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Pedagogical adaptation of indigenous and non-indigenous species in Biology: experiences from teaching classification of living things in Tanzania

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Abstract. This study examined teachers' pedagogical strategies for adapting non-indigenous and indigenous species in teaching the classification of living things in Biology. The research was guided by connectivism learning theory. Questionnaires were administered to 63 biology teachers working in low- and high-biodiversity schools in Tanzania, complemented by interviews and classroom observations. Quantitative data were analyzed using descriptive statistics in Microsoft Excel and IBM SPSS (version 27), including percentages, means, and standard deviations, while qualitative data from interviews and classroom observations were analyzed thematically. The analysis revealed that the most frequently used strategies included the use of pictures and students' prior knowledge to help contextualize species. A moderate use was reported for teachers' personal experiences and storytelling. In contrast, technology-based strategies such as audio-visuals, virtual reality, and online applications were noticeably underused, despite their relevance in the digital age. Limited ICT skills and inadequate infrastructure were major contributors to this under-utilization. The study recommends ongoing professional development programs to enhance teachers' ability to use audio-visual tools, virtual reality, and online resources effectively.

Keywords: pedagogical adaptation, indigenous species, non-indigenous species, classification

1. Introduction

Teaching the classification of living things involves identifying, naming, and grouping organisms within diverse ecosystems [28]. Since species vary across geographical locations, teachers must adapt both indigenous and non-indigenous species in their instruction [26]. Variations in weather, soil, and ecological conditions influence the availability of species in different areas [7]. As a result, some species are accessible for teaching in one ecosystem but not in another. Adapting instruction to these ecological differences is crucial for supporting comprehension, curiosity, and critical thinking [13, 47]. Such adaptation helps teachers make effective use of both locally available and distant species. It also fosters respect for biodiversity and supports conservation awareness among students [65]. Thus, pedagogical adaptation plays an essential role in helping learners understand both local and global ecosystems beyond their immediate environments.

Knowledge of species identification, diversity, and extinction is important for sustaining life on Earth and advancing SDGs 14 and 15, which focus on marine and terrestrial ecosystems [68]. Using species from students' local environments enables learners to connect scientific concepts to real-world conservation challenges and address global biodiversity loss. It also contributes to advancements in agriculture and medicine, aligning with SDGs 2 and 3 [15, 21, 33]. Integrating familiar indigenous species additionally promotes inclusive and equitable education as envisioned in SDG 4, which values cultural diversity and ensures equal access to knowledge across ecological contexts [5]. This

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approach requires recognizing local biodiversity, incorporating traditional knowledge, and allowing students to use familiar languages to support understanding [31]. Teaching classification through locally grounded examples, therefore, supports global efforts toward sustainable development.

In Tanzania, the centralized Biology curriculum is implemented in all schools and monitored by TIE, NECTA, and SQA. While it emphasizes standardized species for teaching classification, it also allows teachers to supplement instruction with species from local and distant environments [52, 54]. Policies encourage integrating science, technology, and digital resources to enhance environmental understanding [69]. The National Curriculum Framework for Basic and Teacher Education (NCFBTE) further emphasizes ICT integration and community involvement to support holistic learning [63]. Government initiatives such as SEQUIP and SMASSE promote effective science teaching, ICT use, and learner-centred pedagogies [6, 19, 63]. Although using familiar species aligns instruction with students' experiences, some challenges persist, including limited instructional materials and reliance on species that do not reflect students' contexts [12, 14, 72].

These challenges have been observed to adversely affect students' learning outcomes, as evidenced by national assessment results. In Form II National Assessments (FTNA), performance in classification has consistently remained below NECTA's 65% satisfactory threshold, declining between 2019 and 2022 before improving in 2023 [51, 56, 58, 60, 62]. Form IV results show slightly better performance, though a decline from 66.22% to 59.86% has been recorded, with inadequate content knowledge identified as a major contributor [50, 55, 57, 59, 61]. These outcomes persist despite repeated exposure to the topic and the availability of diverse species that could support foundational learning before introducing non-indigenous species. Without addressing these issues, repetition alone may not lead to lasting academic improvement, potentially hindering progress toward SDGs related to biodiversity conservation, food security, health, and quality education [68]. Understanding how teachers adapt indigenous and non-indigenous species is therefore essential for mobilizing resources and strengthening capacity-building efforts.

Studies from other countries highlight the value of contextualized and localized instructional resources. Research in the Philippines emphasized the importance of using species familiar to students to enhance engagement and performance [43]. Similarly, findings from Turkey showed that indigenous species help make learning more relatable and improve conceptual understanding [65]. Additional studies in Uganda and Tanzania have documented the diversity of indigenous species available in local ecosystems [41, 49]. However, the strategies teachers use to integrate both indigenous and non-indigenous species into Biology classification lessons remain underexplored.

This study, therefore, investigates how teachers adapt indigenous and non-indigenous species when teaching classification in the biology curriculum, focusing on the strategies they employ and the challenges they encounter. The study is anchored in constructivist and connectivist perspectives. Constructivism emphasizes building new knowledge on students' prior experiences, highlighting the importance of using familiar indigenous species before introducing unfamiliar ones [36]. Connectivism underscores the role of digital and networked resources in broadening access to species beyond local contexts [46]. Together, these perspectives frame the need to understand how teachers adapt species to enhance comprehension, critical thinking, and global ecological awareness.

