Available online at https://journal.rescollacomm.com/index.php/ijrcs/index

International Journal of Research in Community Service

e-ISSN: 2746-3281
p-ISSN: 2746-3273

Vol. 7, No. 2, pp. 85-92, 2026

A Conceptual Framework for Developing Appropriate Technology Based on Local Needs to Promote Sustainable Community Independence and Welfare

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Abstract

Appropriate technology has emerged as a strategic approach to address community development challenges, particularly in resource-constrained environments. However, many technology-based initiatives fail due to a mismatch between proposed solutions and actual community needs, as well as limited integration of local potential and participation. This study aims to develop a conceptual framework that integrates participatory design and local resource optimization, which has been insufficiently addressed in previous studies that is grounded in community needs, local resources, and participatory principles. The study adopts a qualitative and using a structured literature synthesis and thematic analysis approach by synthesizing findings from previous literature related to community-based development and appropriate technology. The framework is structured through three main stages: identifying community needs, analyzing local potential and resources, and designing appropriate technology based on user-centered and context-based principles. In addition, the framework incorporates participatory processes and multi-stakeholder collaboration to enhance implementation effectiveness. The framework suggests that appropriate technology designed with simplicity that appropriate technology designed with simplicity, affordability, and adaptability can improve relevance, usability, and sustainability. The integration of local materials, skills, and cultural values strengthens community self-reliance, while participatory approaches foster ownership and increase adoption. Furthermore, the proposed framework demonstrates potential impacts on both economic and social dimensions, including increased productivity, expanded economic opportunities, improved skills, and stronger community engagement. In conclusion, this study highlights that appropriate technology should be viewed not only as a technical solution but also as a strategic tool for empowering communities and supporting sustainable development. A holistic approach that integrates local context, resources, and participation is essential to ensure long-term success and scalability.

Keywords: Appropriate technology, community development, local resources, participation, sustainability

1. Introduction

Despite its prominence, sustainable development initiatives often fail due to the lack of context-appropriate technology in addressing global socio-economic challenges, particularly in developing regions where disparities in welfare, access to resources, and economic opportunities remain significant. The concept emphasizes the integration of economic growth, social inclusion, and environmental sustainability as interconnected pillars that must be addressed simultaneously to ensure long-term development outcomes (Hariram et al., 2023; Winston, 2022). In this context, achieving sustainable community welfare requires not only policy interventions but also active participation from local communities as key actors in the development process.

However, many empowerment initiatives fail to integrate technological design effectively as a fundamental approach to achieving sustainable development, as it enhances the capacity of individuals and communities to manage their own development processes, improve livelihoods, and reduce dependency on external assistance (Kurniawan et al., 2023; Nazeri et al., 2024). Through participatory approaches, communities are encouraged to utilize local resources effectively, engage in decision-making, and develop adaptive strategies to overcome socio-economic challenges, thereby strengthening resilience and promoting sustainable independence.

A crucial element in community empowerment is the incorporation of local wisdom, which represents the collective knowledge, cultural values, and traditional practices that have evolved within a community over time. Local

wisdom functions as social capital that supports trust, cooperation, and sustainability in development initiatives (Kurniawan et al., 2023). Development strategies rooted in local contexts tend to be more acceptable and effective, as they align with the socio-cultural characteristics and actual needs of the community.

In addition, governance and institutional support play an important role in ensuring the effectiveness of development programs. Strengthening village governance structures and enhancing institutional capacity are essential to align development initiatives with community needs (Maolani, 2019). Empirical evidence from decentralized systems in Indonesia further indicates that locality-based approaches are more responsive to diverse socio-economic conditions across regions (Tobing-David et al., 2024).

Technological advancement has also contributed significantly to sustainable development, particularly through the emergence of smart cities and smart villages that emphasize digital innovation and community-centered approaches (Zavratnik et al., 2020). However, the effectiveness of technological interventions largely depends on their relevance to local contexts. Technologies that are not aligned with community needs often result in low adoption rates and limited long-term impact.

