# Variations in Pre-Primary Education Infrastructure Within and Across Administrative Sectors in Rwanda

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**Abstract**

This study investigates disparities in the quality of pre-primary education settings in Rwanda, where centre-based, community-based, and home-based modalities coexist under a single policy framework. Drawing on data from 4,875 settings across 91 administrative sectors in seven districts, we applied multilevel models to distinguish within-sector differences between setting types from between-sector variation linked to socioeconomic status (SES). Infrastructure quality was modeled as three latent factors: physical facilities, access to public infrastructure, and operational quality. Findings show that home-based settings—most common in rural and lower-SES sectors—exhibited substantially lower quality than centre-based settings, with standardized gaps of –0.73 *SD* in physical facilities and –0.85 *SD* in operational resources. These differences persisted even after accounting for sector-level SES, underscoring the role of modality itself in shaping access to quality environments. Community-based settings expanded access but showed similar structural challenges, with weaker effects that diminished once SES was considered. Between-sector results further revealed that SES strongly predicted access to public infrastructure, while operational quality remained more directly tied to setting type. Taken together, these results demonstrate how multilevel disparities in structural quality emerge both within and between communities, highlighting the dual importance of setting modality and local socioeconomic conditions. These findings point to sequenced policy responses as one pathway forward, beginning with a minimum structural package in home-based settings and complemented by training, funding innovations, and supportive oversight.

## Introduction

Access to quality early childhood care and pre-primary education is widely recognized as a critical potential determinant of children's long-term cognitive, socio-emotional, and educational outcomes (Berlinski et al., 2009; Heckman, 2006; Yoshikawa et al., 2013). As part of the United Nations Sustainable Development Goals, specifically Goal 4.2, access to quality pre-primary education is recognized as a right of every child and a global priority (United Nations, 2015). This emphasis on high-quality early education is rooted in its potential to improve school readiness and academic outcomes, ultimately expanding lifelong opportunities, particularly for children from lower-resourced backgrounds or countries (Bietenbeck et al., 2019; Campbell et al., 2014; Duncan & Magnuson, 2013; Heckman, 2008; Patrinos & Psacharopoulos, 2020). While disparities in access to quality early childhood programs exist globally (Flood et al., 2022; A. Raikes et al., 2023; Rege et al., 2018), the challenges faced by young children in low- and middle-income countries are often more severe than those encountered in high-income countries (Britto et al., 2014; Krafft et al., 2024; Neuman & Powers, 2021).

In Rwanda, expanding access to pre-primary education has been a priority within the government's broader commitment to achieving universal education and aligning with the Sustainable Development Goals (Ministry of Education, 2018). Significant progress has been made in recent years, with policies focused on increasing enrollment rates and improving the quality of early childhood education services (Binagwaho et al., 2016; National Child Development Agency, 2022; UNICEF, 2024). However, disparities in both access and quality persist, particularly between urban and rural areas, where

infrastructure limitations pose a major challenge to realizing equitable education for all children (Ministry of Education, 2018; Sachs et al., 2024; UNICEF, 2024).

Governance and financing of Rwanda's pre-primary system are shared by the Ministry of Education and the National Child Development Agency—responsible for system oversight, standard-setting, public provision, and early childhood development initiatives and evaluations—alongside local governments, private and faith-based providers, and NGOs. Rwanda's pre-primary education landscape consists of three main settings:

1. Centre-based**:** A formal early learning and development setting where children undergo sensory-motor, social-emotional, and cognitive-language development support, as well as training on school readiness by experienced caregivers.
2. Community-based**:** An improvised setting, normally arranged by members of the community, where temporary structures are turned into learning areas for young children.
3. Home-based**:** An informal setting where a group of neighboring households designates one home to serve as a center for children's early learning during the day, providing care until parents pick their children up after work.

Of the three, centre-based and home-based settings are currently the most prevalent, each presenting unique challenges and opportunities to promote equitable access to quality early learning (Ministry of Gender & Family Promotion, 2016).[1]

[1] Financing streams to providers, as documented in our dataset, include fees, public funds, and in-kind/NGO support; we summarize these patterns in the Funding Streams subsection and Appendix Figure A.1.

Oversight operates through sector-level officers who are mandated to receive monthly reports from caregivers and parents' committees and to conduct supervisory visits (National Child Development Agency, 2019). In practice, however, the intensity of monitoring varies considerably by type of setting, with centre-based provision more closely aligned with national standards than home- or community-based models.

**Centre-Based Pre-Primary Settings: Access, Quality, and Socioeconomic Barriers**

Centre-based pre-primary settings, typically formal institutions located in urban areas, are generally regarded as providing higher-quality early education. They benefit from regulated standards, greater access to resources, and structured curricula designed to support children's holistic development (Burchinal et al., 2010, 2014; Phillips et al., 2000). These settings are more likely to employ qualified caregivers with specialized training in early childhood development, and staff development initiatives have been shown to improve classroom quality in both high- and low-and middle countries (Peisner-Feinberg et al., 2001; Pianta et al., 2009; Sylva et al., 2010; Wolf, 2019). Infrastructurally, centre-based provision is also more likely to meet basic WASH standards—including handwashing stations, safe waste disposal, and reliable water—providing safer, more inclusive environments for participation and learning (Britto et al., 2011; McCoy, Waldman, et al., 2018; UNESCO, 2020). Purpose-built classrooms and age-appropriate learning materials further distinguish centre-based provision from other modalities (Britto et al., 2017; Magnuson & Waldfogel, 2016).

Despite these advantages, centre-based settings often require substantial financial contributions from families, limiting access for lower-income households (UNESCO, 2020; World Bank, 2018). In Rwanda, where many families live below the poverty line,

enrollment fees pose a significant barrier (Ministry of Education, 2018). [2] Moreover, centre-based settings are primarily concentrated in higher-income, urban areas where families are better able to pay these costs (Rao et al., 2021; World Bank, 2018). This spatial and economic concentration contributes to disparities in access, with children from urban, higher-SES backgrounds disproportionately benefiting from centre-based quality (UNESCO, 2020).

Regulatory oversight also differentiates centre-based provision from home- and community-based models. Rwanda's centre-based pre-primary settings are most closely aligned with the National Child Development Agency's standards and are subject to direct monthly supervision by Sector Education Officers, and Social and Economic Development Officers (National Child Development Agency, 2019). Their formal infrastructure and closer alignment with system standards mean that monitoring is relatively more consistent than in the other modalities.

**Community-Based Settings: Expanding Access Through Local Initiatives**

Community-based pre-primary settings in Rwanda are typically established by local residents who mobilize shared resources to provide early learning opportunities. They often operate of communal buildings, temporary structures, or improvised facilities, with caregivers recruited from the community itself (National Child Development Agency, 2019; UNICEF, 2017). A key advantage of these settings lies in community ownership and local knowledge, which can reduce distance barriers, foster cultural

[2] The government of Rwanda does not currently offer household-level fee subsidies for Early Childhood Education (ECE). It provides, however, population-level financial and programmatic support through a combination of public investment, and partnerships with NGOs and international donors.

alignment, and create opportunities for parental involvement or linkages to basic health services (Abimpaye et al., 2020; Gelli et al., 2018; Mwaura et al., 2008).