1.1. About the current study

Biology teachers in ordinary-level education in Tanzania are expected to use both locally available species and species from other ecosystems [52, 54]. The NCFBTE also requires ICT integration and community participation in teaching and learning [53]. Despite these provisions, students continue to struggle with learning classification [12]. Contributing factors include insufficient instructional materials [12, 72] and the use of species that do not relate to students' experiences [14]. National assessments also show performance levels ranging from poor to average, with inadequate knowledge frequently cited as a challenge [50, 51, 55–62]. This is notable given the rich biodiversity available in students' environments, which can be used alongside non-indigenous species, and the ongoing professional development programs such as SEQUIP and SMASSE that support ICT use and the

adaptation of instructional methods [6, 63].

Previous studies show that contextualizing learning resources and incorporating indigenous species enhances engagement, understanding, and environmental awareness [43, 65]. However, little is known about the strategies teachers use to integrate indigenous and non-indigenous species, or the challenges they encounter. This study, therefore, addresses this gap to support effective learning of classification and contribute to broader efforts toward achieving sustainable development goals.

1.2. Research questions

1. What pedagogical strategies do teachers use to integrate indigenous and non-indigenous species in teaching the classification of living things?
2. What challenges hinder teachers from integrating indigenous and non-indigenous species in teaching classification?

2. Literature review

2.1. Theoretical framework

Piaget's cognitive development theory posits that meaningful learning occurs when students integrate new information into their existing schemas through assimilation and accommodation, achieving cognitive equilibrium [30, 48]. Teachers facilitate this process through scaffolding, helping learners resolve cognitive conflict and reorganize their schemas to construct new knowledge [3, 38].

Complementing this view, Siemens' connectivism theory extends learning into the digital era by highlighting the role of technology, networks, and diverse information sources in enabling learners to link local and global knowledge [70]. Digital tools such as PlantNet, iNaturalist, virtual laboratories, and simulations support the study of both indigenous and non-indigenous species, enabling students to analyze, compare, and apply knowledge across multiple ecological contexts [9, 21, 71, 73].

Within this combined theoretical framework, teachers function as instructional adaptors who help students connect local experiences with global species knowledge, develop analytical and classification skills, and cultivate sustainable conservation practices. These roles support the alignment of classroom learning with broader environmental and sustainability goals.

2.2. Empirical literature review

Existing research highlights the importance of integrating indigenous knowledge, local species, and technology to strengthen science education, yet a notable gap persists. Studies conducted in Nepal and South Africa [10, 27, 65] show that teachers frequently use locally available materials, incorporate students' cultural and ecological experiences, and link science concepts to indigenous knowledge. These practices enhance relevance, comprehension, and environmental awareness. However, these studies primarily focus on knowledge systems rather than the pedagogical integration of actual species into classroom instruction.

Likewise, technology research enhanced teaching [9, 11, 18, 23, 67]. The research further demonstrates that virtual reality, mobile plant identification apps, iNaturalist, and digital imaging tools improve student engagement, species identification skills, and overall learning outcomes. Despite these benefits, technological barriers such as limited access, inadequate training, and infrastructure constraints remain challenges.

Across the reviewed studies, one critical gap becomes evident: no research has explicitly examined how teachers integrate both indigenous and non-indigenous species when teaching the classification of living things, particularly within the Tanzanian context. This gap underscores the need for targeted investigation into teachers' pedagogical strategies and the challenges they encounter in adapting species for instructional purposes.

3. Methods

3.1. Research approach and design

This study employed a mixed-methods approach using a convergent parallel design that combined phenomenography with a cross-sectional survey to provide a comprehensive understanding of instructional adaptation in teaching the classification of living things. Quantitative data were collected through questionnaires administered to biology teachers to explore their perceived strategies for integrating indigenous and non-indigenous species. These data enabled the calculation of descriptive statistics, including frequencies, means, and standard deviations.

Qualitative data were collected simultaneously through teacher interviews and classroom observations to capture lived experiences, challenges, and institutional support related to species integration. In the convergent parallel design, both data sets were collected independently and analyzed separately before being integrated during interpretation. The phenomenographic component facilitated exploration of teachers' varied conceptions and experiences, while the cross-sectional survey generated descriptive insights that phenomenography alone could not provide.

Overall, the mixed-methods design strengthened the study through triangulation and complementarity, offering a more holistic and nuanced understanding of instructional adaptation than either method could achieve independently.

3.2. Study location

This study was carried out in the Dodoma and Iringa Regions. Dodoma was chosen because it includes a district with relatively low species diversity [35], making it suitable for examining how teachers adapt their instruction in areas with limited biodiversity when teaching the classification of living organisms. In contrast, Iringa Region contains a district that forms part of the extensive Eastern Afromontane biodiversity hotspot, which supports a high number of species [16]. This provided an opportunity to explore teachers' instructional adaptation in a high-biodiversity environment. It is essential to compare the strategies used in these two contrasting contexts for understanding teachers' flexibility in adapting species examples. Such a comparison can also generate insights that can be applied across ecosystems with varying levels of biodiversity in Tanzanian secondary schools.

