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Prioritizing the Attributes of the Training and Mentoring Programme for the Environmental Management Projects in the UNESCO Vhembe Biosphere Reserve, South Africa

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Abstract

Environmental management projects in biosphere reserves often struggle with limited capacity and weak long-term sustainability, despite their ecological and socio-economic importance. The study used Participatory Budgeting (PB) and the Analytic Hierarchy Process (AHP) to prioritize the attributes of a training and mentoring program for sustainable environmental management in the VBR. A sequential exploratory mixed-methods design grounded in engaged scholarship was used. In the qualitative phase, 32 purposively selected project members generated the programme's knowledge areas, skills, teaching methods, and assessment approaches through reflection circles. In the quantitative phase, the project members ranked these items using Participatory Budgeting (PB), and the rankings were validated and refined using the Analytic Hierarchy Process (AHP). Participants identified eight knowledge areas comprising 45 skills and prioritized legislated and OHS requirements, environmental health, financial planning, policies, systems and procedures, among others. They preferred workshops, practical demonstrations, and on-the-job training, assessed through practical reports and group projects by experts from tertiary institutions. AHP resolved PB ties without contradicting its rankings. The study's results provided important information for the co-design of a training program with the community to support environmental management projects in biosphere reserves. Such a program can be institutionalized through university–community engagement systems. Moreover, the study demonstrated that integrating PB with AHP produces a hybrid decision-support model that enhances legitimacy, transparency, and analytical rigor in participatory programme design.

Keywords: Vhembe Biosphere Reserve; capacity building; co-design; engaged scholarship; environmental management; training programme; mentoring programme; participatory budgeting

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1. Introduction

Ecosystem services have sustained human livelihoods since time immemorial, providing the biological, physiological, and economic foundations on which societies depend [1].

These services fall into three broad categories: disposal services, where the natural environment acts as an absorptive sink for residuals; productive services, which supply key inputs to economic systems; and consumptive services, which provide physiological and recreational resources for human wellbeing. In biodiversity-rich regions, these services underpin both formal and informal economies, with livelihoods closely tied to the health of natural capital [2,3]. Recognizing this dependency, green economy principles have emerged to advocate for decoupling economic growth from environmental degradation, providing low barriers to entry into the mainstream economy for the poorest community members and positioning environmental resources as a pillar of inclusive, sustainable socio-economic development.

South Africa exemplifies both the opportunity and the challenge of translating natural capital into equitable socio-economic outcomes. The country is home to nearly 10% of the world's known plant species and 15% of all known coastal marine species, distributed across nine unique biomes, three of which have been declared global biodiversity hotspots [4]. It is also the only country to contain an entire floral kingdom, the Cape Floristic Region. This extraordinary biological diversity, combined with a rich repository of indigenous knowledge, constitutes one of the country's most significant strategic assets, with potential applications in the natural products sector, bioprospecting for pharmaceutical and cosmeceutical development, and the use of indigenous species as food sources. However, despite this wealth, South Africa's Gini coefficient of 0.69 remains among the highest in the world [2], underscoring the persistent failure to translate environmental endowments into broadly shared prosperity. Addressing this paradox requires governance models that actively incorporate marginalised communities as co-producers of knowledge and beneficiaries of the bioeconomy.

Biosphere reserves, as internationally designated learning landscapes under UNESCO's Man and the Biosphere (MAB) Programme, offer a strategic framework for reconciling conservation with inclusive development. Recent scholarship increasingly positions biosphere reserves as "living laboratories" for co-produced sustainability transitions, where collaborative governance and transdisciplinary learning are central to conservation effectiveness [5,6]. In these contexts, the integration of academic knowledge with community-held ecological wisdom is not merely desirable but essential. Meaningful collaboration must be anchored in genuine partnerships between academia and grassroots communities, partnerships through which both parties come together to co-develop solutions that maintain the balance between human activity and ecological integrity [7]. Co-designed socio-ecological governance strategies are increasingly recognised as essential for enabling inclusive bioeconomy transitions and aligning local development with global sustainability frameworks, such as the Sustainable Development Goals (SDGs) and the Convention on Biological Diversity [8,9].

Despite this growing recognition, the practical reality of biodiversity governance often falls short of these ideals. Decision-making within bioeconomy and environmental management initiatives continues to be dominated by academics, government officials, and researchers, with communities treated largely as passive consumers of externally produced knowledge and strategies rather than as active co-producers [10]. This exclusion is increasingly cited as a primary reason why many environmental resource management projects fail to achieve their intended goals of driving inclusive green growth. Communities that have historically depended on environmental resources possess a rich and often undocumented stock of indigenous knowledge and ecological wisdom, knowledge that is critical for the design of contextually appropriate, sustainable management systems. When this knowledge is overlooked, interventions risk being ill-suited to local conditions, leading to limited uptake and ultimately failing to sustain the communities they seek to serve.

Universities located within the biosphere reserves occupy a uniquely advantageous position to bridge this divide. Institutions such as the University of Venda are increasingly recognized as boundary organizations capable of facilitating knowledge co-production, participatory learning, and transdisciplinary capacity building at the interface between academia and community [5,11]. Their engaged scholarship mandate calls for research and teaching to be grounded in genuine community partnership, moving beyond extractive research models toward collaborative inquiry that generates knowledge with rather than about, communities. However, realizing this potential requires deliberate methodological frameworks that structure co-design processes and ensure community voices actively shape the governance of environmental resources.

Against this backdrop, the study used Participatory Budgeting (PB) and the Analytic Hierarchy Process (AHP) to prioritise the attributes of a training and mentoring programme for sustainable environmental management in the VBR. The VBR, as South Africa's largest UNESCO biosphere reserve, provides a compelling and contextually rich site for examining how participatory co-design methodologies can strengthen the capacity of environmental management projects while advancing inclusive rural development. Relative to existing participatory training frameworks, which typically emphasise either community consultation in programme design or technical competency transfer, this study contributes a structured co-design model that integrates democratic preference elicitation with consistency-tested multi-criteria prioritisation to translate beneficiary preferences into implementable programme priorities. This contribution is empirically grounded in the context of the Vhembe Biosphere Reserve, where a transdisciplinary participant composition comprising community beneficiaries, academic facilitators, and postgraduate co-facilitators demonstrates how participatory training design can be simultaneously inclusive, analytically rigorous, and contextually responsive. This paper is structured into 6 sections. Section 2 provides a conceptual framework encompassing co-design, biosphere reserves, and sustainable development; Section 3 outlines the research methodology; Section 4 presents the results; Section 5 discusses the results; Section 6 presents the conclusions, including methodological reflections, limitations, and directions for future development.

Research Questions

This paper addresses three research questions:

- RQ1—What key skills should be prioritized in the training and mentoring programme for Environmental Management Projects in the UNESCO Vhembe Biosphere Reserve?
- RQ2—What programme delivery approaches do project beneficiaries and their academic and postgraduate partners prefer?
- RQ3—How should competency attainment in a co-designed training and mentoring programme be assessed, and by whom?

2. Conceptual Framework

This study draws on an integrated conceptual framework that brings together four interrelated bodies of scholarship: co-design and knowledge co-production, participatory governance theory, training and mentoring as capacity-building instruments, and biosphere reserves as socio-ecological learning systems. Together, these frameworks provide theoretical scaffolding for understanding how participatory methodologies can be deployed to co-design effective capacity-building programmes within complex, resource-dependent conservation landscapes such as the Vhembe Biosphere Reserve.

2.1. Co-Design and Knowledge Co-Production

Co-design has emerged as both a methodological and epistemological response to the limitations of top-down approaches to socio-ecological governance. It refers to structured, iterative collaboration between researchers, practitioners, and end-users across all phases of a project, from problem definition and programme design through to implementation and evaluation [12,13]. Unlike conventional research models in which communities are treated as passive recipients of expert knowledge, co-design recognises that meaningful, durable solutions to complex challenges require the distributed agency of all stakeholders involved [14,15]. Contemporary frameworks emphasise iterative feedback loops, shared decision-making, and the integration of diverse knowledge systems, including indigenous and experiential knowledge, as constitutive elements of the design process rather than supplementary inputs.

Knowledge co-production extends this logic to governance, arguing that the legitimacy and contextual validity of sustainability interventions are directly contingent on the depth of stakeholder participation in knowledge generation [16]. Recent scholarship in participatory governance highlights that effective co-production requires transparency, early and meaningful stakeholder involvement, and structured facilitation to guard against elite capture and tokenistic participation [17]. This is particularly critical in rural biosphere reserve contexts, where power asymmetries between external experts and local communities are pronounced, and where the failure to integrate community knowledge has been repeatedly linked to poor project sustainability and limited local ownership [5,10].

2.2. Training and Mentoring as Instruments of Capacity-Building

Training and mentoring programmes are structured interventions designed to develop the technical, managerial, and social competencies necessary for effective project implementation and long-term sustainability [18,19]. In the context of environmental resource management, such programmes serve a dual function: they build individual and organisational capacity while simultaneously embedding knowledge within communities rather than externalising expertise to transient consultants or visiting researchers. This distinction is critical. Externally delivered training may generate short-term skill acquisition but rarely produces the adaptive capacity and institutional memory needed for lasting socio-ecological resilience [9].

Recent evidence demonstrates that mentorship, characterized by sustained, relational guidance between more experienced practitioners and emerging community leaders, enhances long-term project sustainability by fostering contextual learning, peer accountability, and the integration of indigenous knowledge [19]. In biosphere reserve settings, co-designed training and mentoring programmes are increasingly recognised as mechanisms for operationalising the adaptive governance principles underpinning UNESCO's Man and the Biosphere vision, thereby enabling communities to move from passive beneficiaries to active stewards of socio-ecological systems [5,6].

2.3. Participatory Budgeting and the Analytic Hierarchy Process in Sustainability Governance

The methodological contribution of this study lies in integrating two complementary decision-support tools: Participatory Budgeting (PB) and the Analytic Hierarchy Process (AHP). Participatory Budgeting is a democratic mechanism for prioritising resource allocation and programme attributes through structured stakeholder deliberation [20,21]. By enabling participants to rank and assign weight to competing programme elements, PB enhances the legitimacy, fairness, and community ownership of governance decisions [22]. Its strength lies in its democratic character; it ensures that prioritisation reflects the preferences of those most affected by the outcomes, rather than those with the most institutional power.

However, PB alone does not resolve inconsistencies in preference aggregation or guarantee stability in participatory rankings. The Analytic Hierarchy Process (AHP) [23] addresses this limitation by providing a structured multi-criteria decision-making framework that decomposes complex decisions into hierarchical judgments, tests for internal consistency, and reduces ambiguity in the ranking of alternatives. Its application in environmental and sustainability governance has confirmed its utility in validating participatory outputs and enhancing analytical rigour [17,24]. When integrated with PB, AHP produces a hybrid decision-support model that preserves the democratic legitimacy of participatory processes while introducing the methodological rigour necessary to translate community preferences into actionable, defensible programme priorities. Recent methodological scholarship increasingly advocates for such hybrid frameworks as best practice in complex sustainability decision-making contexts [16,22].

2.4. Biosphere Reserves as Socio-Ecological Learning Systems

Biosphere reserves, designated under UNESCO's Man and the Biosphere (MAB) Programme, are structured around three complementary functions: conservation of biodiversity and landscapes; support for economic and human development that is socio-culturally and ecologically sustainable; and logistical support for demonstration projects, environmental education, and research [25]. This tripartite mandate makes biosphere reserves inherently suited to the kind of integrative, multi-stakeholder governance that co-design and participatory approaches require. In this sense, they are not merely protected areas but socio-ecological systems in which human communities are constitutive rather than external actors.