In Rwanda, many community-based settings are located near health posts, primary schools, and sector offices, which can facilitate service integration and enable supervisory visits by local authorities. They are formally embedded within the National Child Development Agency supervision cascade: caregivers submit monthly reports to Sector Education Officers and Social and Economic Development Officers, while managing committees share information with local leaders, and sector officers are expected to conduct regular visits (National Child Development Agency, 2019).

Yet despite this formal integration, community-based settings face persistent structural challenges. Their reliance on improvised facilities and community contributions makes systematic monitoring difficult to sustain (Gelli et al., 2017; Mwaura & Marfo, 2011). Many lack trained caregivers, adequate learning materials, or safe, stimulating environments, and their informality limits regulatory oversight and consistency (Chen & Wolf, 2021; A. Raikes et al., 2023).

**Home-Based Settings: An Accessible but Unequal Alternative**

Home-based pre-primary settings are most common in rural areas, where access to formal, structured care is limited (Lanigan, 2011; Moore et al., 2019). They typically involve informal arrangements organized by community members or relatives, often with minimal or no fees, which lowers financial barriers for low-income families. Their flexibility and community orientation make them culturally relevant and accessible, particularly in rural contexts where formal institutions are scarce (Porter, Paulsell, Del Grosso, et al., 2010).

Structurally, however, home-based provision is marked by inconsistency. Facilities often lack basic WASH infrastructure, with handwashing, sanitation, and safe water access provided informally or absent altogether (McCoy, Waldman, et al., 2018; UNESCO, 2020). Caregivers rarely hold formal early childhood qualifications, and operating schedules are determined by household routines rather than standardized hours, producing uneven exposure for children (Halle et al., 2009; Rusby et al., 2016). Learning materials and physical spaces are typically limited, raising concerns about their ability to support sustained child development (Blau & Currie, 2006; H. Raikes et al., 2005). Additionally, these settings often depend on in-kind contributions from the community and external support, raising concerns about their sustainability and their capacity to provide a stable, quality educational experience over time (Bromer & Henly, 2009; Porter, Paulsell, Nichols, et al., 2010).

While home-based pre-primary settings are formally recognized by Rwanda's National Child Development Agency, their regulation relies heavily on community-level structures. Caregivers are expected to report monthly to cell authorities, while parents' committees oversee daily operations and mobilize resources, often in conjunction with community health workers (National Child Development Agency, 2019). This dependence on voluntary parent leadership and local committees underscores the informal character of oversight compared to centre-based provision.

Despite these limitations, home-based settings remain critical in extending access to underserved and remote areas of Rwanda. In many communities they represent the only viable solution for children to receive early learning opportunities. Yet their comparatively lower quality risks reinforcing inequities in developmental outcomes (Lu

et al., 2020; McCoy, Salhi, et al., 2018). Children in home-based environments often experience less structured learning and limited infrastructure, which may impact their developmental progress and underscore the need to bridge this quality gap. Finally, in low- and middle-income countries, home-based pre-primary settings may offer relatively greater value than higher-income countries, where alternatives such as maternal care are often more accessible and better resourced (Bernal et al., 2019; Duncan et al., 2023; Justino et al., 2023).

**The Role of Socioeconomic Status**

Socioeconomic status (SES) is likely to play a critical role in shaping access to and the quality of pre-primary education in Rwanda. Previous research suggests that SES, often measured by average years of completed schooling, influences not only access but also families' choices and perceptions of care quality (Black et al., 2017; Fuller et al., 2004; OECD, 2017). Higher SES families are more likely to have access to centre-based settings, where infrastructure and caregiver qualifications are typically superior. However, these settings are often unaffordable for lower-income families, creating barriers to access (Magnuson & Waldfogel, 2016; Yoshikawa et al., 2016).

Thus, in addition to access, higher SES families tend to be more attuned to what constitutes a beneficial environment for child development, both at home and in educational settings (Bornstein & Bradley, 2014; Bradley & Corwyn, 2002). Better equipped to distinguish between various forms of care, these families are more likely to select those they believe will provide optimal developmental outcomes for their children. By contrast, lower SES families may have fewer options and tend to prioritize basic accessibility and affordability in their choices (Johnson et al., 2017; Tang et al., 2024).

This dual impact of SES— shaping both access to quality infrastructure and pedagogical processes and the educational environment within the home—contributes to a "double inequality" (Krafft et al., 2024), further exacerbating disparities in child development outcomes (Carlin et al., 2019; Padilla & Ryan, 2020).

**The Present Study**

While the importance of early childhood education is globally recognized, there is limited research on the potential disparities in accessing pre-primary education settings with high-quality infrastructure in low- and middle-income countries. Most existing studies have focused primarily on access, with fewer examining how the quality of infrastructure varies across setting types and regions (UNESCO, 2020; World Bank, 2018). International research has consistently highlighted structural dimensions—such as staff qualifications, operating schedules, and access to basic facilities—as critical determinants of early education quality and equity (NICHD Early Child Care Research Network, 2002; Vandell & Wolfe, 2000). In high-income countries, these features were highly salient in earlier decades when provision was uneven, but as structural baselines have become quasi secured, they now show more limited variation and weaker associations with outcomes in recent studies (Kelly et al., 2025).

By contrast, in low- and middle-income contexts, disparities in infrastructure and staffing remain pronounced, making structural inputs central to both access and quality (McCoy, Waldman, et al., 2018; Wolf et al., 2019). Rwanda provides a distinctive case: centre-based, home-based, and community-based pre-primary settings coexist under one policy framework but differ markedly in their resources and oversight. This study

therefore focuses exclusively on structural indicators, examining whether global patterns of disparity are evident across modalities and geographical areas in Rwanda.

To guide the investigation, we asked three research questions: 1) To what extent do access and enrollment differ across centre-based, home-based, and community-based pre-primary settings pre-primary settings in urban and rural areas? 2) How does infrastructure quality vary across these three types of settings? 3) What is the association between infrastructure quality and socioeconomic status (SES) across geographical areas, and does this association differ by setting type? By addressing these questions, the present study aims to provide empirical evidence to inform policy interventions that promote equitable access to quality pre-primary education in Rwanda and comparable low- and middle-income contexts.

## Method

### Data

This study utilized data from a comprehensive 2023 mapping of pre-primary services in Rwanda, commissioned by the National Child Development Agency and conducted by Esri Rwanda. This mapping provided updated insights into the spatial distribution and quality of services, covering center-based, community-based, home-based, workplace, and emergency pre-primary settings. All indicators of interest were collected using direct observation and GIS-based classification for facility proximity, and self-reports from centre managers for staff and operating metrics. Each indicator corresponds to minimum standards outlined in Rwanda's Integrated ECD regulations and guidelines (Ministry of Gender and Family Promotion, 2020; National Child Development Agency, 2019), and is widely recognized in the global literature as a structural marker of quality—either because it ensures safe and inclusive participation

(WASH indicators), facilitates multisectoral linkages and oversight (proximity indicators), or provides stability and instructional time (staff qualifications and operating hours/days). Data collection focused on five regions: Kigali Province, which includes the districts of Gasabo, Kicukiro, and Nyarugenge, along with the districts of Nyanza (Southern Province), Nyamasheke (Western Province), Rulindo (Northern Province), and Rwamagana (Eastern Province).

In addition to the Esri Rwanda 2023 data, the study incorporated data from Rwanda's 2022 national census, specifically figures on the population of children and sector-level educational attainment. The census reported a total population of 13,246,394, with 1,071,139 children aged 3 to 5 years, accounting for 8.09% of the overall population. The data for this study were analyzed across 91 administrative sectors within the seven sampled districts. In total, the dataset includes 4,875 pre-primary settings, servicing a total of 207,521 children aged 3 to 5 years.