3.3. Sample size and sampling procedures

To investigate the pedagogical adaptation of indigenous and non-indigenous species in teaching the classification of living things in the biology curriculum, biology teachers were sampled through purposive and convenience sampling (table 1). Kanaki and Kalogiannakis [25] suggest that the use of clear sampling frameworks helps in obtaining a representative sample while reducing potential bias in the study and ensuring the reliability of study findings.

3.4. Data collection methods and instruments

3.4.1. Observation

Classroom observation was the primary data collection method because it enabled the researcher to capture actual classroom interactions and teaching practices. An observation guide was used to record strategies employed in integrating indigenous and non-indigenous species during classification lessons. The guide consisted of two sections: preliminary information and the main observation items. The preliminary section documented details such as observation number, date, district, class size, class level, subtopic, and teacher gender. The main section included items related to strategies for adapting indigenous and non-indigenous species.

As lessons progressed, the observer recorded teachers' activities using the guide for later analysis. The tool was digitized and uploaded to the Kobo Toolbox App, which facilitated the ranking and

Table 1
Sampling technique, sample Size, and data collection methods [29].

Sampling technique	Sample size	Data collection method	Distribution	Criteria
Purposive	63	Questionnaire	37 from low biodiversity areas, 26 from high biodiversity areas	Teachers eligible to participate in the study included all biology teachers currently teaching in the selected schools
Convenience sampling	20	Classroom observation	12 from a low biodiversity area, 8 from a high biodiversity area	Teachers were selected for classroom observation based on their availability and willingness to participate
Purposive sampling	8	Interview	4 from a low biodiversity area, 4 from a high biodiversity area	Teachers were selected based on their highest teaching experience

Key: A low biodiversity area means a habitat with low species richness. A high biodiversity area means a habitat with high species richness.

documentation of observed practices. Each item was rated on a scale from 0 to 2, where 0 indicated that a practice was not observed, 1 indicated occasional observation (once or twice), and 2 indicated frequent observation. Additional spaces were provided for comments and clarifications on partially or fully observed practices.

To maintain objectivity, the observer remained a non-participant throughout all classroom sessions. The observation guide, adapted from Kamati [24] and Jones [22], ensured validity and reliability in capturing instructional practices. Observations covered Form One to Form Four Biology classes, with each session lasting approximately 80 minutes. All observed lessons focused specifically on the classification of living things.

3.4.2. Interviews

Interviews were conducted to gather teachers' perspectives on the adaptation of indigenous and non-indigenous species when teaching classification topics. This method was selected because it supports deeper exploration of participants' experiences and allows clarification of questions where necessary [8]. Through prompting and explanation, the researcher ensured that participants clearly understood each question before responding.

A semi-structured interview guide was developed for this purpose and included one central question on species adaptation. The guide was adapted from Tupas [64] and Kamati [24]. During each interview, participants were given sufficient time to respond, allowing the researcher to obtain detailed and accurate information. Sessions ranged from 30 to 35 minutes. With participants' consent, interviews were audio-recorded to ensure accurate transcription and analysis.

3.4.3. Questionnaire survey

A questionnaire was used to collect data on biology teachers' perceptions of pedagogical strategies for integrating indigenous and non-indigenous species. This method was suitable for gathering information from 63 teachers across 20 schools. This helped to capture teachers' views on species integration at scale.

The questionnaire comprised two main sections, combining both open- and closed-ended questions. The first section captured demographic information, including education level, years of Biology teaching experience, duration of teaching in the respective district, gender, class taught, and training attended. The second section contained 24 items requiring teachers to indicate their level of agreement

on pedagogical adaptation practices using a five-point Likert scale: strongly disagree (SD), disagree (D), neutral (N), agree (A), and strongly agree (SA). The Likert scale items were adapted from Jones [22].

To improve the return rate and streamline data collection, the questionnaire was digitized and uploaded to the Kobo Toolbox App, enabling teachers to complete it using tablets or computers.

3.5. Trustworthiness of the study

Trustworthiness of the qualitative data was ensured through dependability, credibility, confirmability, and transferability. Dependability and confirmability were strengthened by maintaining a detailed audit trail documenting all research procedures, including school selection, sampling of teachers from low- and high-biodiversity districts, development of the observation protocol, and steps followed during data collection. This documentation provides a transparent account of how decisions were made and how findings were derived.

Credibility was enhanced through member checking; whereby participating teachers verified the accuracy of interpretations drawn from interview and observation data. Triangulation of data sources, specifically classroom observations and interviews, further improved credibility. Transferability was supported by providing rich descriptions of the 63 participating teachers, including their teaching experience and the biodiversity characteristics of the schools in Dodoma and Iringa Regions.

3.6. Data analysis methods

Quantitative data were analyzed using descriptive statistical procedures in Microsoft Excel and IBM SPSS (version 27). Percentages, means, and standard deviations were calculated to summarize teachers' perceptions of species integration strategies.