Recent literature increasingly frames biosphere reserves as transdisciplinary knowledge systems, sites where scientific knowledge, policy imperatives, and indigenous ecological wisdom converge to support adaptive governance, resilience-building, and sustainability learning [5,26]. However, it has been cautioned that the transformative potential of biosphere reserves is frequently constrained by structural and institutional limitations, including insufficient community participation, weak governance frameworks, and inadequate capacity-building infrastructure [6,9]. The VBR, as South Africa's largest biosphere reserve and part of the global UNESCO MAB network, represents a critical case for examining how participatory co-design can overcome these constraints by generating capacity-building interventions that are simultaneously responsive to local socio-economic realities and aligned with global sustainability frameworks, including the SDGs and the Convention on Biological Diversity.

Taken together, these four conceptual pillars form a coherent theoretical architecture for this study: co-design and knowledge co-production establish the epistemological foundation; training and mentoring provide the programmatic vehicle; PB and AHP constitute the methodological toolkit; and the biosphere reserve framework situates the inquiry within a globally recognized system of sustainability governance.

3. Materials and Methods

3.1. Study Area

This study was conducted in the Vhembe Biosphere Reserve, located in Limpopo Province, South Africa (Figure 1). Designated by UNESCO under the MAB Programme in 2009, the VBR is the largest of South Africa's 10 biosphere reserves, covering 30,701 km^2 [25]. It lies within the Savanna (Bushveld) biome, with pockets of grassland and forest, and encompasses ecologically significant landscapes, including the Soutpansberg and Blouberg mountain ranges, the Mapungubwe World Heritage Site, and the Kruger National Park, which together constitute the core conservation areas of the reserve [27]. The VBR supports a population of approximately 1.5 million people, of whom 97% reside in rural areas [28].

Agriculture and tourism are the primary livelihood activities, while 66% of households rely on firewood as their main fuel source [27]. High unemployment and limited economic opportunities characterise much of the reserve, making sustainable natural resource management critical for rural livelihoods. The VBR's combination of rich biodiversity, World Heritage status, socio-economic vulnerability, and active GEF SGP-funded community projects makes it an appropriate site for investigating the co-design of mentoring and training programmes to sustain rural livelihoods [5].

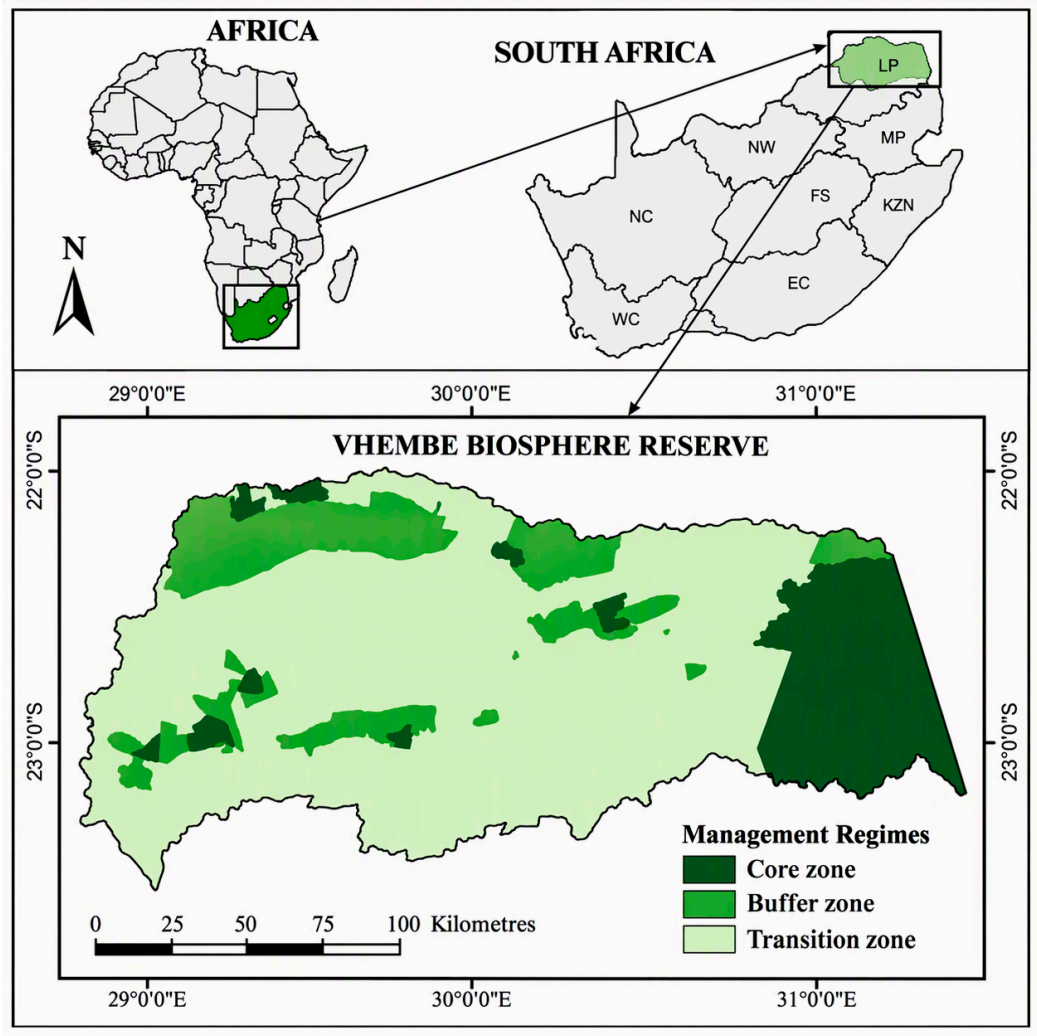


Figure 1. Location of the Vhembe Biosphere Reserve in Limpopo Province, South Africa (Adapted from [29]).

3.2. Research Design and Epistemological Positioning

This study employed a sequential exploratory mixed-methods design grounded in engaged scholarship. A qualitative phase (reflection circles) generated the programme factors, which were then prioritised quantitatively using PB and AHP. This integrated approach positions universities as active partners in the co-production of knowledge with communities, rather than as external observers [11]. This epistemological orientation aligns with participatory co-production methodologies in sustainability science, which hold that knowledge generated with affected communities is more contextually valid, more likely to be adopted, and more effective at producing lasting change than knowledge imposed from outside [5]. The research was structured around a three-phase process for the co-design of a training and mentoring programme for environmental management projects in the VBR, as summarised in Figure 2.

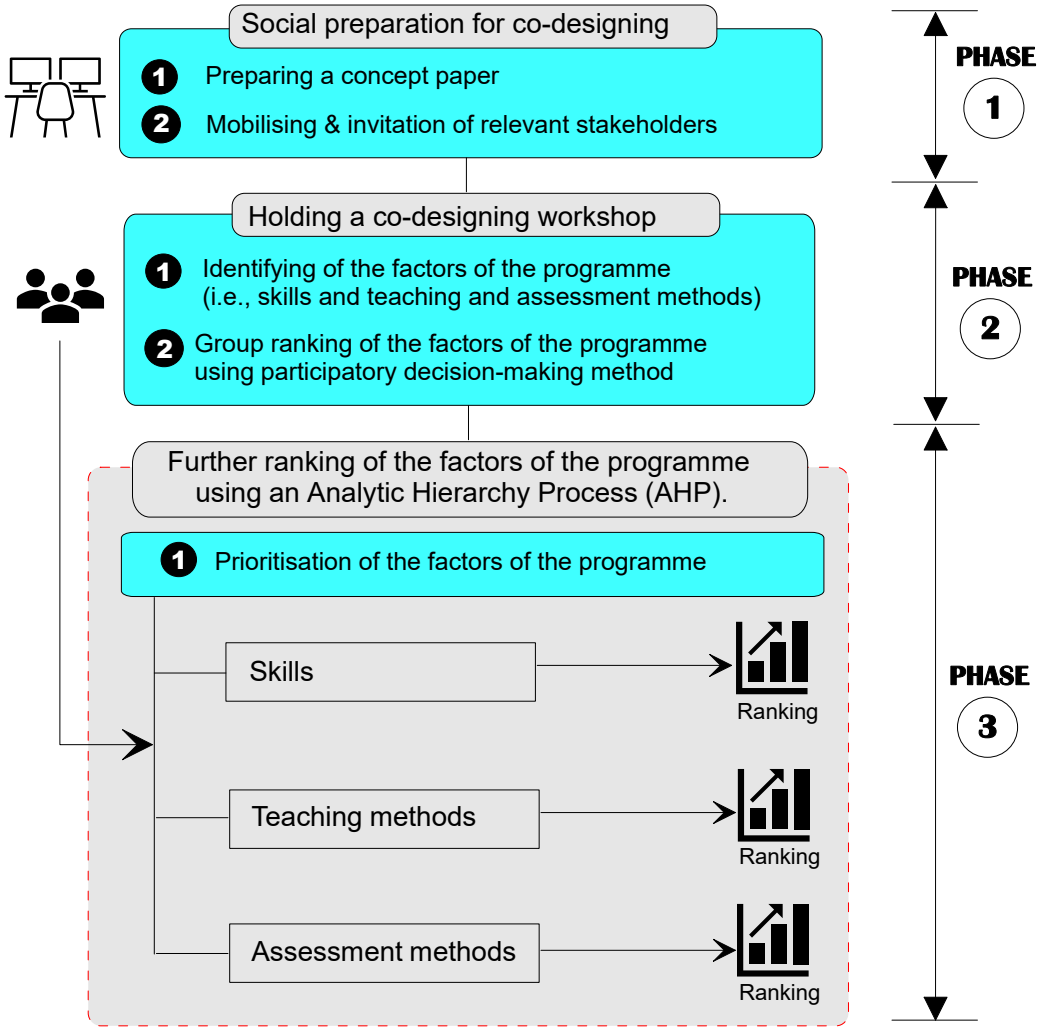


Figure 2. The three-phase procedure for the co-design of a training and mentoring programme for environmental management projects in the VBR. Note: Cyan = the participatory/qualitative phases (Phase 1 and Phase 2); Grey = the analytical/quantitative phase (Phase 3), Red dashed border = the AHP validation component within Phase 3.

3.3. Participant Selection and Sampling

Purposive sampling was employed to identify participants with direct experience of, and a substantive stake in, environmental management projects within the VBR. A total of 32 members were drawn from twelve environmental management projects funded by the Global Environment Facility Small Grants Programme (GEF-SGP) (Table 1). Of the 32 participants, 18 were female, while 14 were male. Twenty-four were adults, with eight young people. Most of the participants (n = 27) held leadership or coordination roles in different environmental management projects in the VBR. Added to this were five academics and three postgraduate students from the University of Venda (UNIVEN) who served as workshop facilitators and co-facilitators. This composition reflects the transdisciplinary intent of the study: GEF-SGP project members contributed lived experience and indigenous ecological knowledge; academics provided disciplinary expertise and methodological facilitation; and postgraduate students served as trained co-facilitators, bridging the academic and community registers.

The selection of participants from twelve GEF-SGP projects ensured diversity of environmental management contexts, spanning agriculture, aquaponics, renewable energy, wildlife conservation, and environmental education, thereby enhancing the breadth and transferability of the co-designed programme.

Table 1. Demographic characteristics of participants (n = 32).

