were assessed using pretest–posttest competency scores, normalized gain (N-gain) analysis, and participatory capacity scoring to document changes in participants' knowledge and entrepreneurial capabilities (Hake, 1998; Kemmis & McTaggart, 2005). Accordingly, this study aimed to evaluate the extent to which an integrated, cross-border green entrepreneurship mentoring program strengthened the capacities of women-led mango MSMEs and to examine its implications for inclusive regional economic development.

METHOD

Research Design and Approach

The program adopted a participatory action research (PAR) approach involving iterative cycles of planning, action, observation, and reflection, with participants actively contributing to problem identification and the development of training modules (Kemmis & McTaggart, 2005). This approach was integrated with community-based development, a green entrepreneurship framework (Demirel et al., 2019), gender mainstreaming principles emphasizing women's access to resources, agency, and achievements (Kabeer, 1999), and an international academic partnership with Politeknik Tuanku Syed Sirajuddin (PTSS), Perlis, Malaysia. Program outcomes were evaluated using a one-group pretest–posttest design, supplemented by direct observation, focus group discussions (FGDs), and document review.

Participants and Location

The program ran from May to October 2026 in Kabupaten Langkat, Deli Serdang, Serdang Bedagai, and Karo, Provinsi Sumatera Utara, with a study visit to PTSS in Arau, Perlis. Twenty-five women were selected purposively according to three criteria: they had run a mango-based enterprise for at least two years, they agreed to complete the full 90-hour sequence, and they intended to continue the business afterwards. Purposive selection ensured that support reached women already active in the value chain, in line with earlier community engagement in the province (Hasanah et al., 2024; Lubis et al., 2025).

Intervention Design

Five modules were delivered through lectures, demonstrations, hands-on practice, simulations, and individual coaching (Table 1). Module content was co-designed with PTSS

lecturers and food technicians, and the financial module drew on earlier work on literacy and digital payment among MSMEs in the region (Sari & Sari, 2025; Sari et al., 2023).

Table 1. Training Modules, Duration, and Main Content

Module	Hours	Main content	Method
Green entrepreneurship and circular economy	12	Green business concepts, SDGs, circular economy, Perlis case	Interactive talk, case study
Zero-waste mango processing	24	Juice, jam, chips, dodol, peel mask, seed butter, leaf tea, quality control	Demonstration, hands-on practice
Digital marketing and branding	18	Social media, product photography, marketplace onboarding, copywriting	Workshop, account mentoring
Eco-packaging and certification	18	Recyclable packaging, labels, NIB, PIRT, halal procedures	Design workshop, agency visit
Financial literacy and KUR access	18	Bookkeeping, break-even, KUR procedures, QRIS and fintech	Simulation, consultation
Total	**90**		

Source: Program curriculum of the UNPAB–PTSS team (2026), adapted from Sari et al. (2023) and Faried et al. (2023).

Data Collection and Instruments

Business competency was measured with a 0–100 test for each module, administered before the first session and after the last. Practice indicators (product variants, by-product use, accounts, credit applications, bookkeeping, digital payments, marketplace activity, and packaging) were recorded through a baseline survey adapted from national financial inclusion items, field observation, and administrative documents such as OSS, PIRT, and BPJPH records. Capacity in each of the five dimensions was scored jointly by facilitators and participants on a 1–5 scale at baseline and endline (Kemmis & McTaggart, 2005; OECD, 2019).

Data Analysis

Descriptive statistics summarised the change in each indicator. Because a relative increase depends heavily on the starting score, learning effectiveness was also expressed as the normalised gain (Hake, 1998):

$$g = (S_post - S_pre) / (100 - S_pre) \qquad (1)$$

Values of $g \geq 0.7$ were read as high, $0.3 \leq g < 0.7$ as medium, and $g < 0.3$ as low. Results were then organised along the OECD (2019) evaluation criteria and a Theory of Change. Figure 2 shows the flow of implementation.