In this context, the concept of appropriate technology provides a practical approach to bridging the gap between technological advancement and community applicability. Appropriate technology emphasizes simplicity, where simplicity is measured by ease of use, affordability by cost relative to local income levels, and adaptability by the ability to function across varying local conditions, and adaptability, ensuring that technological solutions can be effectively utilized within local communities (Sonjaya et al., 2024). When aligned with local needs and resources, such technologies have the potential to enhance productivity, support local economic activities, and contribute to sustainable development outcomes.

Furthermore, approaches such as open innovation and community-based enterprises have demonstrated potential in supporting community empowerment and sustainable economic development. The development of village-owned enterprises (BUMDes), for example, has been shown to strengthen local economies and create employment opportunities (Harinurdin et al., 2025; Pawitan et al., 2025), while community-based tourism contributes to income generation and inclusive growth (Jackson, 2025).

Despite the growing body of literature, many studies remain focused on conceptual discussions or policy frameworks, with limited emphasis on translating these concepts into structured approaches for developing appropriate technology based on local needs. In addition, the integration of governance and stakeholder collaboration into technology design remains underexplored (Wang et al., 2023). Therefore, this study aims to propose a conceptual framework for developing appropriate technology based on local community needs by integrating principles of community empowerment, local wisdom, and sustainable development. The proposed framework is intended to provide a systematic approach for designing contextually relevant and accessible technological solutions that support sustainable community independence and welfare.

2. Materials and Methods

2.1. Materials

This study utilizes secondary data and relevant theoretical sources to support the development of an appropriate technology framework based on local community needs. The materials consist of scientific literature, journal articles, government reports, and previous studies related to community empowerment, sustainable development, local wisdom, and appropriate technology. These sources are used to identify common challenges faced by communities, explore local potential, and understand the role of participatory approaches in technology development. The collected materials provide a comprehensive basis for constructing a conceptual framework that aligns technological solutions with socio-cultural and economic conditions. In addition, supporting tools such as literature mapping and thematic analysis were employed to systematically organize and interpret the collected information. These tools facilitate the identification of key variables and relationships relevant to the development of appropriate technology in community contexts.

2.2. Methods

This study adopts a conceptual and qualitative approach by integrating a community-based participatory perspective with an appropriate technology development framework. The method focuses on synthesizing existing knowledge to design a structured approach for developing technology that is relevant, accessible, and sustainable within local communities. The research process begins with problem identification and needs analysis, where relevant literature is reviewed to identify common socio-economic challenges and community needs, particularly in areas with limited access to technology and resources. This is followed by the analysis of local potential and context, which explores local resources, community capabilities, and socio-cultural characteristics influencing technology adoption.

Based on these findings, a conceptual design of appropriate technology is developed by integrating identified needs, local potential, and key principles such as simplicity, affordability, and adaptability. The next stage involves the development of a structured framework that illustrates how appropriate technology can be planned, introduced,

and utilized within a community setting. The proposed framework is then evaluated using comparative analysis with existing frameworksby analyzing its feasibility, relevance, and potential impact based on existing theories and findings from previous studies. Finally, sustainability considerations are incorporated by assessing long-term feasibility, including economic viability, ease of use, and potential for replication in similar community contexts. The overall research process is illustrated in Figure 1.