Characteristics	Category	*n*	%
Gender	Female	18	56.3
	Male	14	43.7
Age group	Youth	8	25
	Adult	24	75
Project role	Office-bearers or coordinators	27	84.4
	Ordinary member or volunteer	5	15.6

3.4. Data Collection Methods and Techniques

Data were collected during a structured, two-day, single-session intensive co-design workshop held at a local lodge in Thulamela Local Municipality, facilitated under the theme "Developing a Training and Mentoring Programme for GEF-SGP Funded Projects". The 32 community participants were organized into four reflection circles of eight members each, deliberately composed to prevent elite capture and ensure representation across project types and community backgrounds [20]. Five senior academic staff from UNIVEN served as lead facilitators in each reflection circle, supported by three trained postgraduate students as co-facilitators.

The reflection circle was adopted as the primary data collection structure based on established learning cycle models [30,31], both of which define reflection as an iterative process in which individuals critically analyse their experiences, extract meaning, and apply new insights to future action. Embedding the reflection cycle into the co-design process encouraged participants to connect training content to real-life contexts, critically process their project management experiences, and develop actionable strategies grounded in community ownership, all of which are essential for sustaining effective environmental management initiatives [31].

A semi-structured interview guide framed the deliberations in each reflection circle around three core questions: (a) Which groups of people require the relevant skills and competencies? (b) What approaches to programme delivery are preferred? (c) How should competency attainment be assessed? While the questions were presented in English, deliberations were conducted primarily in Tshivenda and Xitsonga, the participants' vernacular languages, to ensure inclusive, effective communication and minimise language-based barriers to participation. Upon reaching consensus within each circle, a chairperson and scribe were appointed to capture responses on flipcharts. An audio recorder was used to document all deliberations after obtaining participants' consent. Given that deliberations were conducted primarily in Tshivenda and Xitsonga, and to accommodate participants with varying literacy in written consent documentation, informed consent was obtained verbally from all participants. The consent script was read aloud to the participants and translated into Tshivenda and Xitsonga. The process was audio-recorded with participant permission. Following the reflection circles, scribes presented their groups' consolidated responses during a facilitated plenary session, after which all qualitative data were systematically recorded and stored for further analysis. As the purpose of this phase was to generate items for ranking, no thematic coding or qualitative analysis software was used, and the deliberations are not analysed as discourse in this paper.

3.5. Participatory Budgeting for Programme Prioritisation

Following the qualitative data collection phase, participants were requested to identify and rank the training needs, knowledge areas, teaching methods, and assessment approaches that should constitute the training and mentoring programme. To facilitate this ranking process, the study employed Participatory Budgeting (PB). In this study, seeds rather than money were used as symbolic tokens during the participatory ranking and

scoring exercise. This approach is consistent with participatory rural appraisal methods, which commonly employ locally available materials such as seeds, beans, pebbles, or stones to facilitate voting, ranking, and quantification of participants' preferences [32,33].

This democratic decision-making mechanism ensures the voices of primary beneficiaries are meaningfully represented in the development of programmes and policies [20]. Originally developed in Porto Alegre, Brazil, in 1989 to prioritise public services, PB has since been applied extensively in participatory planning and resource allocation across diverse governance contexts [34]. Its advantages include promoting democratic accountability, transparency, social justice, and community ownership in decision-making [35].

The PB exercise was conducted in four steps. First, the 32 participants were divided into four ranking groups, again carefully composed to minimise the risk of elite capture, a recognised limitation of PB processes [20]. Second, each group was allocated 50 seeds (equivalent to ZAR 50.00) for the identified programme factors drawn from a fixed total, with the preferred factors receiving the most seeds and the least preferred receiving the fewest. Third, a scribe recorded the seeds allocated to each factor, and facilitators checked that each group's total equaled 50. Fourth, the final relative weights were calculated using the mean weighting formula presented in Equation (1):

$$w_j = \frac{\left(\sum ix_{ij}\right)}{m} \quad (1)$$

where w_j is the mean relative weight of factor j, x_{ij} is the number of seeds/points allocated to factor j by ranking group i, and m is the number of ranking groups (m = 4).

Factors with equal mean weights were retained as tied in the PB ranking, and the tie was resolved at the AHP stage (Section 3.6). Because each group's allocation was a deliberate group decision and only four groups took part, no allocations were treated as outliers or excluded.

3.6. Analytic Hierarchy Process for Consistency Testing and Tie-Breaking

While PB provides an effective mechanism for capturing community preferences, it does not include a procedure for detecting inconsistencies in the resulting priorities, which can lead to ambiguous or unstable rankings in which multiple factors are ranked equally important. To address this limitation, the study applied the Analytic Hierarchy Process (AHP) as a second-stage validation and prioritisation tool. Generally, the AHP [23] is a widely used multi-criteria decision-making (MCDM) 354 framework that structures complex decisions into hierarchical comparisons, enabling the systematic quantification of relative preferences and the measurement and correction of inconsistencies [24].

In this study, AHP served as a tie-breaking and consistency-testing procedure applied to researcher-derived pairwise comparisons, translating the PB preference weights onto [23]'s nine-point scale (Table 2). This procedure does not constitute an independent validation of the PB rankings, since the pairwise judgments were not separately elicited from participants; rather, it provides a mathematically consistent re-expression of the same underlying preference data, whose principal contribution is to disambiguate factors that PB had scored as tied.

Table 2. Scale of relative importance used in the AHP pairwise comparisons [23].

Scale	Degree of Preference
1	Equally important
2, 4, 6, 8	Intermediate values between adjacent judgments
3	Moderately more important
5	Strongly important

Table 2. *Cont.*

Scale	Degree of Preference
7	Very strongly important
9	Extremely important

The constructed matrices were reciprocal and transitive: reciprocal matrices represent internally consistent judgments, while transitivity ensures that if Factor A is judged more important than Factor B and B as more important than C, then A is necessarily more important than C [24]. Consistency was assessed using the Consistency Ratio (*CR*), calculated as:

$$CR = \frac{CI}{RI} \tag{2}$$

where *CI* is the Consistency Index, measuring the degree of departure from perfect consistency, and *RI* is the Random Consistency Index for a matrix of the corresponding size. CI is derived from:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

where λ_{max} is the principal eigenvalue and n is the number of factors being compared. AHP results are considered acceptable when CR $\leq$ 0.10.

The CR values obtained across all factor matrices are presented in Figure 3. In this case, CR values are expressed as percentages to facilitate visual comparison across matrices of different sizes. The conventional acceptance threshold of CR $\leq$ 0.10 therefore corresponds to 10% on the figure's vertical axis, marked by a dashed reference line. Of the ten matrices tested, nine satisfied this threshold, with CR values ranging from 0.6% to 9.3% (equivalent to raw CR values of 0.006 to 0.093). The "methods and approaches for teaching" matrix was the sole exception, yielding a CR of 9.3% (equivalent to a raw CR of 0.093), which was still within the acceptable uncertainty level. Additional details on the established parameters for the AHP ranking calculations are presented in Table 3. It is important to note that the comparison of the CR values and the number of factors considered, shown in Figure 3, indicates that the CR values increased as the size of the comparison matrix increased, ranging from 0.6% for a matrix of 3 factors to 9.3% for a matrix of 16 factors. The detailed computations of the PB and AHP pairwise comparison matrices are presented in Appendix A (Tables A1–A23).

Table 3. Additional AHP parameters that were established during the ranking of the attributes of the programme.

Attributes	Criterion	*n*	λmax	CI	RI	CR
Skills	Managing Health and Safety	3	3.007	0.0035	0.58	0.6
	Environmental Management	4	4.032	0.0108	0.90	1.2
	Financial Management	8	8.414	0.0592	1.41	4.2
	Human Resource Management	4	4.046	0.0153	0.90	1.7
	Project Management	5	5.148	0.0370	1.12	3.3
	Strategic Leadership and Management Leadership for Sustainable Development	8	8.612	0.0874	1.41	6.2
	Basic research on strategic decision making	3	3.012	0.0058	0.58	1.0
	Indigenous knowledge and practices communication	10	11.032	0.1147	1.49	7.7
Assessment Method	Preferred Assessment Methods	9	9.904	0.1131	1.45	7.8
	Who Should Carry Out the Assessment?	4	4.027	0.0090	0.90	1.0
Teaching Method	Methods and Approaches for Teaching	16	18.219	0.1479	1.59	9.3

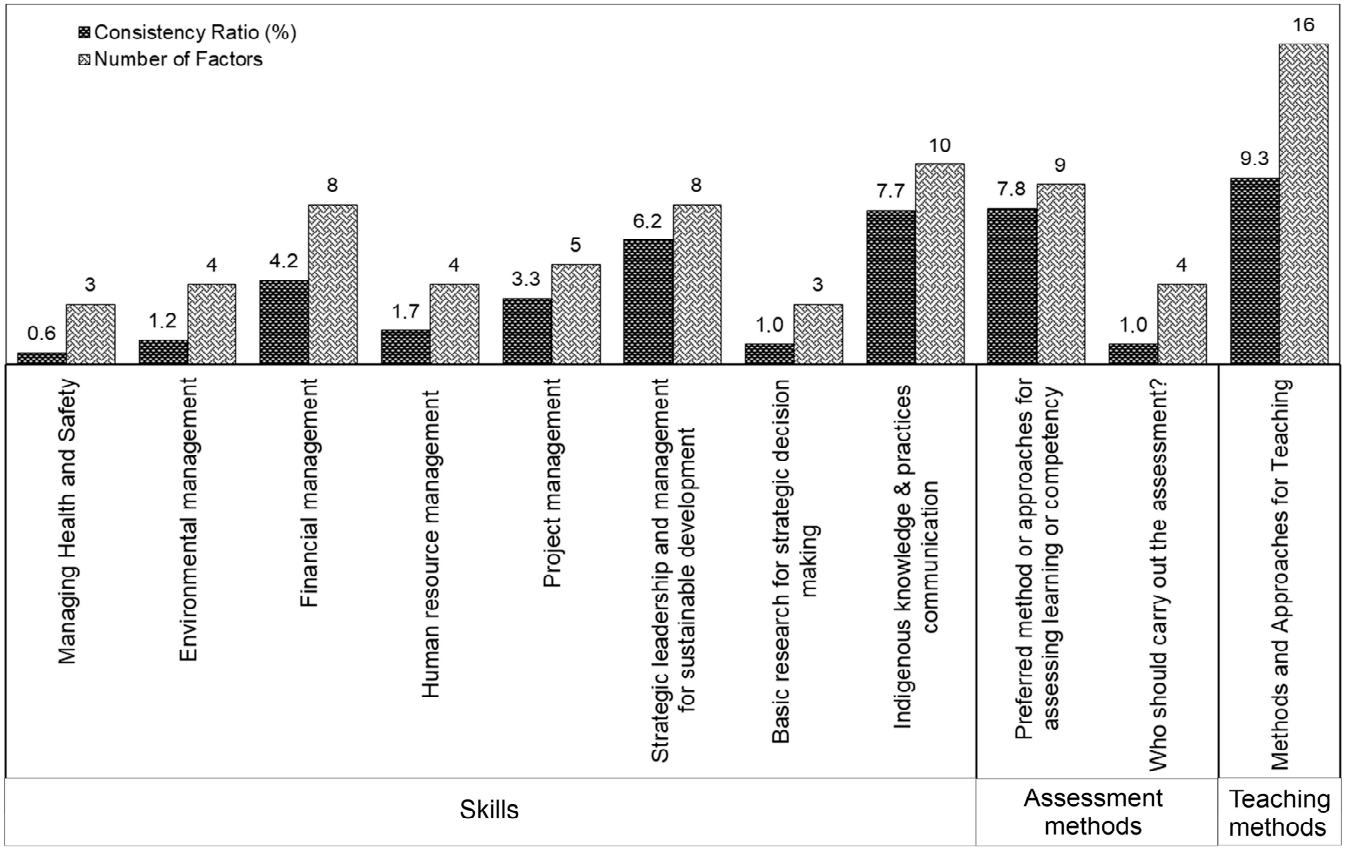


Figure 3. Obtained Consistency Ratio (CR) values and the corresponding number of evaluated factors.