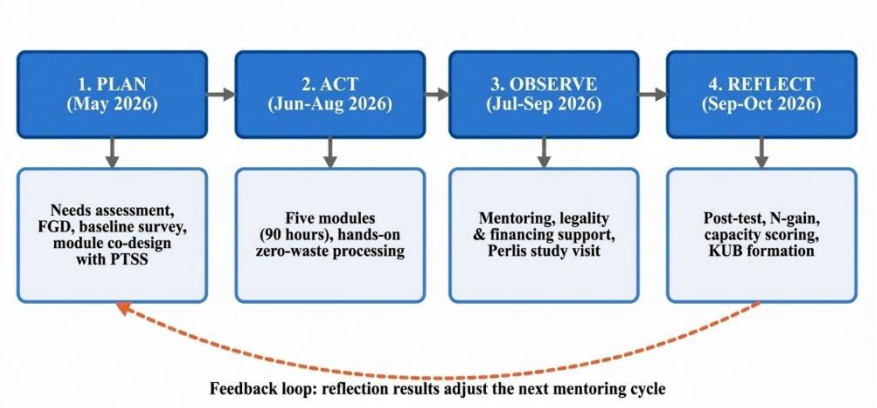


Figure 1. Flowchart of Program Implementation Following the PAR Cycle
Source: UNPAB–PTSS team design (2026), adapted from Kemmis and McTaggart (2005).

RESULT AND DISCUSSION

Participant Profile

Most participants (68%) were aged 30–45 years, 24% were 46–55, and 8% were under 30. On average they had run their businesses for 7.8 years. Table 2 shows that, despite this experience, the starting point was weak on every dimension. The profile mirrors the wider picture of rural MSMEs in the province, where enterprises contribute to household income but lack technology, capital, and management skills (Hasanah et al., 2024; Sembiring et al., 2024).

Table 2. Baseline Profile of Participants (n = 25)

Characteristic	Baseline condition	Data source
Dominant age group	30–45 years (68%)	Baseline survey
Average business experience	7.8 years	FGD and interviews
Product diversification	1–2 products (80%)	Field observation
Prior green entrepreneurship training	24% (6 persons)	Pre-test
Formal business account	40% (10 persons)	Survey
Non-recyclable plastic packaging	88% (22 persons)	Observation

Source: Primary data of the UNPAB–PTSS team (2026).

Production Capacity and Zero-Waste Innovation

After the 24-hour processing module and follow-up mentoring, 23 of the 25 women (92%) were producing at least three new variants. The average number of products per participant increased from 1.6 to 4.2, a rise of 162.5%. New lines included cold-pressed juice, jam, chips, dodol, chutney, a face mask from peel, butter from the seed kernel, and herbal tea from leaves. Use of peel and seed by-products jumped from 12% to 76% of participants, and estimated value added per kilogram moved from IDR 8,000–15,000 to IDR 35,000–120,000, a three- to eight-fold increase.

These gains support the view that whole-fruit processing is where the hidden value of mango lies (Jahurul et al., 2015). They also echo earlier findings from the province that integrating crops with complementary activities creates extra income streams for rural households (Faried et al., 2022) and that farmers' welfare rises with production capacity and capital (Fadlan et al., 2024).

The zero-waste approach puts the circular economy principle of keeping materials in use into everyday practice (Kirchherr et al., 2017).

Knowledge and Human Capital

Mean competency across the five modules rose from 40.3 to 72.4, a relative increase of 79.6% (Table 3 and Figure 3). Digital marketing recorded the largest relative gain (+98.3%), followed by green entrepreneurship (+92.7%) and zero-waste processing (+91.7%). Financial literacy showed the smallest relative gain (+53.8%), largely because it began from the highest score. All five N-gain values fell in the medium band, with an overall value of 0.54. Zero-waste processing (0.64) and green entrepreneurship (0.58) were the most effective modules, whereas eco-packaging (0.46) and financial literacy (0.47) still need reinforcement (Hake, 1998).

Table 3. Competency Scores and Normalised Gain by Module (n = 25)

Module	Pre-test	Post-test	Increase (%)	N-gain	Category
Green entrepreneurship and circular economy	38.5	74.2	+92.7	0.58	Medium
Zero-waste processing	41.0	78.6	+91.7	0.64	Medium
Digital marketing and branding	35.2	69.8	+98.3	0.53	Medium
Eco-packaging and certification	40.1	67.5	+68.3	0.46	Medium
Financial literacy and KUR access	46.8	72.0	+53.8	0.47	Medium
Overall	**40.3**	**72.4**	**+79.6**	**0.54**	**Medium**

Source: Pre-test and post-test data of the UNPAB–PTSS team (2026); N-gain calculated with Eq. (1) following Hake (1998).