Qualitative data from interviews and classroom observations were analyzed thematically. The analysis followed the steps proposed by Ary et al. [1]: familiarization and organization, coding and reduction, and interpretation and representation. Data were first transcribed and then systematically coded. The codes were grouped into categories that were subsequently used to generate themes. A hybrid coding approach was applied, with codes emerging both deductively from the study's conceptual framework and inductively from the field data.

3.7. Ethical considerations

Ethical clearance was obtained from the University of Dodoma through the Institutional Research Review Ethics Committee (IRREC) under reference number MA.84/261/86/135, and research clearance was granted by the Vice Chancellor under reference numbers MA.84/261/86/133 and MA.84/261/86/134. These clearances were submitted to the Regional Administrative Secretaries (RASs) of Dodoma and Iringa Regions to secure permission to conduct the study. Subsequent permits were obtained from Dodoma City Council and Kilolo District Council, allowing access to schools.

School heads introduced the researcher to the biology teachers of their schools. Informed consent was obtained from all participants before data collection. The teachers were informed that their participation was voluntary and they could withdraw from the study at any time. This study values the importance of anonymity and accommodates a higher level of privacy and confidentiality for all conversations and data collected. Thus, all identifying information was removed to ensure that individual teachers could not be identified in the study. Gathered data was exclusively used for this study, and respect for the dignity of participants was prioritized and adhered. In this study, all sources of information were acknowledged through citing and referencing so as to avoid plagiarism. Also, the tools for data collection – observation guide, questionnaire, and interview guide – were attached to demonstrate that the findings are based on authentic field data rather than fabricated or falsified information. Adherence to ethical procedures prevents research misconduct in the study [37].

4. Findings

4.1. Pedagogical strategies for integrating indigenous and non-indigenous species

The study presents findings from classroom observations on strategies used to integrate indigenous and non-indigenous species when teaching the classification of living things. Results indicate that teachers employ a range of strategies, including leveraging students' prior knowledge, drawing on their own life experiences, inviting community experts, using real-life scenarios, introducing familiar species, and utilizing pictures. Table 2 indicates the usage of a variety of strategies across different biodiversity areas among biology teachers.

Table 2
Observed strategies for teachers' instructional adaptation [29].

Strategy	Area	Frequently observed	Occasionally observed	Not observed
Use of students' prior knowledge	High biodiversity	4 (50.0)	3 (37.5)	1 (12.5)
	Low biodiversity	1 (8.3)	6 (50.0)	5 (41.7)
Teachers' life experiences	High biodiversity	1 (12.5)	–	7 (87.5)
	Low biodiversity	1 (8.3)	–	11 (91.7)
Inviting community experts	High biodiversity	–	–	8 (100.0)
	Low biodiversity	–	–	12 (100.0)
Real-life scenarios	High biodiversity	–	1 (12.5)	7 (87.5)
	Low biodiversity	–	–	12 (100.0)
Bringing familiar species	High biodiversity	6 (75.0)	–	2 (25.0)
	Low biodiversity	3 (25.0)	2 (16.7)	7 (58.3)
Audio-visual materials	High biodiversity	–	–	8 (100.0)
	Low biodiversity	–	–	12 (100.0)
Virtual reality	High biodiversity	–	–	8 (100.0)
	Low biodiversity	–	–	12 (100.0)
Use of pictures	High biodiversity	1 (12.5)	–	7 (87.5)
	Low biodiversity	8 (66.7)	1 (8.3)	3 (25.0)
Online applications	High biodiversity	–	–	8 (100.0)
	Low biodiversity	–	–	12 (100.0)

Key: Frequently observed means observed more than three times. Occasionally observed means observed once or twice. Not observed means completely not observed.

The comparison between high- and low-biodiversity settings reveals that teachers adapt their instructional strategies according to the ecological richness of their environment. In high-biodiversity areas, teachers more frequently draw on locally available species and students' existing ecological knowledge, indicating that the surrounding environment serves as a natural resource for contextualized teaching. Conversely, in low-biodiversity areas, teachers rely primarily on visual aids such as pictures, likely due to limited access to local species for demonstration. The infrequent use of teachers' personal experiences and the absence of community experts in both settings suggest that these strategies remain underutilized, even where ecological resources are available. Similarly, the complete lack of technology-based strategies across contexts highlights systemic challenges in ICT access and integration. Table 3 provides examples illustrating how teachers operationalize these strategies in practice, depending on their environmental context.

The teachers also rated the strategies they perceive to use in integrating indigenous and non-indigenous species when teaching classification of living things. The findings indicated that teachers use strategies like students' prior knowledge, teachers' own experiences, inviting elders' experts

Table 3
Practices on integration of indigenous and non-indigenous species [29].