4. Results

The co-design workshop yielded a comprehensive, structured set of outputs that collectively define the attributes of the training and mentoring programme for environmental management projects in the Vhembe Biosphere Reserve. Participants identified eight key knowledge areas, each with specific skills, as well as preferred teaching and assessment methods. All identified elements were subsequently ranked using both Participatory Budgeting and the Analytic Hierarchy Process. In this case, the Analytic Hierarchy Process (AHP) was used to address inconsistencies in participants' judgments that could not be easily accounted for or quantified using the Participatory Budgeting (PB) method. Therefore, the rankings generated by the two techniques are expected to be broadly consistent, though not directly comparable. The AHP is expected to produce more accurate and consistent rankings, informed by the priorities identified through the PB method. The results are presented graphically across three subsections: knowledge areas and priority skills, preferred teaching methods, and preferred assessment methods and assessors.

4.1. Knowledge Areas and Priority Skills

In response to RQ1, the co-design process identified the stakeholder groups requiring training and mentoring support as the 32 community-based participants from twelve GEF-SGP-funded environmental management projects in the VBR, spanning agriculture, aquaponics, renewable energy, wildlife conservation, and environmental education. These participants identified 8 knowledge areas and 45 associated skills as the competency domains requiring training and mentoring support. The specific skills prioritized within each knowledge area are presented in Table 4, and their relative rankings are shown in Figure 4a,b.

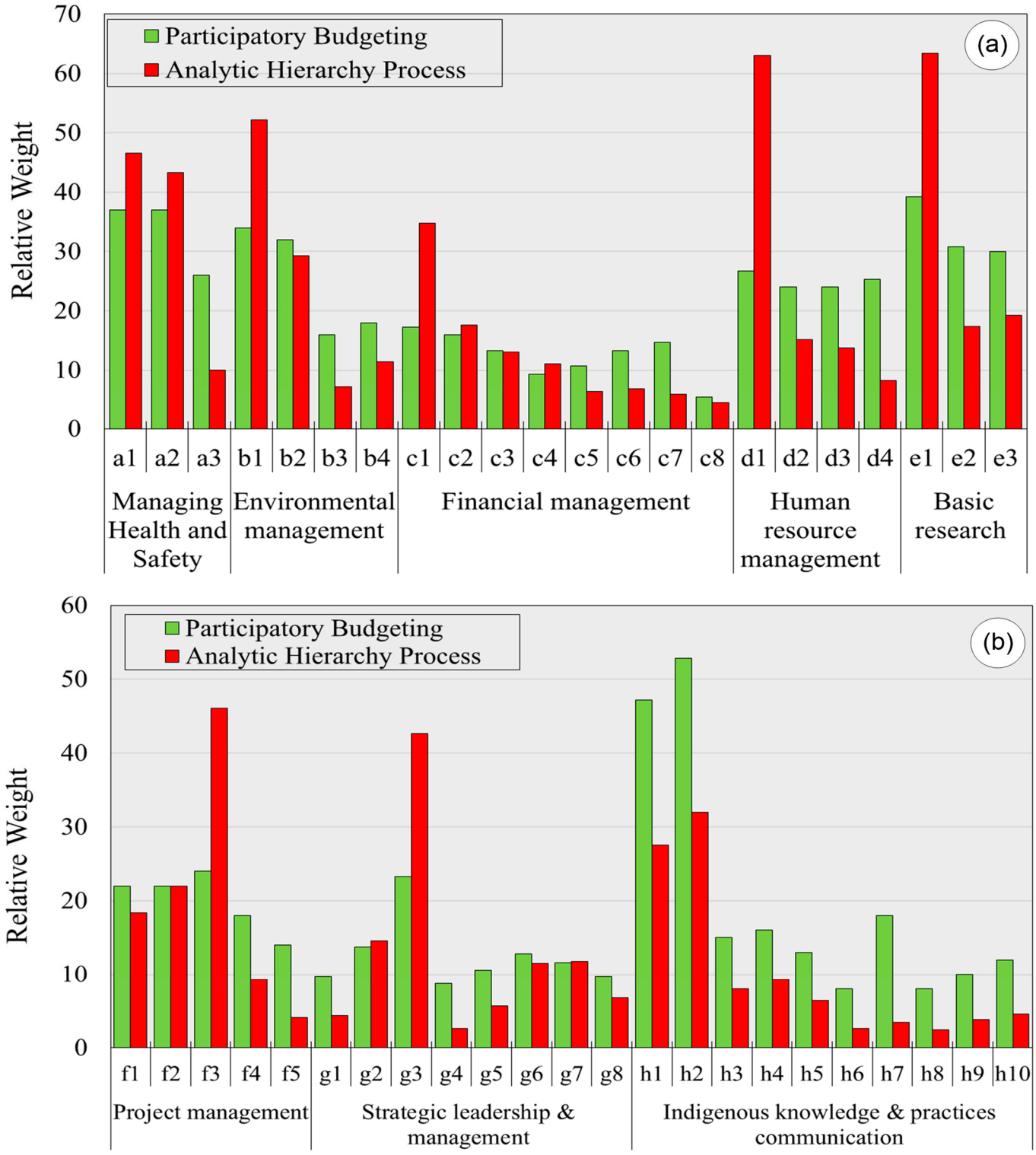


Figure 4. (**a**) Ranking of skills for the training and mentoring programme across knowledge areas A–D (symbols as defined in Table 3). (**b**) Ranking of skills for the training and mentoring programme across knowledge areas E–H (symbols as defined in Table 3).

The identified skills were subsequently ranked using PB and validated using AHP, as not all skills can receive equal emphasis within a finite programme. Figure 4a,b present the ranked priority of skills across all eight knowledge areas. A key methodological distinction emerged between the two ranking techniques: because PB lacks an internal mechanism to control inconsistency in participants' judgments, it assigned equal weight to certain skills

within a knowledge area. The AHP resolved these ties by applying pairwise comparison matrices, producing a consistent and differentiated ordering of skill priorities.

Table 4. Knowledge areas and associated skill sets required for the sustainable management of environmental management projects in the Vhembe Biosphere Reserve.

Knowledge Area	Symbol	Specific Skills
Managing Health and Safety	a_1	Legislated occupational health and safety requirements
	a_2	First aid
	a_3	Personal hygiene
Environmental Management	b_1	Sustaining the health of the environment
	b_2	Waste management
	b_3	Recycling
	b_4	Harnessing renewable energy
Financial Management	c_1	Financial planning
	c_2	Creating budgets
	c_3	Fundraising
	c_4	Smart investment decision-making
	c_5	Assessing cash flow (basic accounting)
	c_6	Analysis of financial statements (income statement, balance sheet, cash flow)
	c_7	Financial reporting
	c_8	Managing tax
Human Resource Management	d_1	Policies, systems, and procedures
	d_2	Skills auditing and development
	d_3	Performance management
	d_4	Governance and conflict resolution in the workplace
Basic Research for Strategic Decision-Making	e_1	Understanding research
	e_2	Planning and executing studies
	e_3	Application of research results in project implementation
Project Management	f_1	Introduction to project management
	f_2	The rationale for professional project management
	f_3	The project management process
	f_4	Effective marketing
	f_5	Risk management
Strategic Leadership and Management for Sustainable Development	g_1	Distinguishing effective from ineffective leadership and management
	g_2	Strategic thinking and planning
	g_3	Governance (terms of reference, committee structures, and key practical elements)
	g_4	Developing a culture of competence
	g_5	Building meaningful working relationships
	g_6	Team building and teamwork
	g_7	Problem-solving, crisis management, and conflict resolution
	g_8	Nurturing effective leadership for improved project performance
Indigenous Knowledge and Communication	h_1	Cultural norms, traditions, and protocols
	h_2	Indigenous knowledge systems
	h_3	Digital, social, and political factors influencing 21st-century communication
	h_4	Effective communication for sustainable interpersonal relationships and leadership
	h_5	Report writing
	h_6	Public speaking and presenting to diverse audiences
	h_7	Writing a fundable proposal
	h_8	Active listening
	h_9	Social interaction and interpersonal relations
	h_{10}	Harnessing the power of social media for project enhancement

The AHP weights are generally larger and more dispersed than the PB weights (Figures 4–6). This difference arises from the distinct measurement scales of the two methods rather than from disagreement in the underlying preferences. PB weights are a linear, additive allocation of a fixed number of seeds, averaged across four ranking groups, which compresses differences between factors. AHP weights are derived from the principal eigenvector of pairwise comparison matrices on Saaty's nine-point ratio scale, so a modest

difference in PB scores is re-expressed as a multiplicative importance ratio, and direct and indirect comparisons compound in favour of the leading factors. Because the pairwise judgments were derived from the PB weights, the two sets of weights are not independent estimates; the differences are largest where PB scored factors as tied or near-tied (e.g., d1–d4 and e1–e3), which is precisely where AHP was applied to differentiate them. Where PB scores were already differentiated, the two methods converged (e.g., c3, c4, g6, g7, C5–C7). The rank order, rather than the absolute magnitude of the weights, is therefore the basis for interpreting programme priorities.

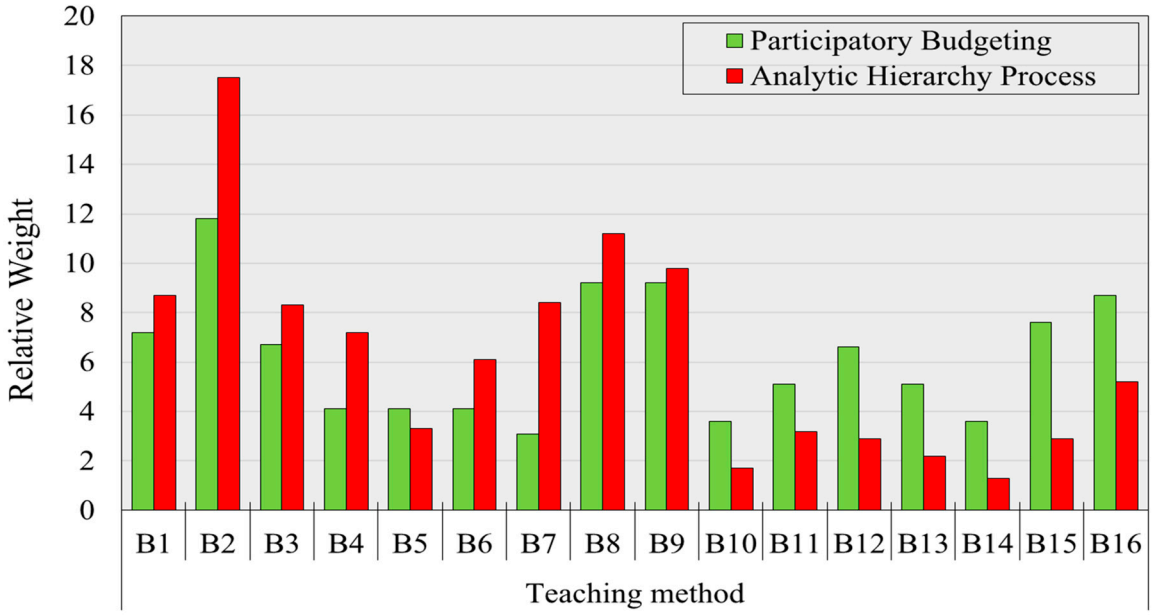


Figure 5. Ranking of teaching methods for the training and mentoring programme (symbols as defined in Table 3).