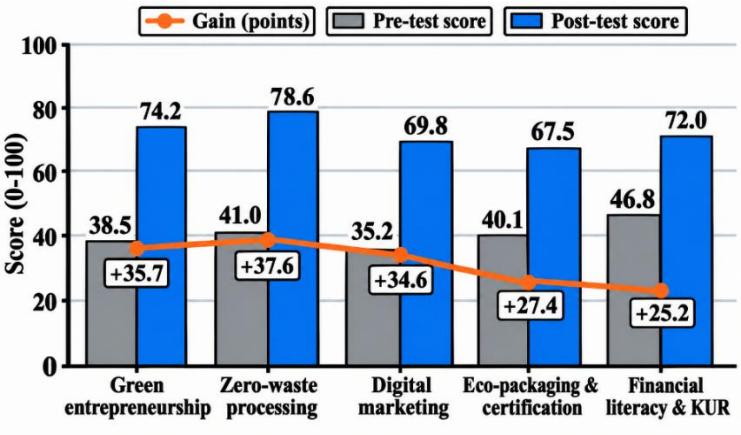


Figure 3. Bar–Line Chart of Pre-test and Post-test Competency Scores

Source: Pre-test and post-test data of the UNPAB–PTSS team (2026), processed.

In practice, 22 participants (88%) now manage marketplace accounts on Shopee, Tokopedia, or TikTok Shop together with business social media, against only five (20%) before the program. This result agrees with evidence that digital technology raises the selling power of village MSMEs (Fadlan et al., 2023) and that digital branding widened the market reach of coastal entrepreneurs in Pulau Ketam (Sari, Faried, et al., 2025). Read through Kabeer's (1999) lens, higher competency represents greater agency for women as entrepreneurs, not merely a set of technical skills.

Access to Capital and Financial Inclusion

The financial literacy clinic produced clear shifts in practice (Figure 4). Ownership of an active formal business account rose from 40% to 92%, routine bookkeeping from 28% to 84%, and the use of QRIS or other digital payments from 16% to 80%. Fourteen participants (56%) applied for or obtained KUR, a grant, or a cooperative loan, up from 12% at baseline.

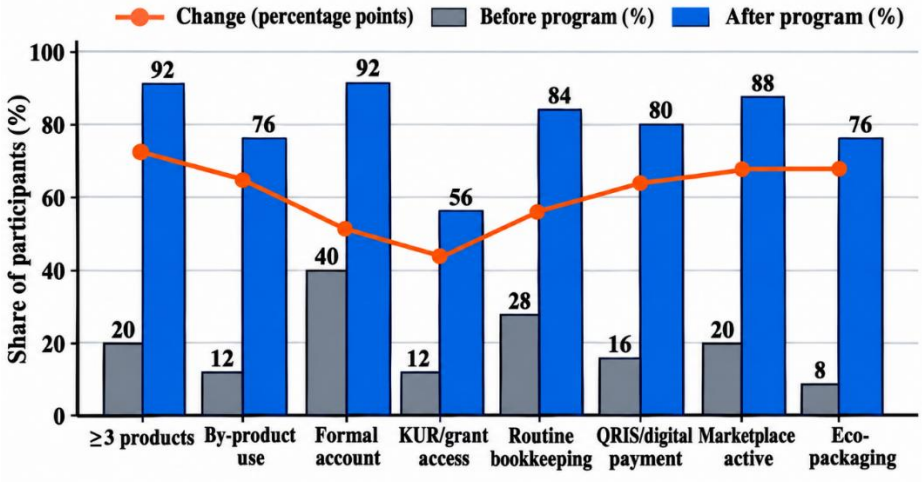


Figure 4. Bar–Line Chart of Key Practice Indicators Before and After the Program

Source: Primary data of the UNPAB–PTSS team (2026), processed.