Strategy	Classroom practices
The use of pictures of species	**Example 1:** The teacher used form four students' books from the Tanzania Institute of Education (TIE) to show students the pictures of species found in the class Crustacea, such as prawn, crab, and lobster.
	Example 2: The teacher used the TIE students' book three to show students the picture of a pine plant and its reproductive parts, which are male and female cones.
	Example 3: The teacher used a picture of an animal species that underwent a histological section in explaining the triploblastic layers. Teacher 1: "We are triploblastic...our bodies are made up of three body layers...there is a picture I'm showing you here (The teacher uses the tablet to show a picture of dissected animalia species to show the triploblastic layers)...so how can you see these layers (A teacher then calls one student and uses him to demonstrate how the layers can be seen and then explains the arrangement as shown in a picture)."
Bringing familiar species	The teacher brought the most familiar species to be used in teaching the concepts of angiosperms. The teacher brought *Zea mays* (maize plants), *Sorghum bicolor* (sorghum), and *Hyparrhenia hirta* (thatch grasses) for teaching the concepts of monocotyledonous plants. The teacher also brought *Vigna unguiculata* (cowpea plants), *Hibiscus sabdariffa* (roselle), *Eucalyptus tereticornis* (eucalyptus leaves), *Helianthus giganteus* (sunflower plants), and *Amaranthus viridis* (African spinach) to be used in teaching the concepts of Dicotyledonae.
Students' prior knowledge	**Example 1:** Teacher: "You know the bean plant and its leaves. Which leaves resemble the bean leaves?" Students: "Mango plant leaves."
	Example 2: Teacher: "What are the other leaves that resemble maize leaves?" All students: "Sorghum leaves and millet leaves."
	Example 3: Teacher: "Do you know the lizard?" All students: "Yes." Teacher: "Have you ever seen it?" Students: "Yes." Teacher: "Where?" Students: "Behind the house, on the wall."
Teachers' life experiences	Teacher: "Some of the reptiles are useful. There are times I travel to different regions and find businessmen selling men's belts, wallets, and shoes made from crocodile skin. When you see these items are often seen as luxury products because crocodile leather is tough and stylish."
Real-life scenarios	The teacher used a real-life scenario to teach moss plants in the division Bryophyta. Teacher: "Agnes went to the forest to collect some firewood to use at home for cooking. While she was collecting the firewood, she came across a wet, fallen tree lying on the ground, covered all over with small green organisms. Curiously, Agnes leaned in and touched them; they felt soft and damp under her fingers. She had never seen anything like it before and wondered what these green things were and why they were growing on the wet tree. With many questions in her mind, she decided she would ask her biology teacher when she goes to school. Now, can you help Agnes identify what these green organisms might be, and explain why they are growing on the wet, fallen tree?"

of the community, real-life scenarios, bringing the most familiar species, audio-visual materials, virtual reality, pictures, and online applications. Table 4 indicates the frequency, mean, and standard deviation in each strategy.

The findings indicate that teachers use a variety of strategies to integrate indigenous and non-indigenous species in classification lessons. The most frequently employed approaches were activating students' prior knowledge and using pictures of species, both reported by over 95% of teachers.

Table 4
Perceived strategies for teachers' pedagogical adaptation.

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Average	Standard deviation
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)		
I use students' prior knowledge of species that exist in their environment.	34 (54)	26 (41.3)	–	3 (4.8)	–	4.4	0.7
I use my own life experiences through narrating stories about species that are found in their living environment, and unfamiliar species that do not exist in their environment.	26 (41.3)	23 (36.5)	–	7 (11.1)	7 (11.1)	3.9	1.4
I normally invite elders and community experts to share with students about the indigenous species present in their environment.	4 (6.3)	2 (3.2)	1 (1.6)	22 (34.9)	34 (54)	1.7	1.1
I use real-life scenarios to teach species found within students' environment and those found beyond it.	22 (34.9)	24 (38.1)	1 (1.6)	3 (4.8)	13 (20.6)	3.6	1.5
I normally bring the most familiar species and use them in teaching before introducing and teaching new, unfamiliar species to students.	26 (41.3)	19 (30.2)	2 (3.2)	2 (3.2)	14 (22.2)	3.7	1.6
I use audio-visual materials to display unfamiliar species that are found in other places in the world.	21 (33.3)	15 (23.8)	1 (1.6)	14 (22.2)	12 (19)	3.3	1.6
I use virtual reality to introduce species of the ecosystems that are not found within the students' local environment.	2 (3.2)	3 (4.8)	3 (4.8)	9 (14.3)	46 (73)	1.5	1.0
I use pictures of species to teach students in contexts where such species are not found within their local environment.	34 (54)	28 (44.4)	–	1 (1.6)	–	4.5	0.6
I use online applications like PlantNet and iNaturalist to help students assign scientific names to the indigenous and non-indigenous species.	9 (14.3)	11 (17.5)	4 (6.3)	8 (12.7)	31 (49.2)	2.3	1.6

Strategies such as drawing on teachers' life experiences, introducing familiar local species, and using real-life scenarios were moderately used. In contrast, technology-based approaches, including audio-

visual materials, online applications, and virtual reality, were among the least utilized. Community-based strategies, such as inviting elders or local experts, were also infrequently adopted.

4.2. Challenges that impede pedagogical adaptation of species

The qualitative findings reveal several factors that hinder teachers' efforts to integrate indigenous and non-indigenous species during classification lessons. These factors fall under four major themes: technology-related challenges, unavailability of teaching species, teacher-related challenges, and instructional pacing pressure. Each theme is supported by participants' quotations.