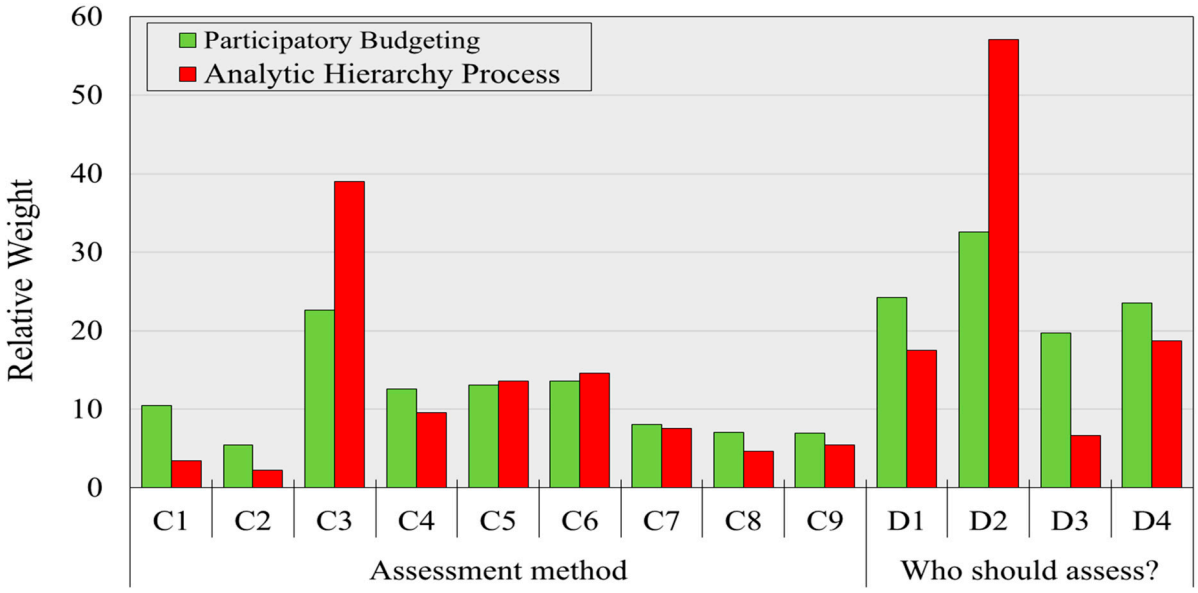


Figure 6. Ranking assessment methods and preferred assessors for the training and mentoring programme (symbols as defined in Table 4).

A representative example of AHP's resolving power is observed in the Health and Safety knowledge area, where PB ranked a_1 (legislated occupational health and safety requirements)

and a_2 (first aid) as equally important. The AHP pairwise comparison, conducted at a Consistency Ratio (CR) of 0.06, well within the acceptable threshold of ≤ 0.10, established that a_1 was marginally but consistently more important than a_2. A comparable pattern was observed in the Project Management knowledge area, where PB assigned equal weight to f_1 (introduction to project management) and f_2 (the rationale for professional project management). In contrast, AHP differentiated between them in favour of f_1.

Across all eight knowledge areas, the AHP identified the following as the highest-priority skills for the programme: a_1 (legislated occupational health and safety requirement); b_1 (sustaining the health of the environment); c_1 (financial planning); d_1 (policies, systems, and procedures); e_1 (understanding research); f_3 (the project management process); g_3 (governance, developing terms of reference and establishing committees); and h_2 (indigenous knowledge systems). It is important to note that the AHP rankings did not contradict the PB results but rather refined them: since AHP scoring was anchored in the PB preference weights, the two methods produced complementary outputs that together reflect both the democratic preferences of the participants and the analytical rigour required for programme design.

4.2. Preferred Teaching Methods

Participants ranked sixteen possible teaching methods (Table 5) using PB, and AHP subsequently validated the results. Figure 5 presents the combined rankings. The three preferred teaching methods, consistent across both PB and AHP, were: B2 (workshops or seminars), ranked first; B8 (practical demonstration), ranked second; and B9 (on-the-job training, learning by doing), ranked third. This preference pattern reflects a strong participant orientation toward active, experiential, and context-embedded learning over passive, lecture-based instruction, a finding consistent with the situated learning needs of rural environmental management practitioners [31].

Table 5. Teaching methods identified and ranked by participants.

Symbol	Teaching Method
B1	Lectures
B2	Workshops or seminars
B3	Exposure visits or placement
B4	Radio talk shows or lessons
B5	E-learning
B6	Group projects
B7	Individual projects
B8	Practical demonstration
B9	On-the-job training (learning by doing)
B10	Guests and experts (elders with wisdom)
B11	Competitions (debates, essays, posters)
B12	Peer teaching or demonstration
B13	Use of electronic materials (e.g., videos)
B14	Experiential storytelling
B15	Mentoring and coaching
B16	Awareness campaigns and exhibitions

The preference for workshops and seminars as the primary delivery mode aligns well with the co-design philosophy underpinning the programme: it positions learning as a collective, deliberative process rather than an individual, didactic one. Practical demonstration and on-the-job training further reinforce the primacy of experiential knowledge, which resonates with the indigenous knowledge and community wisdom that participants identified as central to sustainable environmental management in the VBR context.

4.3. Preferred Assessment Methods and Assessors

Participants ranked nine assessment methods and four assessor types (Table 6) using the same PB and AHP procedure. The results of both ranking methods, presented in Figure 6, were consistent and identified the following as the three preferred assessment approaches, in descending order of priority: C3 (practical reports), C5 (group projects), and C6 (group competitions). Notably, these top three assessment methods align closely with the top three teaching methods identified in Section 4.2, suggesting an internally coherent participant vision of a programme anchored in practical, collaborative, and demonstrable competency development rather than rote knowledge recall.

Table 6. Assessment methods and preferred assessors for the training and mentoring programme.

Symbol	Aspect	Method/Assessor
C1–C9	Assessment methods	
C1		Test (closed book)
C2		Test (open book)
C3		Practical reports
C4		Individual project
C5		Group project
C6		Group competition
C7		Experiential storytelling
C8		Electronic assessment tools
C9		Portfolio of evidence
D1–D4	Who should assess?	
D1		Peers
D2		Experts from tertiary institutions
D3		Experts from grassroots communities
D4		A combination of the above

Regarding the individuals best suited to conduct assessments, both PB and AHP consistently identified D2 (experts from tertiary institutions) as the preferred assessors, with D1 (peer assessment) ranking second. This finding underscores the value participants place on credentialled, external validation of competencies, possibly reflecting the importance of formal recognition for career and project funding purposes while also affirming the role of peer-based accountability in sustaining learning communities within the biosphere reserve. The convergence of PB and AHP rankings across all three aspects of the programme reflects the internal mathematical consistency of the AHP re-expression of the PB data, rather than independent corroboration between two separately derived data sources, since the two rankings are related by construction (see Section 3.6).

5. Discussion

The results of this study advance understanding of how participatory co-design can be operationalised as a structured governance mechanism for capacity-building in biosphere reserve contexts. Four interrelated themes emerge from the findings: the methodological contribution of the PB–AHP hybrid model; the epistemological significance of participants' learning preferences; the systems-oriented nature of the prioritised skill set; and the implications of hybrid legitimacy structures for biosphere reserve governance. Each is discussed in turn, with reference to the broader sustainability science and participatory governance literature.

5.1. Co-Design as a Structured Governance Mechanism: Beyond Symbolic Participation

This finding is interpreted through the lens of co-design and knowledge co-production theory, which holds that the legitimacy and contextual validity of sustainability interventions depend on the depth of stakeholder participation in knowledge generation rather than

on consultation alone. The findings demonstrate that co-design in the VBR context functions not merely as a consultative exercise but as a structured socio-technical governance process through which community knowledge is systematically translated into institutional priorities. This distinction is theoretically significant. Empirical studies across the UNESCO World Network of Biosphere Reserves have consistently shown that participatory processes frequently fail to influence actual decision outcomes due to weak prioritisation mechanisms, the absence of analytical validation tools, and susceptibility to elite capture [17,36,37]. The approach adopted in this study responds directly to these limitations.

By integrating Participatory Budgeting (PB) with the Analytic Hierarchy Process (AHP), the study introduces a PB-AHP refinement and tie-breaking framework that advances beyond consultation toward operationalised co-production [5], a process in which stakeholder preferences are not merely recorded but systematically refined, tested for consistency, and translated into implementable programme priorities. PB contributes democratic legitimacy and collective preference formation, ensuring that the voices of primary beneficiaries shape the programme architecture. AHP introduces mathematical consistency and ranking precision, resolving the ambiguities and equal-weight inflation that PB alone cannot address. Together, the two methods constitute an emerging hybrid governance innovation that bridges deliberative democracy and multi-criteria decision analysis, a combination increasingly advocated in sustainability decision-making literature [9,16,22].

5.2. Experiential Learning Preferences and Epistemological Alignment

The interpretation of these findings draws on training and mentoring as capacity-building instruments, thereby distinguishing externally delivered training from co-designed programmes that embed knowledge within communities and foster adaptive capacity. The strong preference for workshops and seminars, practical demonstration, and on-the-job training as the primary modes of programme delivery reflects more than a pragmatic orientation toward skills acquisition. It signals a deeper epistemological alignment between participants' learning preferences and the situated, relational, and practice-oriented knowledge traditions of African indigenous learning systems, in which knowledge is understood as embedded in experience and social context rather than abstracted into formal, classroom-bound instruction [38]. This finding resonates with experiential learning theory [31], which positions concrete experience and active experimentation as the most generative sites of adult learning, particularly in applied governance and resource management contexts.

This epistemological alignment has important implications for programme design. It suggests that effective capacity-building in rural biosphere reserve settings cannot be achieved through conventional training models that privilege formal instruction over participatory, place-based learning. Recent comparative evidence from Southern African biosphere reserves confirms that place-based and community-anchored learning significantly improves stakeholder engagement, knowledge retention, and long-term implementation effectiveness [26,39]. These patterns are consistent with the articulation of biosphere reserves as learning landscapes for sustainability transformation [8], sites where experiential learning and transdisciplinary knowledge exchange are not supplementary features but constitutive functions of the reserve's governance identity [6].

5.3. Integrated Skill Prioritisation and Systems-Oriented Capacity Building

This pattern is interpreted through the biosphere reserves as a socio-ecological learning systems framework, positioning biosphere reserves as transdisciplinary knowledge systems in which scientific, policy, and indigenous knowledge converge to support adaptive governance and sustainability learning. The prioritisation of environmental health

management, financial planning, governance, project management, and research literacy as the highest-order competencies reflects a sophisticated, systems-oriented understanding of what effective environmental project management in the VBR requires. Rather than calling for isolated technical skills, participants identified an integrated competency bundle that spans ecological, institutional, financial, and knowledge-management domains. This system's perspective is consistent with sustainability science literature, which argues that environmental governance in socio-ecological systems requires transdisciplinary competency frameworks rather than siloed disciplinary training [3,40].

The VBR findings are not unique in this regard. Comparable patterns have been documented across the global network of UNESCO biosphere reserves: in Pendjari (Benin), effective reserve governance has been shown to require the integration of ecosystem services knowledge with institutional governance capacity; in European biosphere reserves, transdisciplinary training has been linked to improved policy implementation; and in Latin American contexts, co-produced knowledge systems have been associated with enhanced adaptive capacity under climate change [6,41]. The convergence of these international findings with the VBR results suggests that the VBR is not an isolated case but reflects a structural pattern of capacity deficit and co-design response that is common across biosphere reserves in the Global South contexts characterised by high ecological value, constrained institutional resources, and rural communities whose livelihoods are directly dependent on the health of socio-ecological systems.