Bookkeeping appears to be the bridge between women's enterprises and formal lenders. Sembiring et al. (2023) found that adopting the SAK EMKM reporting standard eases access to creditor financing, and Sari et al. (2023) showed that financial literacy and inclusion jointly lift MSME performance. Digital payment adoption follows from digital financial literacy (Sari & Sari, 2025), and digital finance has been linked to higher community income in the Pulau Ketam reserve area across the border (Sari, Faried, Sianipar, et al., 2026). Because microcredit alone tends to have modest average effects (Ananda et al., 2023; Banerjee et al., 2015), the program paired credit facilitation with bookkeeping and product upgrading rather than treating loans as an end in themselves (Lusardi & Mitchell, 2014).

Market Access and Cross-Border Networks

Certification support enabled every participant to obtain a Nomor Induk Berusaha (NIB) through OSS, 18 (72%) to secure a PIRT permit, and 12 (48%) to register for halal certification at BPJPH (Table 4). The study visit to PTSS Perlis and a business matching session connected the group with six potential buyers and distributors in Malaysia. Participants reported that margins on premium processed products rose from 15–25% to 35–48% of the selling price.

Table 4. Market Access and Network Outputs (n = 25)

Output	Achievement	Evidence
Business identification number (NIB) via OSS	25 (100%)	OSS documents
PIRT permit	18 (72%)	Permit documents
Halal certification at BPJPH (in process)	12 (48%)	Registration records
Active marketplace accounts	22 (88%)	Platform verification
Potential Malaysian buyers or distributors	6 connections	Business matching
Reported margin on premium processed products	15–25% → 35–48%	Participant reports

Source: Primary data of the UNPAB–PTSS team (2026).

Legality, packaging, and branding are the gatekeepers to modern retail and export markets. Women entrepreneurs in North Sumatra have reported that branding strategies raise buyer interest (Losi & Fadlan, 2022), and cooperative-based mentoring with a Malaysian partner has strengthened women's marketing and bookkeeping elsewhere in the province (Lubis et al., 2025). The cross-border link with PTSS extends the collaborative governance model that UNPAB and its partners have applied to coastal areas (Faried et al., 2025), taking it from the local to the bilateral level.

Environmental Sustainability and Green Awareness

The 18-hour eco-packaging module reduced the share of participants using non-recyclable plastic from 88% to 28%, a fall of 60 percentage points. Nineteen women (76%) switched to recycled or biodegradable packaging for at least part of their range, and 84% showed a high awareness of green-consumer segments at post-test. These outcomes confirm that circular practices can be adopted at the scale of household enterprises when they are tied to market benefits (Faried et al., 2023; Geissdoerfer et al., 2017). They also show that environmental and economic motives can be pursued together, as the green entrepreneurship literature argues (Demirel et al., 2019). Sustainable resource use, however, depends on local institutional arrangements (Lubis, 2024); for this reason the program closed by forming a joint business group (Kelompok Usaha Bersama, KUB) to maintain shared purchasing of eco-packaging.

Synthesis: Capacity, Results Tree, and Theory of Change

Participatory capacity scores, shown as a spider chart in Figure 5 and in Table 5, met or exceeded the target in every dimension. The largest absolute improvements occurred in production and innovation (+2.2 points) and market and networks (+2.1 points). This multidimensional pattern matches the cluster-readiness logic proposed for small industries in the province (Hasanah et al., 2025).

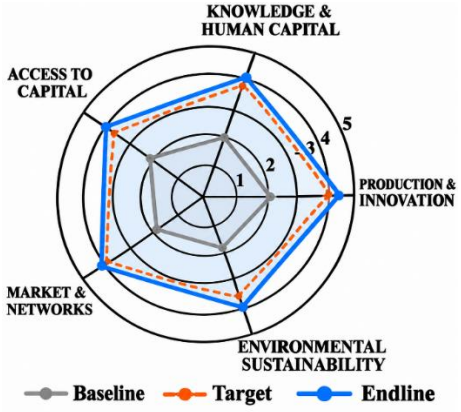


Figure 5. Spider Chart of Partner Capacity: Baseline, Target, and Endline (Scale 1–5)
Source: Participatory assessment of the UNPAB–PTSS team (2026), following OECD (2019).