4.2.1. Technology-related challenges

Effective integration of species often relies on ICT tools for demonstrating organisms not found in the local environment. However, most schools in the study had inadequate facilities, unreliable electricity, and teachers with limited ICT skills. These factors made technology-based integration difficult. Teachers pointed to insufficient ICT equipment as a major barrier. One teacher from a low-biodiversity area reported:

> "In our school, we have only one projector. Sometimes I wish to show students crustacean species not found in their local environment, such as crabs, prawns and lobsters and explain to them the distinctive characteristics that place such species in one group, but it becomes difficult. If I decide to use a tablet instead of the projector, the lesson time becomes inadequate since I use only one tablet to move across the whole class. Therefore, we end up just watching the video without covering the actual content." – (Interview with teacher 6, 9th April 2025)

This experience illustrates how limited ICT resources disrupt lesson planning and discourage the use of visual aids. Teachers also noted electricity shortages as a major obstacle to accessing and presenting digital materials. As one teacher explained:

> "When we want to use species that are outside the school environment, and or those located far away, a lack of electricity becomes a challenge. It is known that, through electricity, we can use various ICT facilities like computers and projectors, but also it can be used to access the internet for downloading pictures and videos of species to show the students. Lacking electricity in our school hinders use from accessing such materials, which becomes a setback in species learning." – (Interview with teacher 5, 9th April 2025)

Such infrastructural challenges limit teachers' ability to use technology to contextualize non-indigenous species, forcing them to rely heavily on locally available organisms.

4.2.2. Unavailability of teaching species

Scarcity of certain species, particularly in low-biodiversity areas, also hindered integration. Teachers from these areas struggled to obtain the skills required in the curriculum. For example, pine (*Pinus roxburghii*), needed for teaching coniferophytes, is rarely found in Dodoma. One teacher noted:

> "... in Dodoma, pine trees are very rare; they are found just in selected gardens." – (Interview with teacher 1, 24th March 2025)

Similarly, hibiscus (*Hibiscus rosa-sinensis*), the recommended species for angiosperms, is difficult to obtain because it does not grow well in Dodoma's dry climate. A teacher explained:

> "We are instructed to use hibiscus flowers in all guidelines, but the challenge is how to get such flowers within our environment. Due to the weather conditions of Dodoma, hibiscus flowers hardly grow, hence they can only be found in some schools and some gardens. Therefore, using them in a normal lesson is difficult as we are required to bring them from the garden owners where we normally buy them." – (Interview with teacher 8, 11th April 2025)

These examples show that species considered "standard" in the curriculum may be unavailable in some regions, making it harder for teachers to integrate both indigenous and non-indigenous species effectively.

4.2.3. Teacher-related challenges

Teacher-related factors also affected species integration. These included limited species knowledge, insufficient ICT competence, habitual teaching practices, and the high cost of obtaining distant species. Teachers admitted that long-standing habits lead them to rely on only a few familiar species, even when many others are available locally. One teacher explained:

> "The biggest challenge that makes us use only a few species and not others, I can say, is mostly just a matter of habit. Some species exist right in our environment, but we find ourselves using only a few. For example, monocotyledonous species found around our school include maize plants, finger millet, bamboo plants, and a variety of thatch grasses, but we always use maize plants only, despite that there are many kinds. Taking an example of dicots, here there are beans, pigeon peas, cowpeas, green peas and sunflowers, but we commonly use only beans but the truth is, there are many species available." – (Interview with teacher 1, 9th April 2025)

This practice narrows students' exposure to biodiversity and limits their deeper understanding of classification concepts. Teachers also reported assessment-driven teaching. They avoid using unfamiliar but suitable species because students become confused when examinations feature the officially prescribed species. As one teacher noted:

> "Students understand when you integrate the indigenous and non-indigenous species, but when they are brought the species in the exams, they become confused in presenting ideas clearly. For example, you may use Jerusalem flowers before introducing hibiscus flowers during teaching the floral formula, but students still become confused when you bring the hibiscus flower, they forget to relate characteristics and focus on their differences..." – (Interview with teacher 4, 2nd April 2025)

Other teachers shared similar concerns when using okra or roselle as substitutes for hibiscus. Teachers further cited limited ICT skills as a challenge:

> "Modern education requires you to have knowledge and skills..." – (Interview with teacher 5, 9th April 2025)

Financial constraints also made it difficult to obtain non-local species:

> "Sometimes, some species are located very far, so incurring the cost to track or acquire them..." – (Interview with teacher 8, 11th April 2025)

4.2.4. Instructional pacing pressure

Teachers reported significant time pressure due to administrative directives and overloaded syllabi. This reduced the time available to prepare or integrate diverse species. One teacher explained:

> "Another challenge is the orders from the office of the District Educational Officer..." – (Interview with teacher 4, 2nd April 2025)

Teachers expressed willingness to use more species, but the number of topics to be covered limited their ability:

> "You may wish to teach many species..." – (Interview with teacher 6, 9th April 2025)

Time constraints also affected technology-based integration, such as using videos:

> "Also, if I decide to bring a video for them to watch..." – (Interview with teacher 6, 9th April 2025)

Even preparing species before lessons was seen as time-consuming, especially when species were located far away:

> "Sometimes, some species are located very far..." – (Interview with teacher 7, 10th April 2025)

Overall, time pressure from both administrative expectations and the demands of lesson preparation limited teachers' efforts to integrate a wide range of species.