5.4. Assessment Preferences and the Architecture of Social Learning

These findings are interpreted through the lens of participatory governance theory, which emphasises that effective co-production requires structured facilitation and transparent decision-making to guard against elite capture and to ensure that community preferences influence actual governance outcomes. The preference for practical reports, group projects, and group competitions as the most appropriate assessment methods and the close alignment of these preferences with the top-ranked teaching methods reveal an internally coherent participant vision of the program. Participants conceptualise both learning and its validation as fundamentally collective, applied, and real-world processes. This orientation reflects a shift from individualised competency testing toward what has been described as social learning systems [36] in which knowledge is validated through collaborative problem-solving and authentic task performance rather than decontextualised examination.

This preference structure is theoretically significant because it supports broader calls for authentic assessment frameworks in sustainability education that simulate actual project dynamics, enhance peer accountability, and generate competency evidence that is meaningful within the operational contexts participants inhabit [42]. The preference for tertiary institution experts as the primary assessors, followed by peers, further illuminates the hybrid epistemic legitimacy structure that operates within the VBR community. Participants simultaneously value formal, credentialled validation, which may be important for project funding, reporting, and career recognition, and peer-based knowledge validation, which reflects the relational and communal character of learning in indigenous and community-based contexts [11]. This hybrid legitimacy architecture, in which scientific authority and experiential knowledge are jointly recognized as valid sources of assessment, is increasingly identified as a hallmark of effective boundary-spanning institutions such as universities embedded in biosphere reserves [5].

5.5. Theoretical and Methodological Contributions

Considered collectively, the findings of this study advance scholarship across three intersecting theoretical domains. First, in co-production theory, the study demonstrates how

structured co-design enhances not only the legitimacy of programme outputs but also their implementability by embedding community preferences within a decision architecture that produces clear, actionable, and defensible priorities. Second, in participatory governance theory, the study shows that PB alone, while democratically valuable, requires analytical reinforcement to move from consultation to influence over decisions; the AHP integration addresses this gap by introducing consistency-tested rankings that transform preference data into governance-grade outputs. Third, in sustainability transitions theory, the study confirms that biosphere reserves can function as transdisciplinary governance laboratories when universities serve as boundary organisations that facilitate structured knowledge co-production rather than unilaterally delivering expertise.

Methodologically, the PB–AHP hybrid model constitutes a replicable decision-support framework that bridges qualitative participatory engagement with quantitative ranking validation. It responds to recent calls in environmental governance research for approaches that integrate deliberative democracy with analytical decision tools, reduce bias and inconsistency in participatory prioritisation, and produce transparent, auditable co-design systems [17,36]. Critically, the model demonstrates that participatory processes can be simultaneously inclusive and mathematically robust, directly addressing a long-standing tension in participatory environmental planning between the democratic imperative of broad inclusion and the analytical requirement of coherent, consistent outputs [9]. This innovation has direct relevance for sustainability governance contexts beyond the VBR, wherever structured participation is required to produce defensible, community-endorsed programme designs.

While the combination of Participatory Budgeting and the Analytic Hierarchy Process has been applied to public budget allocation and project prioritisation contexts, this study advances the methodology in three distinct ways. First, it applies the PB–AHP hybrid model to the design of a capacity-building programme within a biosphere reserve, shifting the model's function from resource allocation to competency framework co-design. Second, it employs a transdisciplinary participant composition spanning community project beneficiaries, academic facilitators, and postgraduate co-facilitators, thereby operationalising the knowledge co-production ideal that biosphere reserves are expected to embody. Third, it demonstrates how the hybrid model can serve as a governance mechanism for translating community preferences into implementable institutional priorities, thereby addressing the persistent gap between participatory ideals and decision-making influence in biosphere reserve governance.

6. Conclusions

6.1. Key Conclusions

This study shows that a training and mentoring programme for environmental management projects in the VBR can be co-designed with its intended beneficiaries to yield ranked, defensible priorities rather than a loose list of wishes. The priorities that emerged point to a systems-oriented view of capacity, in which technical, financial, governance, and knowledge-management competencies are developed together; to experiential, collective learning; and to a hybrid view of legitimacy in which academic credentialing and peer validation both count. More broadly, the study shows that structured decision tools can move participatory processes beyond consultation toward outputs that can be inspected, reproduced, and defended, which is this paper's main conceptual contribution to co-production and participatory governance scholarship. These findings suggest several practical implications. However, these implications should be viewed in relation to co-design outcomes rather than as direct evidence of the prerequisites for implementation.

The findings have the potential to advance the institutionalisation of structured co-design in biosphere reserve management, promote the incorporation of participatory decision-support tools into national biodiversity and rural development policy frameworks, and encourage universities within biosphere reserves to move beyond outreach activities towards more structured co-production approaches [11].

For community-based project implementers and their funders, the competency framework offers a starting point for programming, capacity-building investment, and monitoring of skills development. These implications require further evaluation in relation to their feasibility and the institutional conditions necessary for implementation, including programme costs, governance barriers, policy alignment, and the roles of funders and local authorities, all of which were beyond the scope of this study.

6.2. Methodological Reflections

The application of the sequential design highlighted three key methodological issues.

First, using the reflection circles only to generate items kept the qualitative phase focused. It allowed participants to express their needs in Tshivenda and Xitsonga, but the plenary consolidation may have favoured convergent over divergent views, and the deliberations themselves were not analysed. Second, the PB exercise, which relies on symbolic seeds rather than numerical scoring, is designed to be accessible to participants with varied literacy levels. However, it compressed differences among factors, and with only four ranking groups, a single group's allocation could noticeably shift the means. Third, AHP resolved the ties produced by PB and tested the internal consistency of the rankings, with all consistency ratios below the 10% threshold. However, consistency ratios increased with the number of factors, reaching 9.3% for the sixteen teaching methods, suggesting that long lists should be clustered or shortened before pairwise comparison.

The AHP stage also warrants caution. Because the pairwise judgments were derived from the PB weights rather than elicited separately from participants, AHP served as a consistency and tie-breaking layer rather than as an independent second estimate, and its ratio scale magnified differences in the PB scores. The rank order is therefore the robust output of the hybrid model, whereas the absolute weights are not directly comparable between the two methods. Eliciting direct pairwise comparisons from participants would provide a stronger test, although the burden grows quickly with list size (120 comparisons for sixteen factors).

6.3. Limitations

This study is not without limitations. The findings are drawn from a single biosphere reserve context and a single two-day workshop, which constrains transferability and does not permit assessment of whether the co-designed priorities remain stable or are adopted beyond the workshop setting; no pilot implementation or post-workshop follow-up validation with participants was undertaken. Deliberations were conducted in Tshivenda and Xitsonga and subsequently recorded and consolidated in English. At the same time, this supported inclusive participation; no formal translation protocol (e.g., independent back-translation) was applied, and some nuance may have been lost. Participants were drawn from GEF-SGP-funded projects and were, to some extent, self-selected, which may not represent the full diversity of environmental management initiatives in the VBR.

This paper reports on the quantitative prioritisation component of a larger mixed-methods study; the reflection-circle deliberations generated the items for ranking and were not analysed interpretively. The study also did not assess the practical feasibility of implementing the co-designed programme: programme costs, governance barriers, alignment with national and local policy, and the roles of funders and local authorities were not investigated, nor was any data collected on these topics.

6.4. Future Development

Future work can develop the approach in four directions. First, comparative applications across biosphere reserves with different socio-ecological profiles and levels of institutional capacity would test transferability. Second, eliciting direct pairwise comparisons from participants and testing alternative mappings from PB scores to the Saaty scale would establish the robustness of the weights. Third, a pilot delivery of the programme, with post-workshop member checking and a feasibility and costing study involving funders, local government, and university partners, would demonstrate whether the prioritised content can be delivered and sustained, and longitudinal designs could assess its effect on project performance. Fourth, digital PB–AHP tools could enable broader and more continuous participation, and an interpretive analysis of the reflection-circle deliberations, reported separately, could explain the reasoning behind participants' priorities.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Venda (FSEA/25/IRD/04/1109), 12 September 2025.

Informed Consent Statement: Verbal informed consent was obtained from each participant to accommodate varying levels of literacy and potential challenges associated with written consent documentation.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author for ethical reasons.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AHP	Analytic Hierarchy Process
CR	Consistency Ratio
CI	Consistency Index
GEF-SGP	Global Environment Facility Small Grants Programme
MAB	Man and Biosphere
MCDM	Multi-criteria decision-making framework
PB	Participatory Budgeting
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNIVEN	University of Venda

Appendix A

Table A1. PB analysis results for managing health and safety.

No	Managing Health and Safety	Average Score	Ranking Groups			
			G1	G2	G3	G4
1	Legislated occupational health and safety requirements	37.0	10	10	9	8
2	First aid	37.0	9	9	9	10
3	Personal hygiene	26.0	6	6	7	7
	Total	100	25	25	25	25

Table A2. PB analysis results for environmental management.

No	Environmental Management	Average Score	Ranking Groups			
			G1	G2	G3	G4
1	Sustaining the health of the environment	34.0	8	9	9	8
2	Waste management	32.0	7	13	6	6
3	Recycling	16.0	6	2	5	3
4	Harnessing renewable energy	18.0	4	1	5	8
	Total	100	25	25	25	25

Table A3. PB analysis results for financial management.

No	Financial Management	Average Score	Ranking Groups			
			G1	G2	G3	G4
1	Financial planning	17.3	4	4	5	4
2	Creating budgets	16.0	5	3	4	3
3	Fundraising	13.3	6	3	1	3
4	Smart investment decision-making	9.3	2	4	1	4
5	Assessing cash flow (basic accounting)	10.7	2	2	4	2
6	Understanding and analysis of financial statements: income statement, balance sheet, and cash flow analysis	13.3	2	3	5	3
7	Financial reporting	14.7	3	4	4	4
8	Managing tax	5.3	1	2	1	2
	Total	100	25	25	25	25

Table A4. PB analysis results for human resource management.

No	Human Resource Management	Average Score	Ranking Groups			
			G1	G2	G3	G4
1	Policies, systems, and procedures	26.7	7	6	7	7
2	Skills auditing and development	24.0	7	5	6	6
3	Performance management	24.0	6	6	6	6
4	Governance and conflict procedures in the workplace	25.3	5	8	6	6
	Total	100	25	25	25	25

Table A5. PB analysis for basic research for strategic decision-making.

No	Basic Research for Strategic Decision-Making	Average Score	Ranking Groups			
			G1	G2	G3	G4
1	Understanding research	39.2	10	9	9	10
2	Dirtying our hands: Planning and executing studies	30.8	9	6	8	7
3	Application of research results in project implementation	30.0	6	7	8	8
	Total	100	25	22	25	25

Table A6. PB analysis results for project management.

No	Project Management	Average Score	Ranking Groups			
			G1	G2	G3	G4
1	What is project management?	22.0	6	5	5	5
2	Why manage projects professionally?	22.0	5	6	6	6
3	The project management process	24.0	7	5	5	5
4	Effective marketing	18.0	4	5	5	5
5	Risk management	14.0	3	4	4	4
	Total	100	25	25	25	25

Table A7. PB analysis results for strategic leadership and management for sustainable development.

No	Strategic Leadership and Management for Sustainable Development	Average Score	Ranking Groups			
			G1	G2	G3	G4
1	Distinguishing good and bad leaders and managers	9.7	3	3	2	2
2	Strategic thinking and planning	13.7	4	3	4	3
3	Governance (developing terms of reference and establishing committees; key practical elements)	23.3	6	6	5	7
4	Developing a culture of competence	8.7	2	3	1	3
5	Building meaningful work	10.6	1	3	3	4
6	Team building and teamwork	12.8	5	2	4	2
7	Problem solving (including crisis management and dealing with conflicts)	11.6	2	2	4	4
8	Nurturing effective leadership for improved project performance	9.7	2	4	2	2
	Total	100.	25	26	25	27

Table A8. PB analysis results for methods and approaches for teaching.