**Analytical Rationale**

The analysis contrasts urban and rural areas and incorporates centre-based, home-based, and community-based settings, the three modalities formally recognized in Rwanda's policy framework. Because centre- and home-based provision were the most prevalent in our sample, this comparison remains central. Their distribution across sectors provides a valuable lens for identifying disparities in both access and infrastructure quality. As Figure A.2 illustrates, some sectors are characterized by a predominance of centre-based settings, while others rely more heavily on home-based provision. These uneven distributions likely reflect differences in availability, affordability, and community mobilization, pointing to variation in local needs and resources. Including

community-based settings extends the analysis to a third modality, enabling us to test whether structural disparities observed between centre and home also appear in community-based provision, and whether global patterns of structural quality generalize to Rwanda's mixed system.

**Outcome Variables: Infrastructure Quality Factors**

An exploratory factor analysis of various binary and continuous indicators of infrastructure quality in pre-primary education settings identified a three-factor model with a strong fit (CFI = .955; RMSEA = .06; SRMR = .05). This analysis informed the decision to model these factors as confirmatory latent variables in the subsequent multilevel analysis. Using confirmatory latent factors offers a more robust framework than sum-score indexes, as it accounts for shared variance among indicators, thus enhancing the identification and precision of effects of interest (Cunha et al., 2021). The three latent factors are as follows:

1. Basic Physical Facilities: This factor includes indicators related to fundamental facilities within the settings, specifically the presence of a handwashing station, waste disposal, and piped water.
2. Public Infrastructure Proximity: This factor represents the proximity of public infrastructure to the settings, including health facilities, local government offices, and primary schools.
3. Staff Quality & Operational Metrics: This factor captures continuous variables related to staff qualifications and operational capacity within the settings,

specifically the proportion of qualified educators, the number of operational hours per day, and the number of operational days per week.[3]

**Table 1**

*Structural Quality Indicators*

| Latent Factor | Indicators | Coding | Rationale |
|---|---|---|---|
| Basic Physical Facilities | Handwashing station present | Binary (0/1) | WASH infrastructure improves health, attendance, readiness (UNESCO, 2020) |
| | Waste disposal facility | Binary (0/1) | Sanitation is a structural quality marker (Britto et al., 2017) |
| | Piped water access | Binary (0/1) | Clean water foundational for hygiene and learning (McCoy, Waldman, et al., 2018) |
| Public Infrastructure Proximity | Near a health facility | Binary (0/1) | Facilitates health/nutrition integration (Britto et al., 2011; Gelli et al., 2017) |
| | Near a primary school | Binary (0/1) | Enhances transition & administrative oversight (UNESCO, 2020) |
| | Near a local government office | Binary (0/1) | Reflects feasibility of SEO/SEDO monitoring (NCDA, 2019) |
| Staff Quality & Operational Metrics | Proportion of qualified educators | Continuous (%) | Staff qualifications linked to process quality (Britto et al., 2011; Wolf et al., 2019) |
| | Operational hours per day | Continuous | Proxy for stability and instructional exposure (Sylva et al., 2010; Woldehanna, 2011) |
| | Operational days per week | Continuous | More service days = consistent readiness exposure (Nores et al., 2024; A. Raikes et al., 2023) |

*Note.* Public Infrastructure Proximity indicators were constructed as binary variables using GIS, classifying settings according to whether they were located within a 2-km walking distance of a health facility, a primary school, or a local government office.

Table 1 summarizes the structural quality indicators used in the analysis. Indicators of the first factor (Basic Physical Facilities) represents elements widely recognized as prerequisites for safe and inclusive participation in pre-primary education. Indicators of the second factor (Public Infrastructure Proximity) capture accessibility to complementary services and the feasibility of sector-level oversight in Rwanda's regulatory system. Indicators of the third factor (Staff Quality and Operational Metrics) covers human resource and service stability dimensions. Together, these factors provide a

[3] "Qualification" was operationalized as possession of a state-sanctioned certificate, diploma, or degree in ECD/ECE.

structured framework for examining disparities in infrastructure quality across centre-, home-, and community-based pre-primary settings.

**Socioeconomic Status**

For each administrative sector, socioeconomic status (SES) was operationalized by the average years of completed schooling among residents aged 12 or older. This measure of educational attainment serves as a good proxy for SES, showing a strong negative correlation with the Multidimensional Poverty Index (Pearson's r = -0.89), which is based on multiple non-monetary indicators and calculated as the product of poverty incidence and intensity (Alkire et al., 2021).

**Empirical Strategy**

This study employed a multilevel analysis to capture meaningful variation in infrastructure quality across pre-primary education settings at both the within- and the between-sector levels. Clustering at the district-level, with only seven districts, would have lack both the necessary statistical power and granularity, making sector-level analysis essential. To address the over-representation of sectors in Kigali Province (35 out of 91 sectors), a binary indicator for the province was included in the models.

The analysis modeled three distinct, correlated latent infrastructure factors— basic physical facilities; public infrastructure proximity; staff quality and operational metrics— that were presented in detail in the Outcome Variables section. By modeling these factors as confirmatory latent variables simultaneously, we maintain the specificity of each dimension of infrastructure quality they represent. The measurement of each factor was specified as follows:

$$\text{Physical Facilities}_{ij} = \lambda_1(\text{Handwashing}) + \lambda_2(\text{Waste Disposal}) + \lambda_3(\text{Piped Water}) + \varepsilon_{ij}$$

$$\text{Public Infrastructures}_{ij} = \lambda_5(\text{Health Facility}) + \lambda_6(\text{Government Office}) + \lambda_7(\text{School}) + \varepsilon_{ij}$$

$$\text{Operations}_{ij} = \lambda_8(\text{Qualified Staff}) + \lambda_9(\text{Operational Hours}) + \lambda_{10}(\text{Operational Days}) + \varepsilon_{ij}$$

Each λ represents the factor loading for its respective indicator, and $\varepsilon_{ij}$ is the measurement error term for each factor.

The structural model contrasts center-based settings (reference group) with home-based and community-based settings across sectors and was formalized as follows:

Level 1 (Within-Sector):

$$\text{Infrastructure Factor}_{ij} = \beta_{0j} + \beta_1(\text{Home}_{ij}) + \beta_2(\text{Community}_{ij}) + r_{ij}$$

Level 2 (Between-Sector):

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{SES}_j) + \gamma_{02}(\text{Kigali}_j) + u_{0j}$$

$$\beta_1 = \gamma_{10}$$

$$\beta_2 = \gamma_{20}$$

In this model, $\text{Infrastructure Factor}_{ij}$ vector represents each latent infrastructure factor for the i-th setting in the j-th sector. Coefficients $\beta_1$ and $\beta_2$ capture the within-sector differences in infrastructure quality for home-based and community-based settings, respectively, relative to centre-based settings, with positive values indicating higher quality and negative values indicating lower quality. The parameter $\gamma_{01}$ represents the effect of SES, proxied by educational attainment, on infrastructure quality, while $\gamma_{10}$ and $\gamma_{20}$ capture sector-level effects of home-based and community-based settings, respectively, on infrastructure quality compared to centre-based settings.

