



Teaching life and earth sciences in the digital age in rural areas of central Kongo (DRC): challenges, constraints and prospects in the Boma Bungu sector, Muanda territory

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ABSTRACT

The integration of digital technology into the teaching of Life and Earth Sciences (SVT) promises to make phenomena that are difficult to observe visible, to diversify resources and to support inquiry-based learning. In rural Congo, however, these possibilities are hampered by fragile infrastructure, scarce equipment and unevenly developed professional skills. This study examines the uses, constraints and prospects of digital technology in ten secondary schools in the Boma-Bungu sector, Muanda territory, during the 2025–2026 academic year. A mixed-methods design combines a questionnaire administered to 36 biology teachers, an observation of equipment, ten individual interviews and two focus groups involving twelve pupils. The results show that 83.3 per cent of teachers own a smartphone, but only 16.7 per cent have access to a school computer and 38.9 per cent report regular educational use of digital technology. The main barriers are access to electricity (83.3 per cent), the cost of data (77.8 per cent), a lack of equipment (75.0 per cent) and insufficient training (66.7 per cent). Previous digital training is associated with regular use ($\chi^2(1) = 8.35$; $p = .004$; Cramer's $V = .48$). Qualitative data reveal that digital technology is mainly used in preparation for lessons, whilst simulations, offline videos and group screenings remain marginal. The article advocates a realistic approach: targeted solar power, shared equipment, offline resources aligned with the curriculum, contextualised teaching training and a local maintenance system. Digital technology can thus enhance observation, modelling and environmental education without replacing accessible hands-on activities or the course's connection to the local context of Boma Bungu.

Keywords: teaching of life and earth sciences; digital education; rural areas; teacher training; Boma Bungu; Kongo Central.

1. Introduction, research question and theoretical framework

1.1. Teaching Life and Earth Sciences in a context of digital transition

Life and Earth Sciences occupy a special place in general education. They connect pupils with their own bodies, living organisms, natural environments and the changes taking place on the planet. Teaching these subjects cannot be reduced to the memorisation of specialised vocabulary. It involves observing, comparing, representing, experimenting and reasoning on the basis of facts. The Congolese Life and Earth Sciences curriculum places particular emphasis on learning situations, pupil activity and the construction of applicable

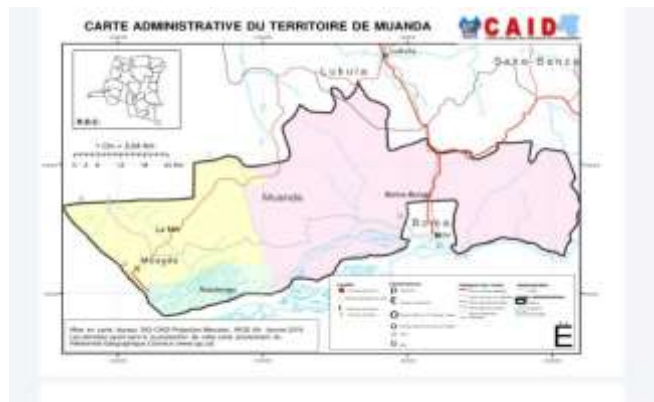
knowledge. Among other things, it includes activities relating to germination, photosynthesis, nutrition, the human body, water and the relationships between organisms and the environment (Ministry of Primary, Secondary and Vocational Education [MEPSP], 2019).

However, this approach faces well-known challenges in schools where laboratories, anatomical models, microscopes and specimen collections are either absent or incomplete. Digital technology therefore appears to offer a useful alternative. A short animation can illustrate blood circulation; a carefully chosen video can demonstrate mitosis or a dissection procedure; a geotagged photograph makes it easier to monitor erosion; a spreadsheet can be used to organise growth measurements. Simulations are particularly relevant when the phenomenon is too slow, too fast, microscopic, dangerous or costly to reproduce. The reviews by Smetana and Bell (2012) and by Rutten et al. (2012) nevertheless conclude that simulation is most effective when it forms part of a guided scenario and complements the experiment rather than replacing it.

The distinction between the mere presence of a device and pedagogical innovation must be established from the outset. An image shown without any questioning may perpetuate a transmission-based approach to teaching. Conversely, a single mobile phone used to document a local observation, compare several hypotheses and present the results can support an authentic scientific activity. In their meta-analysis of secondary-level mathematics and science teaching, Hillmayr et al. (2020) observe a positive effect of digital tools, but emphasise the role of context, teacher support and integration with non-digital methods. A review focusing on multimedia tools reaches a similarly cautious conclusion: the judicious combination of text, images, sound and animation facilitates understanding, whilst an overload or poor design distracts attention (Abdulrahman et al., 2020).

The cognitive theory of multimedia learning sheds light on this tension. Verbal and visual information can reinforce one another if they are carefully selected, organised and then linked to prior knowledge. They can also overload working memory when the screen displays too many secondary elements (Mayer, 2021). For life and earth sciences, the challenge is therefore not to increase the number of files, but to choose a medium that supports a specific intellectual task: observing a detail, interpreting a graph, sequencing the stages of a mechanism, or comparing a model with a local reality.

1.2. Boma Bungu and the rural digital divide



Source: CAID.