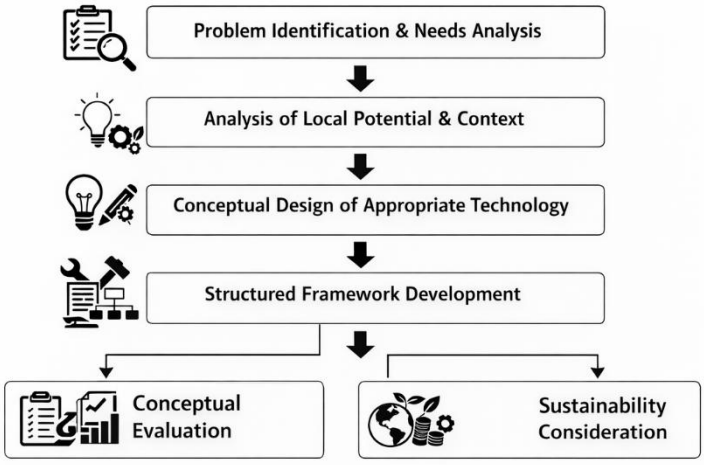

Figure 1: Research methodology flowchart

3. Results and Discussion

3.1. Identifying Community Needs

Identifying community needs is a crucial foundation for developing appropriate technology, as it determines the relevance and sustainability of proposed solutions. In many developing regions, communities continue to face structural challenges such as limited access to technology, low productivity, and limited economic opportunities, which hinder their ability to achieve sustainable self-reliance.

Most studies highlight mismatch with local needs as the primary cause, while others emphasize institutional barriers that many community development and technology-based initiatives fail due to a mismatch between technological solutions and actual local needs. This failure is often attributed to technology implementation that prioritizes technical performance while ignoring the socio-cultural context, local capacity, and user needs. As a result, these technologies tend to experience low adoption rates and limited long-term sustainability. For example, Shin et al. (2019) highlight that many appropriate technology initiatives fail because they are implemented as short-term technology transfers without adequate consideration of local conditions and community engagement. Similarly, Patnaik and Tarei (2022) emphasize that technology adoption in development contexts often fails when technology appropriateness, particularly alignment with social, economic, and environmental factors, is not adequately addressed.

From a theoretical perspective, appropriate technology should be developed based on a bottom-up approach that prioritizes local needs and community participation. Technology designs that ignore local context, traditional knowledge, and social structures often result in ineffective and unsustainable solutions in the long term (Sianipar et al., 2013). Therefore, understanding community needs requires a contextual and holistic perspective that integrates economic, social, and technological dimensions.

In this study, community needs are conceptualized as a combination of practical problems, resource constraints, and development aspirations that must be addressed through context-based technological solutions. By adopting a needs-oriented approach, this study emphasizes that appropriate technology serves not only as a technical innovation but also as a strategic tool to support community empowerment, enhance local capacity, and promote sustainable prosperity.

3.2. Analysis of Local Potential and Resources

Local potential and resources are crucial elements in the successful development of appropriate technology, as they determine the feasibility, adaptability, and sustainability of technological solutions. In the context of community-based development, local potential includes natural resources, human capabilities, traditional knowledge, and existing socio-cultural practices that can support technology implementation.

Previous studies have highlighted that the integration of local resources and knowledge significantly increases the effectiveness of appropriate technology. Technologies that utilize locally available materials and skills are more likely to be accepted, maintained, and replicated within a community. This is because such approaches reduce dependence

on external inputs and encourage community self-reliance. For example, Lee and Na (2019) highlight that appropriate technology is often characterized by the use of locally available resources, low cost, and ease of operation, making it suitable for communities with limited technical and financial capacity.

Furthermore, the role of local knowledge and cultural values is crucial in shaping technology adoption. Community-based practices and local knowledge systems provide valuable insights into resource management and problem-solving strategies. Jokhu and Kutay (2020) demonstrated that involving communities in the design process allows for the integration of these local elements, leading to more sustainable and contextually relevant technological solutions.

However, several common limitations were identified in leveraging local potential. These include limited technical skills, lack of access to information, and inadequate institutional support. In many cases, development initiatives fail to fully utilize local resources due to a top-down approach that ignores community capabilities. Consequently, the potential of local resources remains underutilized, reducing the effectiveness of technology-based interventions. Furthermore, Shin et al. (2019) emphasized that appropriate technology should not be viewed solely as a technical solution but as part of a broader socio-technical system. Successful implementation of appropriate technology requires the alignment of local resources, community participation, and institutional support to ensure long-term sustainability.