By modeling the latent factors collectively while allowing each to retain its distinct dimensionality, the analysis enhances our understanding of how local

socioeconomic conditions and setting types correlate with specific aspects of pre-primary infrastructure quality across Rwanda

## Results

### Patterns of Pre-Primary Enrollment

**Table 2**

*Enrollment by Settings, within Districts (Province)*

| | Setting type | Number of children enrolled | Number of settings | Enrollment within setting type (%) |
|---|---|---|---|---|
| *Gasabo (Kigali)* | Centre | 36,539 | 411 | 78% |
| | Community | 4,644 | 116 | 9% |
| | Home | 5,348 | 276 | 11% |
| *Kicukiro (Kigali)* | Centre | 17,735 | 189 | 72% |
| | Community | 4,304 | 89 | 17% |
| | Home | 2,445 | 86 | 9% |
| *Nyarugenge (Kigali)* | Centre | 13,014 | 128 | 69% |
| | Community | 2,066 | 47 | 10% |
| | Home | 3,735 | 159 | 19% |
| *Nyamasheke (West)* | Centre | 16,356 | 229 | 47% |
| | Community | 4,128 | 204 | 11% |
| | Home | 14,242 | 966 | 41% |
| *Rulindo (North)* | Centre | 17,698 | 144 | 62% |
| | Community | 1,707 | 64 | 6% |
| | Home | 9,002 | 611 | 31% |
| *Nyanza (South)* | Centre | 16,164 | 123 | 69% |
| | Community | 1,541 | 52 | 6% |
| | Home | 5,666 | 357 | 24% |
| *Rwamagana (East)* | Centre | 18,128 | 146 | 58% |
| | Community | 5,131 | 109 | 16% |
| | Home | 7,928 | 369 | 25% |
| Total | Center | 135,634 | 1,370 | 65% |
| | Community | 23,521 | 681 | 11% |
| | Home | 48,366 | 2,824 | 23% |
| | | 207,521 | 4,875 | 100% |

Table 2 reveals significant variation in pre-primary enrollment across different types of settings. Centre-based settings hold the highest overall enrollment, accounting for 65% of total pre-primary enrollment, serving 135,634 children across 1,370 centers. Home-based settings follow, with 23% of enrollment (48,366 children in 2,824 centers), while community-based settings account for 11% (23,521 children in 681 centers). This dominance of centre-based settings underscores their substantial role, particularly in

urban areas. Within individual districts, centre-based settings have the highest enrollment percentages across all regions, especially in urban districts within Kigali Province, such as Gasabo (78%). In contrast, rural districts like Nyamasheke show a higher proportion of children in home-based settings (41%), indicating a strong reliance on informal structures where access to centre-based services may be limited. These descriptive counts highlight a clear urban-rural divide in pre-primary education: urban areas primarily depend on centre-based settings, whereas rural areas increasingly rely on home-based structures as essential access points.

**Pre-Primary Enrollment Rate: Gasabo & Nyamasheke**

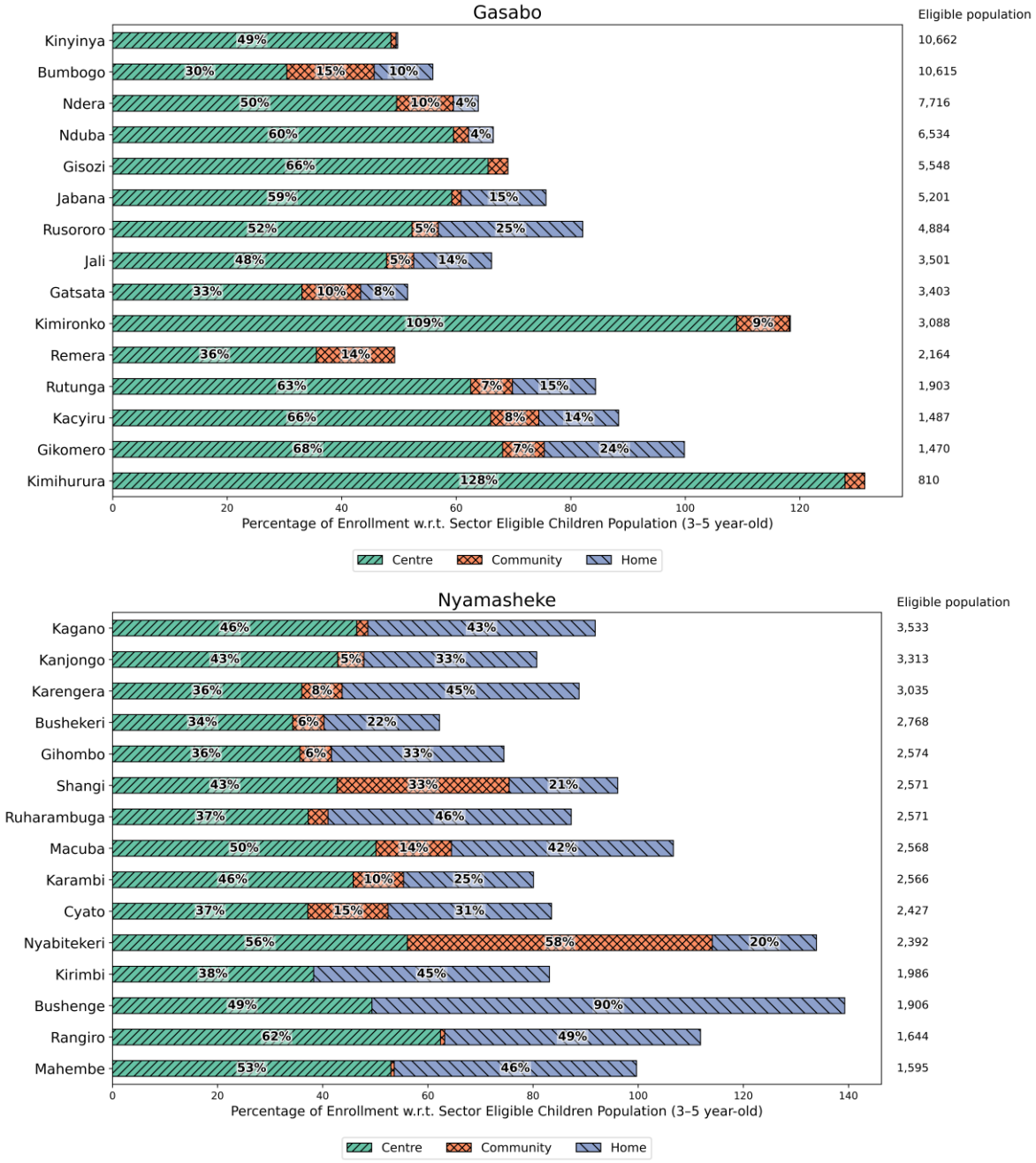
A closer examination of enrollment rates in the urban district of Gasabo and the rural district of Nyamasheke highlights contrasting dynamics that exemplify how urban and rural contexts shape access to pre-primary education in Rwanda. Figure 1 reveals notable differences in cross-sector enrollment rates within these two districts. In Gasabo, the eligible child population ranges from 810 in Kimihurura to 10,662 in Kinyinya, totaling 68,986 children aged 3 to 5 years. Urbanized sectors, such as Ndera, Nduba, and Gisozi, centre-based settings account almost exclusively for the pre-primary enrollments (within-sector rates of 50%, 60%, and 66%, respectively, of sectors' eligible children population). Notably, Kimironko and Kimihurura show rates of 109% and 128%, likely due to influx of children from neighboring areas. In contrast, peripheral sectors like Rusororo and Gikomero also rely on home-based settings (with enrollment rates of 25% and 24%, respectively).