Table 5. Capacity Scores by Dimension (Scale 1–5)

Dimension	Baseline	Endline	Target	Status
Production and innovation	2.1	4.3	4.0	Exceeded
Knowledge and human capital	2.0	4.1	4.0	Exceeded
Access to capital	2.2	3.8	3.5	Exceeded
Market and networks	1.9	4.0	4.0	Achieved
Environmental sustainability	1.8	3.9	3.5	Exceeded

Source: Participatory assessment of the UNPAB–PTSS team (2026).

Figure 6 arranges the findings as a tree in which the overall goal branches into the five dimensions, each anchored by measurable indicators. The branches are linked: new products (D1) depend on competency (D2), which in turn supports access to finance (D3), market expansion (D4), and greener production (D5). This interdependence explains why single-dimension programs often stall (Sembiring et al., 2024).

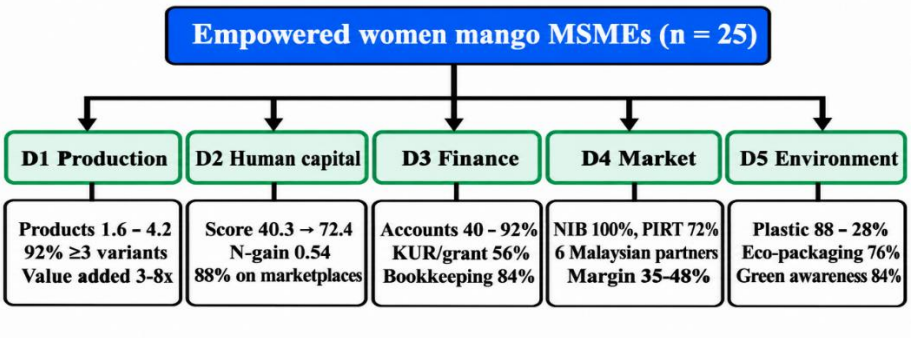


Figure 6. Tree Diagram of Program Results by Dimension
Source: Synthesis of program results by the UNPAB–PTSS team (2026).

Figure 7 presents the implemented Theory of Change, tracing the pathway from inputs and activities to outputs, outcomes, and impact. The PAR feedback loop allowed facilitators to adjust mentoring content after each reflection stage, while the OECD (2019) criteria of relevance, coherence, effectiveness, efficiency, impact, and sustainability guided the assessment (Kemmis & McTaggart, 2005).

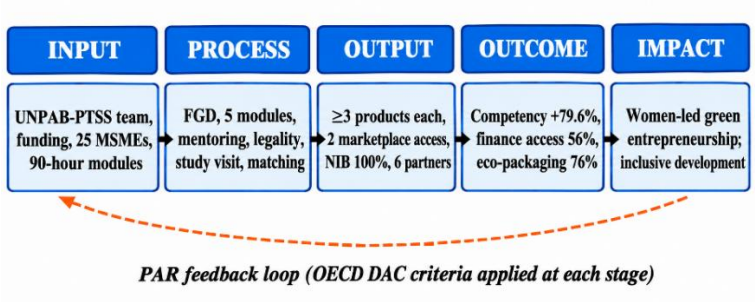


Figure 7. Framework of the Implemented Theory of Change

Source: Adapted from OECD (2019) and the program design of the UNPAB–PTSS team (2026).

Comparison with Previous Studies

Table 6 places the findings alongside earlier work by the team and its collaborators. Prior studies each examined one dimension; the present program integrated five within a single cross-border, women-focused, commodity-specific model, which constitutes its main contribution (Brush et al., 2009; Tambunan, 2019).

Table 6. Position of the Findings Relative to Previous Studies

Previous study	Focus and context	Relation to present findings
Sembiring et al. (2023)	Determinants of MSME income, Desa Pahlawan	Confirmed: bookkeeping and capital access accompanied gains (D3)
Hasanah et al. (2024)	MSME effectiveness and income, Pematang Serai	Extended: from SWOT diagnosis to measured intervention (D1–D4)
Faried et al. (2023)	Circular economy-inspired waste management	Applied: zero-waste processing and eco-packaging (D1, D5)
Fadlan et al. (2023)	Digital technology and MSME selling power	Confirmed: 88% active on marketplaces (D2, D4)
Sari, Faried, et al. (2025)	Digital branding in Pulau Ketam (with Malaysian partner)	Consistent: digital channels widen market reach (D2, D4)
Sari et al. (2023)	Financial literacy and inclusion, Kota Pari	Confirmed: formal accounts rose from 40% to 92% (D3)
Lubis et al. (2025)	Women's cooperative entrepreneurship with a Malaysian partner	Extended: green and commodity-specific focus (D2, D5)

Source: Compiled by the authors (2026).