Based on these considerations, this study conceptualizes local potential as a strategic foundation for developing appropriate technology. By integrating local resources, knowledge, and socio-cultural values into the design process, the proposed framework aims to produce technological solutions that are not only feasible but also sustainable and empower local communities.

3.3. Appropriate Technology Design Proposal

Based on the identification of community needs and analysis of local potential, this study proposes an appropriate technology design that emphasizes simplicity, affordability, and adaptability. These principles are essential to ensure that the proposed technology can be effectively utilized, maintained, and replicated within local communities, particularly in resource-constrained environments. Appropriate technology is fundamentally characterized by its alignment with local conditions and its ability to be controlled and managed by the community itself. This technology is typically designed as a small-scale, low-cost, and user-friendly solution that does not require advanced technical expertise. This aligns with research by Del-Río-Carazo et al. (2022) that appropriate technology should be accessible and operable by local users while supporting long-term sustainability.

Furthermore, appropriate technology design must consider various dimensions of "appropriateness," including technological feasibility, socio-economic relevance, and environmental sustainability. Patnaik and Tarei (2022) point out that the success of appropriate technology depends on the integration of these factors, as technologies that fail to address the social and economic context often experience low adoption and limited effectiveness. Therefore, the design proposed in this study is not limited solely to technical functionality but also encompasses user needs, local resource availability, and cultural compatibility.

The proposed design adopts a user-centered and context-based approach, where technology is developed by considering how it will be used in people's daily activities. This approach ensures that the technology is not only technically feasible but also practically relevant and socially acceptable. Furthermore, the use of local materials and existing skills is prioritized to reduce dependence on external resources and increase community self-reliance.

From a sustainability perspective, appropriate technology should support long-term use and ongoing adaptation. Bishop (2021) shows that technologies designed for specific local contexts, particularly those aligned with social values and cultural practices, tend to demonstrate higher long-term sustainability and adoption.

Based on these considerations, the appropriate technology design proposed in this study is conceptualized as an integrated system that connects community needs, local potential, and sustainability principles. This design serves not only as a technical solution but also as a strategic tool to empower communities and support sustainable development. The conceptual design of the proposed appropriate technology is illustrated in Figure 2.

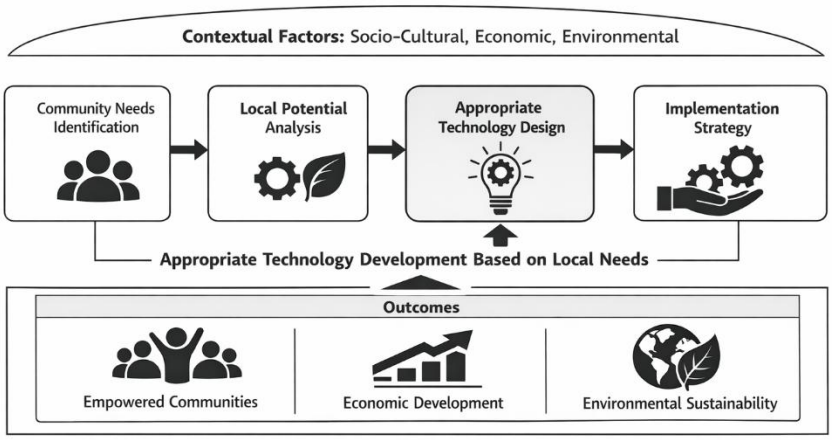

Figure 2: Conceptual framework of appropriate technology development based on local needs

As illustrated in Figure 2, this conceptual framework serves both as a technical model and a strategic approach to community empowerment. It positions technology not merely as a tool, but as a catalyst for sustainable development. The implementation of this design follows a structured yet flexible process, consisting of several key stages: socialization, capacity building, and utilization. These stages are designed to facilitate a gradual and effective introduction of the technology into the community. The process begins with socialization to build awareness and understanding, followed by capacity building to equip community members with the necessary skills, and finally, the utilization stage where the technology is actively applied in daily practices.