Nyamasheke, with an eligible population ranging from 1,595 in Mahembe to 3,533 in Kagano (totaling 37,449 children), demonstrates different dynamics, with a

stronger reliance on home-based settings. Sectors like Kagano, Kanjongo, and Karengera show home-based enrollment rates of 43%, 33%, and 45%, respectively, while Bushenge reaches 90%. Despite the predominance of home-based settings, Nyamasheke still shows moderate enrollment in centre-based settings (34% to 62% across sectors), illustrating the district's more limited but present access to formal centers amid its rural context.

**Figure 1**

*Enrollment Rates across Pre-Primary Setting*



## Infrastructure Quality Average Differences

**Table 3**

*Descriptive Statistics of Quality Indicators & SES Proxy, by Setting Type*

| | Centre | Community | Home | Centre vs. Home | ICC |
|---|---|---|---|---|---|
| Handwashing station | 0.93 (0.25) | 0.79 (0.41) | 0.68 (0.47) | 0.25 ($d$ = 0.61) | 0.38 |
| Piped water | 0.80 (0.40) | 0.35 (0.48) | 0.23 (0.42) | 0.57 ($d$ = 1.39) | 0.40 |
| Waste disposal | 0.92 (0.27) | 0.75 (0.44) | 0.68 (0.47) | 0.24 ($d$ = 0.58) | 0.51 |
| Health facility | 0.87 (0.34) | 0.75 (0.43) | 0.69 (0.46) | 0.18 ($d$ = 0.42) | 0.41 |
| Government office | 0.92 (0.27) | 0.89 (0.32) | 0.78 (0.41) | 0.14 ($d$ = 0.37) | 0.46 |
| Primary school | 0.96 (0.19) | 0.86 (0.34) | 0.82 (0.38) | 0.14 ($d$ = 0.43) | 0.35 |
| Qualified educators | 0.45 (0.43) | 0.26 (0.40) | 0.10 (0.27) | 0.36 ($d$ = 1.07) | 0.42 |
| Operational hours | 5.06 (1.63) | 4.23 (1.00) | 3.84 (0.78) | 1.22 ($d$ = 1.08) | 0.34 |
| Operational days | 4.99 (0.36) | 4.35 (1.36) | 3.83 (1.56) | 1.16 ($d$ = 0.89) | 0.35 |
| SES/Educational attainment | 6.21 (1.73) | 5.65 (1.52) | 4.99 (1.03) | 1.22 ($d$ = 0.94) | |
| *N* | 1,370 | 681 | 2,824 | | |

*Notes.* All mean differences between Centre and Home had *p-value* < .0001. Cohen's $d$ is a measure of effect size that indicates the standardized difference between two group means, where the mean difference is divided by the standard deviation pooled across the Centre and Home settings. ICC: Intra Class Correlations. SES/Educational attainment is measured at the sector level and reflects the average years of schooling in the sector where each setting is located.

Table 3 presents descriptive statistics on key infrastructure and operational metrics, highlighting considerable differences across pre-primary setting types. Centre-based settings exhibit superior infrastructure, with 93% having handwashing stations, 80% having piped water, and 92% having waste disposal facilities. In comparison, home-based settings display lower figures: 68% with handwashing stations, 23% with piped water, and 68% with waste disposal facilities. The substantial effect sizes (e.g., piped water, Cohen's $d$ = 1.39; handwashing stations, $d$ = 0.61) reflect the disparity in basic facilities. For proximity to public resources, centre-based settings show advantages: 87% are near health facilities and 96% are near primary schools, compared to 69% and 82% for home-based settings, respectively. Differences are most marked in proximity to government offices (92% in centre-based vs. 78% in home-based; $d$ = 0.37).

Staff qualifications and operational characteristics further emphasize the gaps. In centre-based settings, 45% of educators are qualified, while only 10% of educators in home-based settings hold qualifications ($d$ = 1.07). Centre-based settings also operate longer hours per day (5.06 vs. 3.84 hours; $d$ = 1.08) and more days per week on average. Community-based settings, positioned between centre- and home-based in infrastructure quality, show limited staff qualifications (26% qualified) and shorter hours, suggesting resource limitations similar to home-based settings but with slightly better infrastructure.

Centre-based settings are, on average, located in sectors where educational attainment is 6.21 years, whereas home-based settings are located in sectors averaging 4.99 years—a difference of 1.22 years (d = 0.94). This suggests that centre-based settings tend to be concentrated in higher-SES sectors, while home-based settings are more common in lower-SES sectors.

**Sector-Level Variability**

Intraclass Correlation Coefficients (ICCs) from Table 3 reveal the extent of sector-level variation in infrastructure quality. For instance, the ICC for waste disposal is 0.51, indicating that 51% of the variance in waste disposal availability is due to between-sector differences, with the remaining 49% is attributed to variation within sectors. High ICC values for key indicators, such as proximity to government offices (0.46) and qualified educators (0.42), suggest that sector-level factors significantly shape infrastructure quality. These ICCs underscore the importance of a multilevel approach, allowing us to account for both sector-level and within-sector differences across Rwanda's pre-primary settings.

## Multilevel Regression Models

**Table 4**

*Infrastructure Quality Factors on Pre-Primary Settings and Sector-Level SES*

| | Level 1 (Within-Sector) | | | Level 2 (Between-Sector) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Physical Facilities | Public Infrastructures | Operations | Physical Facilities | | Public Infrastructures | | Operations | |
| Home | -0.73<br>[-.77; -.70]<br>$p < .001$ | -0.30<br>[-.35; -.25]<br>$p < .001$ | -0.85<br>[-.88; -.81]<br>$p < .001$ | -0.94<br>[-1; -.77]<br>$p < .001$ | -0.33<br>[-.64; -.06]<br>$p = .02$ | -0.38<br>[-.63; -.06]<br>$p = .02$ | 0.08<br>[-.24; .35]<br>$p = .60$ | -0.83<br>[-1; -.63]<br>$p < .001$ | -0.70<br>[-.95; -.31]<br>$p < .001$ |
| Community | -0.48<br>[-.52; -.44]<br>$p < .001$ | -0.17<br>[-.22; -.12]<br>$p < .001$ | -0.35<br>[-.39; -.31]<br>$p < .001$ | -0.26<br>[-.48; -.05]<br>$p = .02$ | -0.12<br>[-.28; .05]<br>$p = .13$ | 0.04<br>[-.24; .32]<br>$p = .80$ | 0.05<br>[-.20; .32]<br>$p = .70$ | -0.28<br>[-.52; -.03]<br>$p = .03$ | -0.21<br>[-.51; 09]<br>$p = .19$ |
| SES | | | | | 0.54<br>[.42; .64]<br>$p < .001$ | | 0.21<br>[.05; .36]<br>$p = .01$ | | 0.11<br>[-.11; .33]<br>$p = .36$ |
| $R^2$ | .46 | .08 | .58 | .67 | .79 | .17 | .41 | .51 | .43 |
| *N* | 4,875 settings; 91 clusters (administrative sectors) | | | | | | | | |

*Notes.* Centre-based pre-primary settings are the reference category. SES: proxied by sector-level average years of completed schooling among residents aged 12 or older. 95% confidence intervals are displayed within brackets.