The findings show that although many indigenous species are available locally and could support classification teaching, several contextual barriers limit their effective use. For teachers to integrate species more freely, curriculum authorities may need to allow flexibility in species selection and consider including commonly available local species in national assessments.

5. Discussion of the findings

The findings indicate that teachers prefer using pictures and activating students' prior knowledge when integrating indigenous and non-indigenous species. This preference aligns with Hasanah et al. [17], who emphasize the importance of building on prior knowledge when teaching complex biological concepts such as classification. Teachers can correct misconceptions about the classification of living things by drawing on what students already know [39]. The frequent use of pictures also reflects earlier studies showing that visual representations help convey information clearly and make complex content more accessible [23, 42].

Other strategies, such as drawing on teachers' life experiences, using real-life scenarios, and employing audiovisual materials, were used moderately. Avraamidou [2] explains that teachers often use their lived experiences depending on their cultural and environmental contexts. These experiences help contextualize textbook knowledge and enrich students' understanding of different species. Similarly, Çeliker [4] reports that real-life scenarios encourage critical thinking and help students relate scientific ideas to everyday life.

Furthermore, the study found that teachers moderately used familiar species before introducing unfamiliar ones. Classroom observations revealed a clear gap: while most teachers in high-biodiversity areas utilized familiar species, many teachers in low-biodiversity areas conducted lessons without any specimens. Although some teachers in low-biodiversity areas reported using substitutes when prescribed specimens were unavailable, their lessons were often theoretically conducted. Many teachers expressed concerns about cognitive overload, especially because such species rarely appear in national examinations. These challenges echo the findings by Ng'etich, Waswa and Kabesa [32],

who report insufficient species as a major obstacle, and by Etobro and Fabinu [12], who highlight material shortages in teaching classification.

Integrating community experts was found to be an underutilized strategy. This contrasts with Makhunga [27], who shows that involving local experts and elders deepens students' understanding of species and their conservation. Seehawer [44] similarly notes that community involvement grounds science learning in students' daily experiences. By overlooking this resource, teachers miss opportunities to enhance relevance and align with the National Curriculum Framework, which encourages community participation.

Technology-based strategies, including virtual reality, mobile applications like PlantNet and iNaturalist, and audiovisual tools, were also rarely used. This pattern corresponds with Saro, Dayupay and Aloyon [42], who report low use of digital resources compared to traditional methods. Idris et al. [18] also note infrequent use of audiovisual materials due to limited access, a challenge echoed by Umeohana [66], who identifies minimal use of basic technological tools such as projectors and microphones. Together, these studies highlight missed opportunities to modernize instruction and improve student engagement.

The study also identified major technological barriers, including limited ICT facilities and unreliable electricity. These constraints align with Patrobas, Machumu and Mtawa [34], who cite poor infrastructure, weak internet, and socio-economic limitations as key obstacles. Similarly, the study by Isma'il and Lukman [20] concludes that the lack of multimedia resources hinders the learning of species in the classification topics. The findings further reveal that ICT illiteracy remains a significant challenge for teachers, consistent with Safitri et al. [40]. Both past and current evidence suggest that inadequate facilities and limited skills are interconnected issues. Sibley et al. [45] confirms that effective digital integration requires both access to ICT and strong pedagogical skills. Although initiatives such as SEQUIP-led ICT seminars exist, many teachers still struggle to apply the training due to weak infrastructure and limited practice opportunities. A coordinated approach that strengthens both skills and infrastructure is, therefore, essential for successful digital integration in biology teaching.

6. Conclusion and recommendations

The study found that teachers use a limited range of pedagogical strategies when adapting indigenous and non-indigenous species in teaching classification of living things. Technology-based strategies that could extend learning beyond students' geographical limitations are rarely applied. This limited use is largely attributed to inadequate teacher competence in ICT integration and insufficient technological infrastructure in schools.

The study recommends continuous professional development programmes tailored to strengthen teachers' capacity to use technology-enhanced strategies, including audiovisuals, virtual reality, and online tools. School administrators should also address logistical challenges, such as the cost of transporting species from other areas, and allow greater flexibility in pacing and content coverage. Increased instructional autonomy will help teachers introduce a wider variety of species and create more contextually relevant learning experiences. The Ministry of Education, Science, and Technology in Tanzania (MoEST) should improve the availability of technological resources. All these initiatives require increased education funding to support ICT infrastructure, including projectors, computers, and networking devices. Additionally, biology teachers are encouraged to involve knowledgeable community members to enrich students' understanding of indigenous species and promote biodiversity conservation.

This study provides practical insights that can improve biology teaching and learning. By identifying gaps in pedagogical approaches and ICT integration, it offers evidence to guide targeted professional development that enables teachers to use digital tools more effectively when teaching species diversity. Enhancing ICT infrastructure and expanding teachers' autonomy will expose students to a broader range of species and reduce dependence on the limited examples emphasized in national assessments. Engaging community members will further strengthen students' ecological

understanding and foster positive attitudes toward biodiversity conservation. Overall, the study presents actionable recommendations for teachers, school leaders, and policymakers aiming to improve the quality and relevance of biology instruction in secondary schools in Tanzania.