A participatory approach is central to this framework. Active community involvement throughout the development and implementation process fosters a strong sense of ownership, which significantly increases the likelihood of successful adoption and long-term sustainability. Through participation, communities are not only users but also contributors to the design process, ensuring that the technology truly reflects their needs and expectations.

Furthermore, the framework underscores the importance of collaboration among multiple stakeholders, including local communities, government institutions, and supporting organizations. Such collaboration enhances both the effectiveness and scalability of the proposed technology, enabling it to be expanded and adapted to other contexts with similar characteristics.

3.4. Potential Impact Analysis

Although this study does not include empirical testing, the proposed framework indicates a strong potential to enhance community welfare when viewed through both theoretical perspectives and findings from prior research. Appropriate technology, by its nature, has consistently been associated with improvements in productivity, operational efficiency, and the strengthening of local economic activities. These benefits emerge because such technologies are designed to fit local conditions, making them easier to adopt and sustain over time.

Evidence from previous studies supports this expectation. Winarko et al. (2022) demonstrate that the implementation of appropriate technology in community-based industries can streamline production processes while simultaneously reducing environmental impact. This dual benefit not only increases efficiency but also contributes to broader goals of sustainable development. In practical terms, improved production systems enable communities to optimize resource use, minimize waste, and enhance the overall quality of their outputs.

Beyond production efficiency, the adoption of appropriate technology also opens up wider economic opportunities. By improving productivity and reducing operational constraints, communities are better positioned to expand their businesses, access new markets, and increase income generation. This creates a multiplier effect, where economic gains at the individual or group level contribute to broader local economic growth.

In addition to economic impacts, the framework also holds significant social implications. Technology-driven empowerment has been widely linked to improved skill development, higher levels of community participation, and strengthened collective capacity. As individuals gain new competencies through the use and management of technology, they become more actively involved in decision-making processes and community initiatives. This not only enhances self-reliance but also fosters a sense of ownership and collaboration within the community.

Overall, the proposed framework is expected to generate positive and interconnected impacts across both economic and social dimensions. Economically, it supports increased productivity, income growth, and business expansion. Socially, it promotes skill enhancement, participation, and community empowerment. Together, these

outcomes position appropriate technology as a strategic instrument for sustainable and inclusive community development.

3.5. Community Participation Perspective

Community participation plays a pivotal role in determining the success of appropriate technology development. A participatory approach not only ensures that technological solutions are relevant to local needs but also strengthens community empowerment by actively involving users in every stage of the process. When communities are engaged from the beginning, the resulting technology is more likely to reflect real conditions, challenges, and expectations, thereby increasing its effectiveness and acceptance.

In this context, technology functions as an enabler of empowerment. It provides tools that facilitate communication, collaboration, and knowledge sharing among community members. More importantly, it creates opportunities for individuals to take part in decision-making processes, allowing them to contribute ideas, express needs, and influence outcomes. This active involvement fosters a stronger sense of ownership and responsibility, which are essential for ensuring sustained use and long-term impact.

Nevertheless, the level of participation is not uniform and is influenced by several key factors. Perceived benefits play a central role, as communities are more likely to engage when they clearly understand the advantages offered by the technology. Accessibility is another critical aspect, including ease of use, affordability, and availability of resources. In addition, social dynamics—such as trust, leadership, and existing community structures—significantly shape the extent to which individuals are willing and able to participate. Bai and Wang (2026) highlight that technological empowerment combined with clear perceived benefits significantly increases community engagement in development initiatives.

Therefore, integrating participatory principles into the design and implementation of appropriate technology is not merely an option but a necessity. By embedding participation into the development process, the proposed framework can achieve higher adoption rates, stronger community ownership, and greater sustainability. Ultimately, participation transforms technology from a simple tool into a collaborative medium that supports inclusive and long-lasting community development.

3.6. Discussion

The findings of this study highlight that the success of appropriate technology development is not solely determined by technical excellence, but rather by the alignment between community needs, local potential, and participatory processes. The integration of these three elements forms a comprehensive approach that addresses common limitations found in previous technology-driven development initiatives.