Table 4 reveals substantial disparities in infrastructure quality across pre-primary settings and highlights the impact of sector-level SES. At the within-sector level, which isolates differences in infrastructure quality between setting types while controlling for sector characteristics, home-based settings consistently demonstrated lower infrastructure quality compared to centre-based settings. For physical facilities, home-based settings were 0.73 *SD* below centre-based settings (95% CI: [-0.77; -0.70], $p < .001$; R-squared = .46), suggesting a marked deficiency in essential resources such as handwashing stations, waste disposal, and piped water—critical for health and hygiene. Operational quality showed an even larger gap, with home-based settings trailing by -0.85 *SD* compared to

centre-based settings (95% CI: [-0.88; -0.81], $p < .001$, R-squared = .58), reflecting reduced operating hours, fewer operational days, and lower qualified staff availability. In contrast, public infrastructure proximity showed a smaller effect, with home-based settings 0.30 *SD* lower than centre-based settings (95% CI: [-0.35; -0.25], $p < .001$), and with only minimal variance explained by setting type (R-squared = .08). These patterns suggest that within sectors, home-based settings are structurally disadvantaged, especially regarding physical facilities and operational resources.

The between-sector results further reveal substantial disparities in infrastructure quality across settings types, with centre-based settings maintaining a significant advantage over home-based and community-based settings, especially in physical facilities and operational metrics. Without controlling for SES, home-based settings scored 0.94 *SD* lower in physical facilities quality than centre-based settings (95% CI: [-1.00; -0.77], $p < .001$), with only a slight reduction in effect when SES was included (0.83 *SD*; 95% CI: [-1.00; -0.63], $p < .001$). Community-based settings also showed lower physical facilities quality relative to centre-based settings, although with a smaller and less precise effect size of 0.26 *SD* (95% CI: [-0.48; -0.05], $p = .02$), which diminished further and became non-significant with SES included (-0.12 *SD*; 95% CI: [-0.28; 0.05], $p = .13$). The explained variance for physical facilities quality between sectors was relatively high, with an R-squared of 0.67 without SES and increasing to 0.79 with SES, suggesting that setting type and SES together account for much of the variance in access to physical facilities.

The between-sector results for public infrastructure show that centre-based settings maintained an advantage over home-based settings, though with a smaller effect

size than observed for physical facilities. Without SES as a control, home-based settings scored 0.38 *SD* lower than centre-based settings in proximity to public infrastructure (95% CI: [-0.63; -0.06], $p = .02$). This effect vanished when SES was included (0.08 *SD*; 95% CI: [-0.24; 0.35], $p = .60$), underscoring sector-level SES as a significant determinant of public infrastructure access near home-based settings. The SES effect itself is 0.21 *SD* (95% CI: [0.05; 0.36], $p = .01$), indicating that higher-SES sectors generally offer have better access to public resources like health facilities and schools. This pattern held consistently across provinces, as the model controlled for Kigali (Rwanda's capital), where public infrastructure is inherently more concentrated. Community-based settings showed negligible differences from centre-based settings in public infrastructure access, both with and without SES included. The between-sector R-squared for public infrastructure was relatively modest, increasing from 0.17 without SES to 0.41 with SES, suggesting SES as a more significant contributor to public infrastructure access across sectors.

The between-sector analysis for operational quality (Table 4) showed marked disparities, with home-based settings continuing to lag behind centre-based settings. Without SES, home-based settings scored 0.83 *SD* lower on operational quality (95% CI: [-1.00; -0.63], $p < .001$), highlighting limitations in qualified staff availability, operational hours, and days. When SES was added to the model, the gap only slightly narrowed to 0.70 *SD* (95% CI: [-0.95; -0.31], $p < .001$), suggesting that SES has a somewhat lesser influence on operational quality than on other infrastructure factors. Community-based settings also displayed lower operational quality than centre-based settings (0.28 *SD*; 95% CI: [-0.52; -0.03], $p = .03$), though this difference was no longer

statistically different from zero once SES was included (0.21 *SD*; 95% CI: [-0.51; 0.09], $p = .19$). The R-squared values for operational quality across sectors were relatively high at 0.51 without SES and 0.43 with SES included, indicating that setting type already captures a substantial portion of the variance in operational quality and that the added shared variance with SES may have slightly diluted the unique explanatory power of setting type (given that operational resources, staff availability, and schedules are often directly tied to whether a setting is centre-based or home-based).

## Discussion

This study examined disparities in infrastructure quality across different pre-primary education settings in Rwanda—specifically, centre-based, community-based, and home-based settings—and assessed the role of sector-level socioeconomic status (SES) associated with these disparities. Using a multilevel analytical approach, the analysis separated within-sector differences between setting types and evaluated the influence of SES at the between-sector level.

The findings indicate that home-based settings consistently demonstrated lower infrastructure quality compared to centre-based settings across all measured factors: physical facilities, proximity to public infrastructure, and operational quality. For example, home-based settings scored 0.73 standard deviations (*SD*) below centre-based settings in physical facilities and 0.85 *SD* lower in operational quality. These differences highlight notable resource gaps, like waste disposal, piped water, operating hours, and qualified staff.

At the between-sector level, higher SES was linked to better physical facilities and enhanced access to public infrastructure across all setting types. Although including

SES in the models partially reduced the disparities between home-based and centre-based settings for physical facilities and public infrastructure access, significant gaps remained. For operational quality, SES had a limited effect, suggesting that pre-primary education setting type is the predominant factor influencing this domain.

These results underscore the structural disadvantages faced by home-based settings in Rwanda. The persistent quality gaps, even after adjusting for SES, imply that children attending home-based settings may lack access to critical resources essential for early childhood development. These outcomes resonate with research on "double inequality" in early childhood education, where both access to and quality of infrastructure favor children from higher socioeconomic backgrounds (Britto et al., 2017; Krafft et al., 2024). The substantial gaps in physical and operational resources within home-based settings underscore the structural barriers that low-SES children face, often attending settings that, while accessible, lack essential quality indicators (Britto et al., 2011; Magnuson & Waldfogel, 2016).

Sector-level SES effects, especially on public resources, reinforce evidence suggesting that high-SES sectors often benefit from greater social and physical capital, thereby deepening disparities for children in low-SES, often rural, areas where access to quality resources remains limited (A. Raikes et al., 2023; UNESCO, 2020). However, the continued quality gaps in home-based settings within high-SES areas imply that improving SES alone may be insufficient to bridge these disparities. Prior studies highlight the need for targeted investments that go beyond physical infrastructure improvements to address quality through direct regulation and resource allocation (Heckman, 2006; Yoshikawa et al., 2013).

Furthermore, the operational quality gaps reflect SES's limited influence on staffing and operational structures across settings. The minimal effect of sector-level SES on operational quality in home-based settings suggests that these environments may be particularly vulnerable to resource constraints beyond local socioeconomic conditions, lacking the robust staffing and extended schedules seen in centre-based settings (Peisner-Feinberg et al., 2001; Phillips et al., 2000; H. Raikes et al., 2005). This emphasizes the importance of differentiated policy responses, where formal regulatory standards and financial support systems could play a critical role in addressing the unique barriers faced by home-based settings.

Collectively, these insights contribute to the broader discourse on early childhood inequality. They illustrate how setting-specific disparities reflect and reinforce existing social and economic divides. They underscore an urgent need for structural reforms that prioritize equity in infrastructure quality, ensuring that all children, particularly those from low-SES backgrounds, have access to high-quality early learning environments is essential as a crucial step toward mitigating deep-seated inequalities (Black et al., 2017; Yoshikawa et al., 2016).