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A. Questionnaire for Biology teachers

Dear participant,

My name is MAGDALENA SASMOS MKENG'E, a student who is currently pursuing a Master of Education (MED) at the University of Dodoma. I am conducting research titled "Assessing Instructional Adaptation in Teaching Classification of Living Things in Biology Subject for Ordinary Level Secondary Schools in Tanzania". I kindly request your participation in providing the information that is needed to accomplish my research. I assure you that the information provided here will be kept confidential and will only be used to serve the purpose of this study only.

Section A: Background information

District: (a) Dodoma City Council (b) Kilolo District Council
Education level: (a) Diploma (b) Degree (c) Postgraduate
Overall teaching experience: .....
Experience in teaching Biology in a particular district: .....
Teaching class: (i) Form One (ii) Form Two (iii) Form Three (iv) Form Four
Sex: (a) Male (b) Female
Age: .....
Training: Put a tick (✓) if you attended the mentioned professional development program:
(i) Integration of indigenous species and non-indigenous species ( )

Section B: Likert scale

The 5-point Likert scale below contains questions based on the strategies for integrating indigenous and non-indigenous species, translanguaging strategies for accommodating diverse local languages and methods for adapting inquiry-based learning activities while teaching the classification of living things. Rate by circling the best option related to your knowledge using a scale from 1 to 5, that is, strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5).

№	Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Strategies for integrating indigenous and non-indigenous species						
1	I use students' prior knowledge of species that exist in their environment.					
2	I use my own life experiences through narrating stories about species that are found in students' living environment and unfamiliar species that do not exist in their environment.					
3	I normally invite elders and community experts to share with students the indigenous species present in their environment.					
4	I use real-life scenarios to teach species found around students' environment and those found out of their environment.					
5	I normally bring the most familiar species and use them in teaching before introducing and teaching unfamiliar species to students.					
6	I use audio-visual materials to display unfamiliar species that are found in other places in the world.					
7	I use simulations during introducing species of the ecosystems found out of their environment.					
8	I use pictures of species in teaching students whose context lacks such kind of species.					
9	I use online applications such as PlantNet and iNaturalist to help students assign scientific names to species found in their environment and identify closely related species located in other parts of the world.					

Thank you for your time and effort.

B. Reliability of questionnaire items

Table 5
Results of internal consistency reliability analysis.

№	Items	Corrected item-total correlation	Cronbach's alpha if item deleted
1	I use students' prior knowledge of species that exist in their environment	0.35	0.87
2	I use my own life experiences through narrating stories about species that are found in their living environment and unfamiliar species that are not found in their environment	0.41	0.87
3	I normally invite elders and community experts to share with students about the indigenous species present in their environment	0.53	0.87
4	I use real-life scenarios (stories from other people) to teach species found around students' environment and those found out of their environment	0.59	0.87
5	I normally bring the most familiar species and use them in teaching before introducing and teaching new unfamiliar species to students	0.51	0.87
6	The use of audio-visual materials to display unfamiliar species that are found in other places in the world	0.36	0.87
7	I use virtual reality during introducing species of the ecosystems found out of their environment	0.17	0.88
8	I use pictures of species in teaching students whose context lacks such kind of species	0.51	0.87
9	I use online applications like PlantNet and iNaturalist to help students assign scientific names to the species found in their environment and identify closely related species located in other parts of the world	0.65	0.86

C. Interview guide for Biology teachers

Dear participant,

My name is MAGDALENA SASMOS MKENG'E, a student who is currently pursuing a Master of Education (MED) at the University of Dodoma. I am conducting research titled "Assessing Instructional Adaptation in Teaching Classification of Living Things in Biology Subject for Ordinary Level Secondary Schools in Tanzania". I kindly request your participation in providing the information that is needed to accomplish my research. I assure you that the information provided here will be kept confidential and will only be used to serve the purpose of this study only.

1. What are the challenges that hinder the integration of indigenous species and non-indigenous species in teaching the topic of classification of living things?

Classroom observation guide

An observation sheet to examine the strategies used to accommodate diverse local languages, indigenous and non-indigenous species and inquiry-based learning activities.

No: .....
Date: ..... Class being observed: .....
District: ..... Class size: .....
Teaching experience: ..... Subtopic: .....
Gender: .....

№	Items	Observed practices	Not observed	Occasionally observed	Frequently observed
A. Integration of indigenous and non-indigenous species					
1	The use of students' prior knowledge of species that exist in their environment				
2	The use of teachers' own life experiences through narrating stories about species that are found in their living environment and unfamiliar species that are not found in their environment				
3	Inviting elders and community experts to share with students the indigenous species that are found in their environment				
4	Using real-life scenarios to teach species that are found around students' environment and those that are not found in their environment				
5	Bringing most familiar species and use them in teaching before introducing and teaching unfamiliar species to students				
6	The use of audio-visual materials to display unfamiliar species that are found in other places in the world				
7	The use of virtual reality during the introduction of species of ecosystems, which are found out of their environment				
8	The use of pictures of species in teaching students whose context lacks such kind of species				
9	The use of online applications like PlantNet and iNaturalist to help students assign scientific names to species that are found in their environment and identify closely related species that are located in other parts of the world				

Thank you for your time and effort.