Implications for Inclusive Regional Development

The results carry three implications. First, for practitioners, the strongest effects appeared where learning was immediately usable: zero-waste processing and green entrepreneurship produced the highest N-gains, while eco-packaging and financial literacy, which require purchases, paperwork, or behavioural change over time, lagged behind. Mentoring after formal training should therefore concentrate on these two areas (Hake, 1998; Lusardi & Mitchell, 2014). Second, for local government, the program shows that certification, credit facilitation, digital onboarding, and environmental guidance reach women micro-entrepreneurs more effectively when they are offered as one package than when they arrive through separate agencies. This is

consistent with the argument that village welfare depends on how public facilities and programs fit residents' actual needs (Sembiring et al., 2024) and with the cluster-based approach to small industry development (Hasanah et al., 2025).

Third, for regional development, mango functions as a base commodity whose value can be multiplied locally. When peel, seed, and leaf become inputs instead of waste, more of the value chain stays in the village, which supports the inclusive growth that tourism and village-fund studies in the province also seek (Wasila et al., 2024; Sembiring et al., 2024). The cross-border dimension adds market access that a purely domestic program could not provide, and it turns the Indonesia–Malaysia academic relationship into a channel for trade and knowledge exchange (Sari, Faried, et al., 2025; Surya et al., 2024). Taken together, these implications place women's green entrepreneurship at the centre of inclusive regional development, in line with the view that empowerment expands both resources and agency (Kabeer, 1999; Brush et al., 2009).

Limitations

Four limitations should be noted. The one-group design has no comparison group, so the changes cannot be attributed to the program with full causal certainty (OECD, 2019). Margins and some practices were self-reported. Measurement ended at program completion, so durability is not yet known. The sample of 25 limits statistical generalisation, although it suits an intensive mentoring model (Kemmis & McTaggart, 2005). A quasi-experimental follow-up at six to twelve months with transaction records is planned.

CONCLUSION

The integrated mentoring program was associated with improvements across five targeted dimensions of women-led mango-based micro, small, and medium-sized enterprises (MSMEs) in North Sumatra (Sumatera Utara), Indonesia. The average number of product varieties increased from 1.6 to 4.2 per participant, while mean competency scores rose from 40.3 to 72.4, corresponding to a moderate normalized gain (N-gain) of 0.54. Formal business account ownership reached 92%, more than half of the participants initiated contact with formal financial institutions, and all participants obtained a Business Identification Number (Nomor Induk Berusaha, NIB). Additionally, six potential Malaysian business partners were identified, and the proportion of participants using nonrecyclable plastic packaging decreased by 60 percentage points. These findings suggested that integrating waste-minimizing mango processing, digital and financial literacy, business formalization, and cross-border collaboration within a single mentoring framework could support entrepreneurial capacity development and environmentally sustainable business practices (Demirel et al., 2019; Kabeer, 1999). However, the absence of a comparison group prevented conclusions regarding the model's superiority over interventions addressing individual barriers separately. Local governments could consider adapting this approach by integrating business certification assistance, facilitation of People's Business Credit (Kredit Usaha Rakyat, KUR), and entrepreneurship mentoring. Furthermore, the partnership between Universitas Pembangunan Panca Budi (UNPAB) and Politeknik Tuanku Syed Sirajuddin (PTSS) provided a potential framework for similar collaborative initiatives in other ASEAN regions with comparable

horticultural resources. The program's objectives and observed outcomes aligned with Sustainable Development Goals (SDGs) 5 (Gender Equality), 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), and 17 (Partnerships for the Goals). Future research should incorporate comparison groups, longitudinal monitoring, and verified transaction records to assess the intervention's effects on business income, financial sustainability, and long-term environmental performance.

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