Methods and Approaches for Teaching	Average Score	Ranking Groups			
		G1	G2	G3	G4
Lecturers	7.2	4	2	5	3
Workshop or seminars	11.8	9	4	4	6
Exposure visits or placement	6.7	2	4	3	4
Radio talk shows or lessons	4.1	1	2	2	3
e-Learning	4.1	1	1	4	2
Group project	4.1	1	1	2	4
Individual project	3.1	1	1	1	3
Practical demonstration	9.2	5	8	3	2
On-the-job training (learning by doing)	9.2	3	7	6	2
Guests/experts (elders with wisdom)	3.6	1	2	2	2
Competition (e.g., debates, essays, posters, etc.)	5.1	2	2	3	3
Peer teaching or demonstration	6.6	4	3	4	2
Use of electronic materials (e.g., videos)	5.1	1	5	2	2
Experiential storytelling	3.6	1	1	2	3
Mentoring and coaching	7.6	6	2	5	2
Awareness campaign and exhibition	8.7	7	4	2	4
Total	99.8	49	49	50	47

Table A9. PB analysis results for the preferred method or approaches for assessing learning or competency.

Preferred Method or Approaches for Assessing Learning or Competency	Average Score	Ranking Groups			
		G1	G2	G3	G4
Test (closed book)	10.5	1	6	2	3
Test (open book)	5.5	1	1	2	3
Practical	22.6	6	9	4	7
Individual project	12.6	4	1	4	7
Group project	13.1	5	1	4	6
Group competing	13.6	2	3	5	7
Experiential storytelling	8.1	2	1	2	6
Electronic assessment tools	7.1	1	1	2	6
Portfolio of evidence	7.0	3	2	0	4
Total	100	25	25	25	49

Table A10. PB analysis results for communication.

Communication	Average Score	Ranking Groups			
		G1	G2	G3	G4
Digital, social, and political factors influencing communication in the 21st century	15.0	4	3	5	3
Effective communication in building sustainable interpersonal relationships and exemplary leadership	16.0	3	3	4	6
Report writing	13.0	3	5	2	3
Presenting in public to diverse audiences	8.0	1	3	2	2
Writing a fundable proposal	18.0	6	4	3	5
Active listening	8.0	2	2	2	2
Social interaction or interpersonal relations	10.0	2	2	4	2
Harnessing the power of social media for enhancing	12.0	4	3	3	2
Total	100	25	25	25	25

Table A11. PB analysis results for Indigenous knowledge and practices.

Indigenous Knowledge and Practices	Average Score	Ranking Groups			
		G1	G2	G3	G4
Cultural norms, traditions, and protocols	47.2	13	9	13	12
Indigenous knowledge system	52.8	12	15	12	11
Total	100	25	24	25	23

Table A12. PB analysis results on who should carry out the assessment.

Who Should Carry Out the Assessment?	Average Score	Ranking Groups			
		G1	G2	G3	G4
Peers	24.2	7	4	7	7
Experts from tertiary institutions	32.6	7	8	7	7
Experts from grassroots communities	19.7	5	4	5	4
A combination of the above	23.5	3	8	3	4
Total	100	22	24	22	22

Table A13. Pairwise comparison matrix of managing health and safety skills.

Criteria	a1	a2	a3	Weight (%)
a1	1.00	1.08	4.66	46.6
a2	0.93	1.00	4.33	43.3
a3	0.22	0.23	1.00	10.0

Table A14. Pairwise comparison matrix of environmental management skills.

Criteria	b1	b2	b3	b4	Weight (%)
b1	1.00	2.00	7.00	5.00	53.2
b2	0.50	1.00	4.00	3.00	28.8
b3	0.14	0.25	1.00	0.50	6.8
b4	0.20	0.33	2.00	1.00	11.2

Table A15. Pairwise comparison matrix of financial management skills.

Criteria	c1	c2	c3	c4	c5	c6	c7	c8	Weight (%)
c1	1.00	1.98	2.66	3.14	5.52	5.04	6.00	7.91	34.8
c2	0.51	1.00	1.34	1.59	2.79	2.55	3.03	4.00	17.6
c3	0.38	0.74	1.00	1.18	2.08	1.90	2.26	2.98	13.1
c4	0.32	0.63	0.85	1.00	1.76	1.61	1.91	2.52	11.1
c5	0.18	0.36	0.48	0.57	1.00	0.91	1.09	1.43	6.3
c6	0.20	0.39	0.53	0.62	1.10	1.00	1.19	1.57	6.9
c7	0.17	0.33	0.44	0.52	0.84	0.84	1.00	1.32	5.8
c8	0.13	0.25	0.34	0.40	0.70	0.64	0.76	1.00	4.4

Table A16. Pairwise comparison matrix of human resource management skills.

Criteria	d1	d2	d3	d4	Weight (%)
d1	1.00	4.17	4.57	7.78	63.0
d2	0.24	1.00	1.09	1.86	15.1
d3	0.22	0.91	1.00	1.70	13.8
d4	0.13	0.54	0.59	1.00	8.1

Table A17. Pairwise comparison matrix of basic research skills for strategic decision-making.

Criteria	e1	e2	e3	Weight (%)
e1	1.000	3.644	3.302	63.4
e2	0.274	1.000	0.906	17.4
e3	0.303	1.103	1.000	19.2

Table A18. Pairwise comparison of project management skills.

Criterion	f1	f2	f3	f4	f5	Weight (%)
f1	1.00	1.00	0.33	2.00	5.00	19.2
f2	1.00	1.00	0.50	2.00	5.00	20.7
f3	3.00	2.00	1.00	5.00	9.00	46.2
f4	0.50	0.50	0.20	1.00	2.00	9.5
f5	0.20	0.20	0.11	0.50	1.00	4.4

Table A19. Pairwise comparison matrix of strategic leadership and management for sustainable development skills.

Criterion	g1	g2	g3	g4	g5	g6	g7	g8	Weight (%)
g1	3.00	1.00	0.20	5.62	2.56	1.27	1.24	2.15	4.4
g2	7.00	5.00	1.00	9.00	7.47	3.70	3.61	6.26	14.6
g3	0.59	0.18	0.11	1.00	0.46	0.23	0.22	0.38	42.6
g4	1.30	0.39	0.13	2.19	1.00	0.50	0.48	0.84	2.6
g5	2.61	0.79	0.27	4.42	2.00	1.00	0.97	1.69	5.7
g6	2.68	0.81	0.28	4.54	2.07	1.03	1.00	1.74	11.5
g7	1.55	0.47	0.16	2.62	1.19	0.59	0.57	1.00	11.8
g8	3.00	1.00	0.20	5.62	2.56	1.27	1.24	2.15	6.8

Table A20. Pairwise comparison matrix of indigenous knowledge and practices communication skills.

Criterion	h1	h2	h3	h4	h5	h6	h7	h8	h9	h10	Weight (%)
h1	1.00	0.86	3.44	2.96	4.30	10.58	8.09	11.46	7.24	5.98	27.5
h2	1.16	1.00	4.00	3.44	5.00	12.31	9.41	13.33	8.42	6.96	32.0
h3	0.29	0.25	1.00	0.86	1.25	3.08	2.35	3.33	2.11	1.74	8.0
h4	0.34	0.29	1.16	1.00	1.45	3.58	2.74	3.88	2.45	2.02	9.3
h5	0.23	0.20	0.80	0.69	1.00	2.46	1.88	2.67	1.68	1.39	6.4
h6	0.09	0.08	0.33	0.28	0.41	1.00	0.76	1.08	0.68	0.57	2.6
h7	0.12	0.11	0.43	0.37	0.53	1.31	1.00	1.42	0.89	0.74	3.4
h8	0.09	0.08	0.30	0.26	0.38	0.92	0.71	1.00	0.63	0.52	2.4
h9	0.14	0.12	0.48	0.41	0.59	1.46	1.12	1.58	1.00	0.83	3.8
h10	0.17	0.14	0.58	0.49	0.72	1.77	1.35	1.92	1.21	1.00	4.6

Table A21. Pairwise comparison matrix of who should conduct the assessment.

Criterion	D1	D2	D3	D4	Weight (%)
D1	1.00	0.31	2.61	0.94	17.5
D2	3.26	1.00	8.52	3.05	57.1
D3	0.38	0.12	1.00	0.36	6.7
D4	1.07	0.33	2.79	1.00	18.7

Table A22. Pairwise comparison matrix of teaching methods.

Criterion	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	Weight (%)
B1	1.00	0.27	1.79	1.35	0.84	0.67	1.92	0.87	1.16	5.03	5.97	2.13	4.79	15.75	3.52	1.69	8.70
B2	3.67	1.00	4.34	2.31	3.49	2.84	5.37	2.71	2.21	10.58	9.35	6.59	5.08	18.66	13.66	2.95	20.28
B3	0.56	0.23	1.00	1.65	2.78	1.12	0.59	0.95	1.37	7.99	0.78	3.32	6.36	4.74	1.42	3.72	7.66
B4	0.74	0.43	0.61	1.00	1.42	1.21	1.03	0.61	1.17	8.51	2.21	3.32	2.33	8.46	1.194	3.33	7.12
B5	1.18	0.29	0.36	0.70	1.00	0.83	0.27	0.16	0.17	1.52	0.77	0.87	0.95	2.68	2.14	0.22	3.08
B6	1.49	0.35	0.90	0.82	1.20	1.00	0.34	0.54	0.84	4.06	3.72	1.84	2.73	5.58	1.16	1.09	5.60
B7	0.52	0.19	1.71	0.97	3.73	2.92	1.00	0.52	1.08	4.84	1.17	2.98	5.48	3.55	6.51	2.85	8.22
B8	1.14	0.37	1.05	1.63	6.08	1.84	1.93	1.00	1.14	11.07	3.26	4.30	7.79	6.54	9.28	0.59	10.50
B9	0.86	0.45	0.73	0.85	5.77	1.19	0.93	0.88	1.00	16.84	7.68	9.76	4.60	3.93	1.19	0.61	9.34
B10	0.20	0.09	0.13	0.12	0.66	0.25	0.20	0.09	0.06	1.00	0.53	0.65	0.45	1.12	0.28	0.32	1.19
B11	0.17	0.11	1.27	0.45	1.31	0.27	0.85	0.31	0.13	1.89	1.00	1.23	1.15	1.56	0.87	0.78	2.96
B12	0.47	0.15	0.30	0.30	1.14	0.54	0.33	0.23	0.10	1.54	0.81	1.00	0.56	6.07	2.78	0.45	2.75
B13	0.21	0.20	0.16	0.43	1.05	0.36	0.18	0.13	0.22	2.23	0.87	1.79	1.00	1.82	1.32	0.12	2.14
B14	0.06	0.05	0.21	0.12	0.37	0.18	0.28	0.15	0.25	0.89	0.64	0.16	0.55	1.00	0.52	0.24	1.17
B15	0.28	0.07	0.70	0.84	0.47	0.86	0.15	0.10	0.84	3.53	1.145	0.36	0.75	1.93	1.00	0.49	2.76
B16	0.59	0.34	0.27	0.30	4.46	0.91	0.35	1.69	1.63	3.08	1.290	2.24	8.32	4.17	2.02	1.00	6.55

Table A23. Pairwise comparison matrix of assessment methods.