From the perspective of community needs identification, this study reinforces the importance of adopting a bottom-up approach. Many prior initiatives have failed due to a top-down orientation that overlooks the real problems faced by local communities. The results suggest that understanding the socio-economic context, cultural values, and daily practices of the community is essential to ensure that technology is both relevant and sustainable. This aligns with the broader theoretical view that development interventions must be grounded in local realities rather than external assumptions.

Furthermore, the analysis of local potential demonstrates that communities possess valuable resources that are often underutilized. By integrating local materials, skills, and knowledge systems into technology design, the proposed framework enhances feasibility and reduces dependency on external support. This finding supports the argument that appropriate technology should be seen as part of a socio-technical system, where success depends on the interaction between human, social, and technical components. However, the study also acknowledges existing challenges, such as limited technical capacity and institutional support, which may hinder optimal utilization of local resources.

The proposed technology design emphasizes simplicity, affordability, and adaptability, which are critical for ensuring accessibility and long-term use. Unlike conventional technology approaches that prioritize advanced features, this study highlights that user-centered and context-based design is more effective in community settings. The discussion suggests that technologies tailored to local conditions are more likely to be adopted, maintained, and scaled. This reinforces previous findings that sustainability is closely linked to cultural compatibility and ease of use.

In terms of impact, the study indicates that appropriate technology has the potential to generate both economic and social benefits. Economically, it can improve productivity, increase efficiency, and expand income-generating opportunities. Socially, it contributes to skill development, community participation, and empowerment. These outcomes are interconnected, creating a positive feedback loop where economic improvements support social development, and vice versa.

Community participation emerges as a central theme across all aspects of the framework. The discussion confirms that participatory approaches significantly enhance technology adoption and sustainability by fostering a sense of ownership among users. When communities are actively involved in decision-making and implementation processes, they are more likely to accept and sustain the technology. However, participation is influenced by factors such as perceived benefits, accessibility, and social dynamics, indicating that engagement strategies must be carefully designed to address these dimensions.

Overall, this study contributes to the understanding of appropriate technology development by proposing an integrated framework that combines needs-based analysis, local resource utilization, and participatory approaches. The discussion suggests that future implementation efforts should focus on strengthening institutional support, improving access to information and training, and fostering multi-stakeholder collaboration. By addressing these aspects, appropriate technology can function not only as a technical solution but also as a transformative tool for sustainable and inclusive community development.

4. Conclusion

This study has developed a conceptual framework for appropriate technology by integrating three main components: identification of community needs, analysis of local potential and resources, and a participatory-based design approach. The research emphasizes that appropriate technology should not be viewed merely as a technical solution, but as a context-driven and community-oriented strategy aimed at addressing real problems while promoting sustainable development. Through a needs-based perspective, the study highlights the importance of aligning technological solutions with socio-economic conditions, cultural values, and local capacities to ensure relevance and long-term applicability.

Furthermore, the analysis of local potential demonstrates that the effective utilization of locally available resources, skills, and knowledge plays a significant role in enhancing the feasibility and sustainability of technology implementation. By incorporating these elements into the design process, the proposed framework reduces dependence on external inputs and strengthens community self-reliance. The study also underlines that appropriate technology must be simple, affordable, and adaptable, allowing it to be easily adopted, maintained, and replicated within resource-constrained environments.

In addition, this study confirms that community participation is a key determinant of successful technology development. A participatory approach not only increases the relevance of technological solutions but also fosters a sense of ownership, responsibility, and empowerment among community members. When communities are actively involved in decision-making and implementation processes, the likelihood of technology adoption and sustainability significantly improves.

Overall, the proposed framework provides a holistic approach to appropriate technology development by integrating technical, social, and environmental dimensions. It demonstrates that sustainable and inclusive community development can be achieved when technology is designed based on local needs, supported by local resources, and implemented through participatory processes. Therefore, appropriate technology serves not only as an innovation tool but also as a strategic instrument for empowering communities and enhancing long-term socio-economic well-being.

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