**Limitations**

While this study's sample, covering seven districts and 91 sectors, offers an insightful overview of pre-primary infrastructure quality across a substantial portion of Rwanda, it does not represent the entire country. Consequently, the findings may not fully reflect the diversity and specific challenges of districts not included in the sample. Variations in socioeconomic status, cultural norms, and regional policies likely influence the types, quality, and accessibility of pre-primary settings in other areas. This limitation

suggests that the findings are not entirely generalizable to the national level and could overlook unique needs or challenges in unstudied regions. Future research could expand on this study by including additional districts to gain a more nuanced understanding of infrastructure quality across all regions of Rwanda.

Additionally, the study's focus on infrastructure quality captures essential aspects of a quality learning environment but does not address all quality dimensions. Key qualitative aspects, such as caregiver-child interactions, curriculum content, staff qualifications beyond credentials, and child developmental outcomes, were beyond this study's scope. Furthermore, elements related to pedagogical practices and emotional support provided within these settings were not evaluated, and there is some evidence that these dimension have a positive impact on child development (Ulferts et al., 2019). While robust infrastructure is essential, it alone does not fully define quality in early education. Future studies should incorporate observational and evaluative measures of pedagogy and processes to provide a more comprehensive assessment of pre-primary setting quality.

## Implications & Future Directions

By examining the findings of this study, we can identify promising avenues for refining policies to enhance Rwanda's pre-primary education sector and support its ongoing development.

### *Funding Streams and Sustainability*

The financial landscape across pre-primary settings in Rwanda reveals notable disparities, underscoring quality discrepancies between settings. As illustrated in Figure A.1 of the Appendix, approximately 58% of centre-based settings rely primarily on fees

alone or a combination of fees and government subsidies, while another 9% operate solely on government funds. This reliance on formalized funding sources aligns with the higher infrastructure and operational standards in these settings, yet it imposes a considerable financial burden on families. For low-income households, these costs may limit access, challenging the goal of equitable early childhood education (Hahn & Barnett, 2023).

In contrast, home-based settings display a broader dependency on in-kind contributions, with 484 out of 2,146 settings supported solely through in-kind contributions (Figure A.1 in the Appendix). These sources are frequently supplemented by owner support or modest fees, funding schemes which accounts for about 42 % of the settings, reflecting a less formalized financial structure that introduces funding volatility. This reliance on non-monetary and external support underscores the vulnerability of home-based settings, particularly in low-SES areas where fee-based income may be less predictable. Notably, around 16% of home-based settings rely exclusively on family fees for operating costs, highlighting that fee-based funding remains significant even among lower-resource settings.

Consequently, these financial dynamics likely contribute to a structurally uneven landscape in which funding variability influences both the stability and quality of pre-primary services across settings, ultimately impacting the children served. Given these dynamics, early childhood development policymakers and stakeholders—i.e., state and local government, along with international partners—could consider expanding formal financial support for home-based settings to meet basic infrastructure standards, fostering greater consistency and quality across settings.

### *Operational Disparities*

Our study's findings underscore significant variation in operational quality across pre-primary setting types, with centre-based settings generally offering longer, more consistent schedules compared to home-based settings. This consistency likely stems from the higher infrastructure standards and more formalized funding streams characteristic of centre-based environments. These operational differences reflect distinct capacities to meet family needs and support children's development. Centre-based settings typically provide extended hours, more qualified staff, and operate more days per week, fostering a structured environment that supports stable routines crucial for early development (Berti et al., 2019; Perry et al., 2023). In contrast, home-based settings, with more flexible yet limited schedules, may lack consistency, potentially affecting children's learning experiences and long-term developmental outcomes. Addressing these operational disparities—through expanded caregiver training and resource allocation—could promote a more equitable and robust pre-primary education system in Rwanda, better aligning with the needs of diverse families (Institute of Medicine and National Research Council, 2015).

### *Workforce Development and Professionalization of Home-Based Care*

One of a potentially promising policy directions is the integration of home-based caregivers into the formal pre-primary workforce. Home-based settings often operate with minimal resources yet demonstrate strong ties to local communities, representing a largely untapped potential for workforce expansion. By offering targeted professional development, training, and support, policymakers could empower home-based caregivers with the skills necessary to deliver quality early childhood care and education (Clarke-

Stewart et al., 2002). This approach would not only raise the quality of education in home-based settings but also foster career pathways for caregivers, contributing to a more robust and professionalized pre-primary education workforce in Rwanda. Over time, with adequate resources and regulatory support, some home-based settings could transition into more formalized institutions, enhancing both the capacity and quality of pre-primary services across the country. This transition would not only expand access to high-quality education but also help address the current workforce shortages in the sector by creating formal roles and professional opportunities for home-based caregivers (for an overview regarding Early Childhood Development workforce policy at scale, see Yoshikawa et al., 2018).

### *Future Research Directions*

While this study highlights key differences in infrastructure quality across pre-primary settings and underscores the potential for workforce development and operational improvements, further research is essential to build a more comprehensive understanding of these issues. Longitudinal studies that examine the impact of different pre-primary settings on child development outcomes over time would provide invaluable evidence for refining and prioritizing these policy directions (Duncan et al., 2023). Moreover, targeted studies on barriers to accessing quality Early Childhood Development services, particularly in rural and lower-SES areas, would offer a clearer view of the contextual challenges faced by families and settings alike, ensuring that policy interventions are effectively tailored to the local landscape (McCoy, Salhi, et al., 2018; A. Raikes et al., 2023).

## Conclusions

This study sheds light on disparities in pre-primary infrastructure in Rwanda, emphasizing how structural and socioeconomic factors shape access to quality early learning environments. Results show that home- and community-based settings, though vital for access in low-resource and rural areas, systematically lack the basic facilities, staffing, and operating stability found in centre-based provision. Because these disparities persist even in higher-SES sectors, improving socioeconomic conditions alone is unlikely to close gaps without targeted regulatory and financial measures.

Policy implications must be grounded in Rwanda's system design. Integrating home- and community-based providers into the current formal framework can raise a minimum structural floor—for example, through targeted micro-grants for handwashing, waste disposal, and basic learning materials—without imposing unaffordable costs on families. Evidence from low- and middle-income countries shows that such light-touch infrastructure improvements, when paired with supportive supervision and modest caregiver training, can improve quality at scale (Gelli et al., 2017; Mwaura & Marfo, 2011; Wolf et al., 2019). More capital-intensive investments such as piped water and permanent classrooms are likely less feasible in the near term and require sequenced district or donor financing.

Finally, while this study focused on structural quality, process quality remains an essential complement. Regulatory authorities are unlikely to shift geographic realities like proximity to sector offices, but they can use these indicators to guide where supervision and co-location of services are most feasible. A pragmatic strategy is to secure a basic structural package everywhere, with particular priority for home-based settings, which

our findings show are the most disadvantaged. Ensuring minimum WASH facilities, simple learning materials, and predictable operating schedules in these settings can provide a low-cost but critical foundation for equity. Once this structural floor is in place, recurrent investment should focus on caregiver training, coaching, and supportive supervision, which international evidence shows are the most effective levers for raising quality. In this way, Rwanda can both expand access and ensure that expansion is accompanied by sustainable gains in quality.