Criterion	C1	C2	C3	C4	C5	C6	C7	C8	C9	Weight (%)
C1	1.00	1.55	0.09	0.35	0.25	0.23	0.45	0.74	0.63	2.43
C2	0.65	1.00	0.06	0.23	0.16	0.15	0.29	0.48	0.41	1.57
C3	11.47	17.73	1.00	4.06	2.87	39.03	5.13	8.48	7.22	58.52
C4	2.82	4.36	0.25	1.00	0.71	0.66	1.26	2.09	1.78	6.85
C5	4.00	6.18	0.35	1.42	1.00	0.932	1.79	2.96	2.52	9.71
C6	4.29	6.64	0.03	1.52	1.07	1.00	1.92	3.17	2.70	8.36
C7	2.24	3.45	0.20	0.79	0.56	0.52	1.00	1.65	1.41	5.42
C8	1.35	2.09	0.12	0.48	0.34	0.32	0.60	1.00	0.85	3.28
C9	1.59	2.45	0.14	0.56	0.40	0.37	0.71	1.17	1.00	3.85

References

1. Amusa, T.O.; Avana-Tientcheu, M.L.; Awazi, N.P.; Chirwa, P.W. The Role of Non-Timber Forest Products for Sustainable Livelihoods in African Multifunctional Landscapes. In *Trees in a Sub-Saharan Multi-Functional Landscape: Research, Management, and Policy*; Springer Nature: Cham, Switzerland, 2024; pp. 153–178.
2. Sulla, V.; Zikhali, P.; Cuevas, P.F. *Inequality in Southern Africa: An Assessment of the Southern African Customs Union*; World Bank Group: Washington, DC, USA, 2022. Available online: http://documents.worldbank.org/curated/en/099125303072236903 (accessed on 26 March 2026).
3. Darwish, S.; Allen, R.R.; Lempke, M. Necessary complexity in the Anthropocene: New approaches in socio-ecological systems thinking, Do No Harm, and fragility integration. *Dev. Pract.* **2023**, *33*, 534–547. [CrossRef]
4. Pyšek, P.; Pergl, J.; Van Kleunen, M.; Dawson, W.; Essl, F.; Kreft, H.; Weigelt, P.; Wilson, J.R.; Winter, M.; Richardson, D.M. South Africa as a donor of naturalised and invasive plants to other parts of the world. *Biol. Invasions S. Afr.* **2020**, *14*, 759–784. [CrossRef]
5. Barraclough, A.M.D.; Reed, M.G.; Coetzer, K.; Price, M.F.; Schultz, L.; Moreira-Muñoz, A.; Måren, I.E. Global knowledge–action networks at the frontlines of sustainability: Insights from UNESCO Biosphere Reserves. *People Nat.* **2023**, *5*, 1430–1444. [CrossRef]
6. Thomsen, J.K.; Måren, I.E.; Cusens, J. Applying the ecosystem services framework in UNESCO's World Network of Biosphere Reserves: Lessons learned and ways forward. *Curr. Opin. Environ. Sustain.* **2025**, *75*, 101539. [CrossRef]
7. Avilés Irahola, D.; Mora-Motta, A.; Barbosa Pereira, A.; Bharati, L.; Biber-Freudenberger, L.; Petersheim, C.; Youkhana, E. Integrating scientific and local knowledge to address environmental conflicts: The role of academia. *Hum. Ecol.* **2022**, *50*, 911–923. [CrossRef]
8. UNESCO. *A Standard Framework for Biosphere Reserve Management Informed by Sustainability Science*; United Nations Educational, Scientific and Cultural Organization: Paris, France, 2024. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000373538 (accessed on 5 April 2026).
9. Sandström, C.; Laudon, H.; Mårtensson, L. Unlocking the potential of biosphere reserves: A review of structural, institutional, and ideational challenges to transformational learning. *Curr. Opin. Environ. Sustain.* **2025**, *75*, 101543. [CrossRef]
10. Cwele, F. Towards an Inclusive, Green Growth Path: A Review of South Africa's National Development Plan's Approach to Economic Growth. Master's Thesis, Stellenbosch University, Stellenbosch, South Africa, 2019.
11. O'Connor, R.A.; Nel, J.L.; Roux, D.J.; Leach, J.; Lim-Camacho, L.; Medvecky, F.; Raman, S. The role of environmental managers in knowledge co-production: Insights from two case studies. *Environ. Sci. Policy* **2021**, *116*, 188–195. [CrossRef]
12. Slattery, P.; Saeri, A.K.; Bragge, P. Research co-design in health: A rapid overview of reviews. *Health Res. Policy Syst.* **2020**, *18*, 17. [CrossRef]
13. TACSI. Unpacking Co-Design. Available online: https://tacsi.org.au/ (accessed on 25 May 2026).
14. Mushkani, R.; Berard, H.; Koseki, S. WeDesign: Generative AI-facilitated community consultations for urban public space design. *arXiv* **2025**, arXiv:2508.19256.
15. Mugari, E.; Nethengwe, N.S.; Gumbo, A.D. A co-design approach for stakeholder engagement and knowledge integration in flood risk management in Vhembe district, South Africa. *Front. Clim.* **2025**, *7*, 1517837. [CrossRef]
16. Sinare, H.; Coetzer, K.; Schultz, L. Participatory governance for people and nature in multifunctional landscapes—Insights from biosphere reserves. *Curr. Opin. Environ. Sustain.* **2025**, *77*, 101585. [CrossRef]
17. Korzenevica, M.; Njaggah, P.; Githu, I.; Matiru, V.; Matere, C. *Public Participation and Community Engagement in Domestic Water Supply Management in Kenya: Progress and Directions*; School of Geography and the Environment, University of Oxford: Oxford, UK, 2024. [CrossRef]
18. Karcher, M.J.; Kuperminc, G.P.; Portwood, S.G.; Sipe, C.L.; Taylor, A.S. Mentoring programs: A framework to inform program development, research, and evaluation. *J. Community Psychol.* **2006**, *34*, 709–725. [CrossRef]

19. Chukwu, O.A.; Nadigel, J.; Kasaai, B.; Boateng, R.; Glazier, R.H.; McMahon, M. Understanding the training, mentorship, and professional development priorities of early career embedded researchers. *Int. J. Health Plan. Manag.* **2024**, *39*, 1277–1297. [CrossRef]
20. Shah, A. Overview. In *Participatory Budgeting*; Shah, A., Ed.; Public Sector Governance and Accountability Series; The International Bank for Reconstruction and Development/The World Bank: Washington, DC, USA, 2007; pp. 1–10.
21. Aziz, H.; Shah, N. Participatory budgeting: Models and approaches. In *Pathways Between Social Science and Computational Social Science: Theories, Methods, and Interpretations*; Springer International Publishing: Cham, Switzerland, 2020; pp. 215–236.
22. Fairstein, R.; Benaède, G.; Gal, K. Participatory budgeting designs for the real world. In Proceedings of the 37th AAAI Conference on Artificial Intelligence, Washington, DC, USA, 7–14 February 2023; Volume 37, pp. 5633–5640.
23. Saaty, T.L. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*; McGraw-Hill: New York, NY, USA, 1980.
24. Musingwini, G.; Minnitt, R.C.A. Ranking the efficiency of selected platinum mining methods using the Analytic Hierarchy Process (AHP). In *Proceedings of the Third International Platinum Conference 'Platinum in Transformation', Sun City, South Africa, 5–9 October 2008*; The Southern African Institute of Mining and Metallurgy: Johannesburg, South Africa, 2008; pp. 319–326.
25. UNESCO. Biosphere Reserves in Africa, 2021. Available online: http://en.unesco.org/biosphere/africa (accessed on 24 May 2022).
26. Klaver, M.; Currie, B.; Sekonya, J.G.; Coetzer, K. Exploring the implementation of UNESCO's MAB program in South Africa: A case study of the Cape Winelands Biosphere Reserve. *Environ. Manag.* **2024**, *74*, 1207–1222. [CrossRef]
27. Gumbo, A.D.; Kapangaziwiri, E.; Mathivha, F.I. A systematic study site selection protocol to determine environmental flows in the headwater catchments of the Vhembe Biosphere Reserve. *Int. J. Environ. Res. Public Health* **2022**, *19*, 6259. [CrossRef]
28. Vhembe Biosphere Reserve (VBR), 2021. Available online: https://www.vhembebiosphere.org/ (accessed on 24 May 2025).
29. Jauro, T.I.; Tesfamichael, S.G.; Rampedi, I.T. Tracking conservation effectiveness in the Vhembe Biosphere Reserve in South Africa using Landsat imagery. *Environ. Monit. Assess.* **2020**, *192*, 469. [CrossRef]
30. Gibbs, G. *Learning by Doing: A Guide to Teaching and Learning Methods*; Oxford Centre for Staff and Learning Development; Oxford Brookes University: Oxford, UK, 2018.
31. Kolb, D.A. *Experiential Learning: Experience as the Source of Learning and Development*, 2nd ed.; Pearson: Upper Saddle River, NJ, USA, 2014.
32. Kumar, S. *Methods for Community Participation: A Complete Guide for Practitioners*; ITDG Publishing: London, UK, 2002.
33. Chambers, R. The origins and practice of participatory rural appraisal. *World Dev.* **1994**, *22*, 953–969. [CrossRef]
34. Bartocci, L.; Grossi, G.; Mauro, S.G.; Ebdon, C. The journey of participatory budgeting: A systematic literature review and future research directions. *Int. Rev. Adm. Sci.* **2023**, *89*, 757–774. [CrossRef]
35. Ibrahim, A.A.A.M. Guidelines for applying budgeting as a tool for participatory democracy in Egypt. In *The Sustainable City VII*; WIT Transactions on Ecology and the Environment; WIT Press: Southampton, UK, 2012; Volume 155, pp. 255–266.
36. Leguia-Cruz, M.; Cerda, C.; Ortiz-Cubillos, N.; Mansilla-Quiñones, P.; Moreira-Muñoz, A. Enhancing participatory governance in biosphere reserves through co-creation of transdisciplinary and intergenerational knowledge. *Front. Environ. Sci.* **2024**, *12*, 1266440. [CrossRef]
37. Koy, J.K.; Ngonga, A.M.M.; Wardell, D.A. Moving beyond the illusion of participation in biosphere reserve governance. *Nat. Conserv.* **2019**, *33*, 33–54. [CrossRef]
38. Dzimbiri, M.N.W. On Decolonizing Geography Education: Curriculum, Pedagogy, and the Production of Knowledge in Higher Education. Ph.D. Thesis, Miami University, Oxford, OH, USA, 2025.
39. Klaver, M.; Currie, B.; Sekonya, J.G.; Coetzer, K. Learning through place-based implementation of the UNESCO MAB program in South Africa's oldest biosphere reserve: A case study of the Kogelberg Biosphere Reserve. *Land* **2024**, *13*, 455. [CrossRef]
40. Cheruiyot, R.; Venter, R. Complex systems and sustainable leadership: Enhancing resilience and sustainability of community-based social enterprises in Soweto, South Africa. *Sustainability* **2024**, *16*, 8555. [CrossRef]
41. Palliwoda, J.; Fischer, J.; Felipe-Lucia, M.R.; Palomo, I.; Neugarten, R.; Büermann, A.; Price, M.F.; Torralba, M.; Eigenbrod, F.; Mitchell, M.G.E.; et al. Ecosystem service coproduction across the zones of biosphere reserves in Europe. *Ecosyst. People* **2021**, *17*, 491–506. [CrossRef]
42. Mbah, M.; Ajaps, S.; Moltha-Hill, P. A systematic review of the deployment of indigenous knowledge systems towards climate change adaptation in developing world contexts: Implications for climate change education. *Sustainability* **2021**, *13*, 4811. [CrossRef]

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