**Availability of data and materials**

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

The authors have no competing interests to disclose.

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**Authors' contributions**

Remy Pages: conception; empirical strategy and data analysis; writing and writing revisions. Gilbert Munyemana: data collection design; writing revisions.

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# Appendix

**Figure A.1**

UpSet Plots of Funding Source Combinations by Setting Type

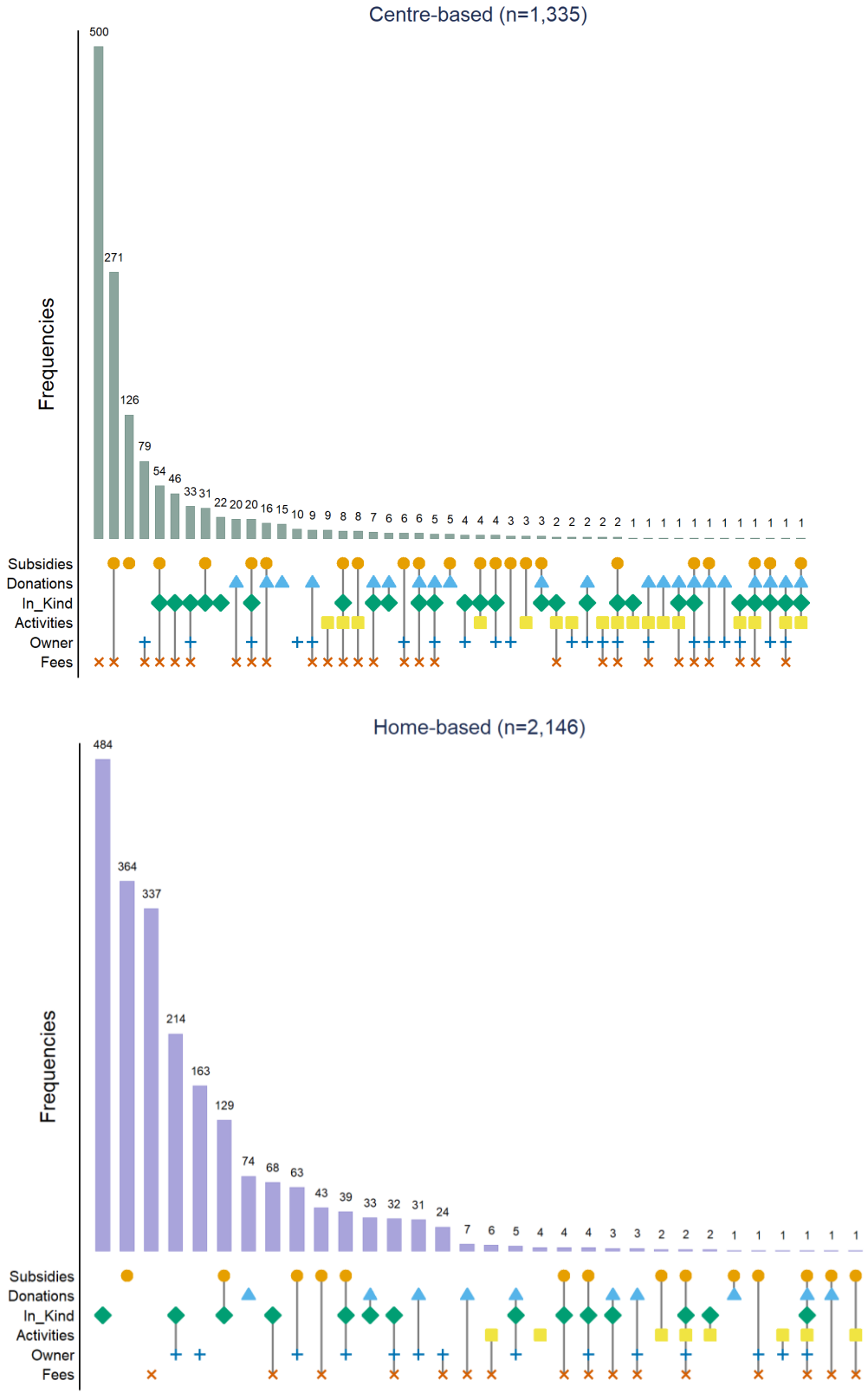

**Figure A.1 (Continued)**

UpSet Plots of Funding Source Combinations by Setting Type

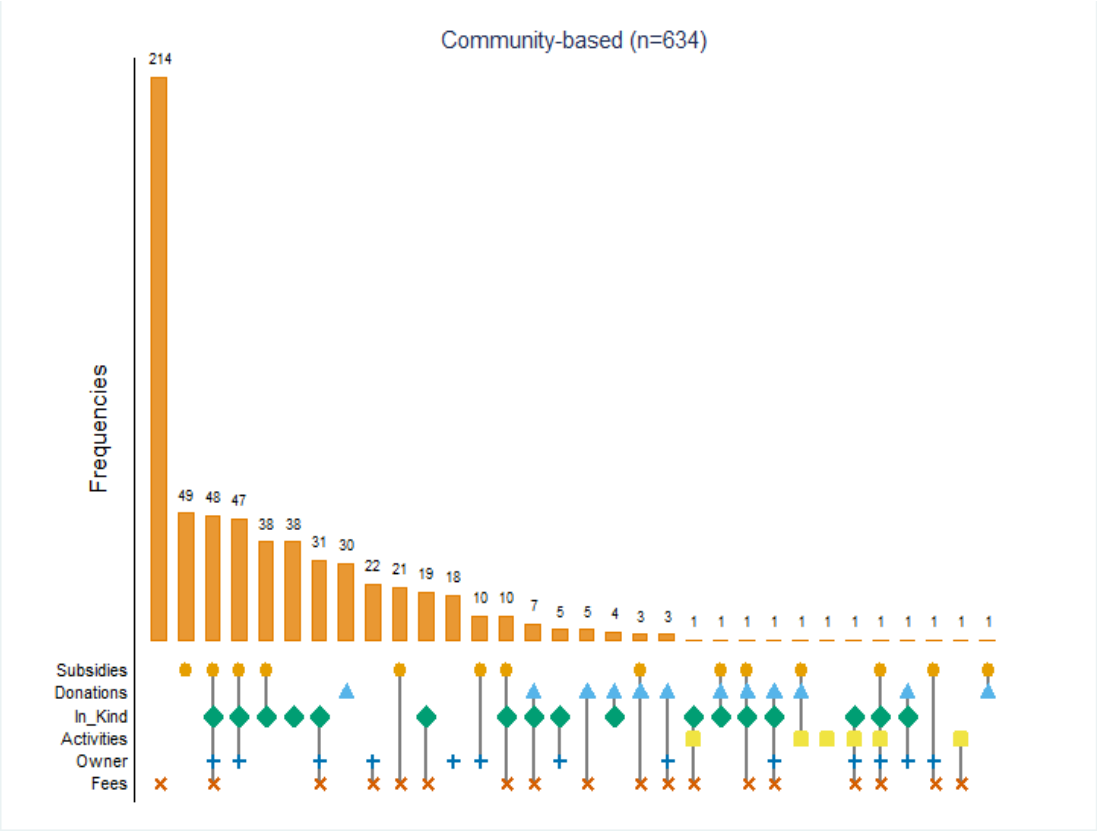

**Figure A.2**

Distribution (%) of Centre-based (Green/Left) and Home-based (Red/Right) Pre-Primary Settings across Administrative Sectors