The Boma Bungu sector is part of the Muanda territory in Kongo Central. The administrative map produced by the Development Indicators Analysis Unit (CAID) shows it to be an area where settlements, institutions and access routes are scattered (CAID, 2016). The official education authority classifies schools in the Boma Bungu sector as belonging to the Muanda 2 sub-division, within the Kongo Central 1 educational province (Ministry of National Education and New Citizenship [MINEDU-NC], 2026a). This rural character does not imply either complete isolation or a lack of telephone access. Rather, it refers to a combination of distances, erratic energy supply, variable mobile coverage and limited purchasing power.

The national assessment of secondary schools' digital readiness highlights the scale of the problem. In the ten provinces studied, including Kongo Central, 61 per cent of state secondary schools are located in rural areas, 7 per cent have electricity, and 76 per cent are covered by at least one mobile network, with no guarantee of a stable data service. The Project for Quality and Relevance in Secondary and Tertiary Education had distributed 799 desktop computers and 9,975 laptops to approximately 291 schools, whilst the country had 29,631 inadequately equipped state secondary schools (Voufo et al., 2024). These national figures should not be applied automatically to the Boma Bungu sector; however, they do show that the shortfall observed locally is part of a structural problem.

The digital divide comprises at least three levels. The first is hardware-related: energy, connectivity, devices, security and repairs. The second concerns usage: knowing how to search for a resource, verify it, save it offline, and display or share it. The third is pedagogical: linking the tool to biology content, scientific reasoning and assessment. UNESCO (2023) therefore calls for any technological decision to be assessed

on the basis of its relevance, equity, evidence of effectiveness and sustainability. Equipment that remains unused due to a lack of electricity or maintenance does little to meet these criteria.

The risk of inequality also exists within the classroom itself. When an activity requires every pupil to have a connected mobile phone, differences in income translate into differences in participation. Girls may face greater restrictions on access to the family's device, whilst pupils living far from a mobile signal or unable to afford mobile plans are disadvantaged. A personal device cannot therefore be made a prerequisite. Equitable integration prioritises collective use, small-group work, the local availability of content, and printed or hands-on alternatives.

1.3. Professional competence and analytical model

The TPACK model developed by Mishra and Koehler (2006) helps to avoid a purely technical interpretation. To teach photosynthesis using an animation, it is not enough simply to know how to play the video. The teacher must have a firm grasp of the scientific content, choose an appropriate approach and understand what the medium makes visible or, conversely, oversimplifies. The relevant competence lies at the intersection of disciplinary, pedagogical and technological knowledge. The UNESCO (2018) digital competence framework for teachers adds a progression ranging from the acquisition of knowledge to its deepening and then to the creation of knowledge, within an institutional environment that supports training and collaboration.

Barriers, for their part, can be categorised according to Ertmer (1999). First-order barriers are external: access, time, support, equipment and connectivity. Second-order barriers relate to beliefs, confidence and conceptions of learning. This distinction does not imply that the latter are merely a matter of individual resistance. Knowledge, a sense of efficacy and the school's culture are constructed together (Ertmer & Ottenbreit-Leftwich, 2010). Reviews focusing on sub-Saharan Africa confirm the combined importance of infrastructure, professional support and pedagogical choices (Hennessy et al., 2010; Msambwa et al., 2024).

Research closer to the life sciences reinforces this framework. In Bangladesh, Farhana et al. (2024) found that biology teachers may have a positive attitude towards digital technology whilst making little use of it, due to a lack of access, training and curricular guidance. In South Africa, Ramnarain et al. (2023) demonstrate that pedagogical beliefs shape the way in which life sciences teachers integrate technology; the tool can reinforce a transmissive approach or

support exploration, depending on the task and the support provided. Tondeur et al. (2017) reach the same conclusion in their systematic review: the relationship between beliefs and practices is reciprocal, context-dependent and rarely reducible to a dichotomy between ‘pro-technology’ and ‘reluctant’ teachers.

1.4. Problem, questions and hypothesis

The Congolese legal framework recognises the importance of innovation and provides for the introduction of information and communication technologies into education, including in open and distance learning formats (Democratic Republic of the Congo, 2014). The 2016–2025 Sectoral Strategy for Education and Training, for its part, has placed quality, equity and governance at the heart of the reform (Government of the Democratic Republic of the Congo, 2015). Between these policy directions and the rural classroom, a practical question remains: what can a life and earth sciences teacher in Boma Bungu actually achieve with the energy, equipment, skills and resources at their disposal?

The study addresses three questions. What digital practices do life and earth sciences teachers report, and what resources do schools make available to them during the 2025–2026 academic year? What material, economic and pedagogical constraints limit these uses? What solutions can improve teaching without creating a dependence on a constant internet connection or sidelining observation of the natural environment? The quantitative hypothesis is that prior digital training is associated with regular pedagogical use.

On the qualitative side, the analysis seeks to understand how stakeholders define useful use and the conditions they consider realistic.

The overall objective is to analyse the challenges, constraints and prospects of digital technology in the teaching of life and earth sciences in the Boma Bungu area. More specifically, the aim is to describe access and practices, to test the link between training and use, to interpret the experiences of teachers and pupils, and then to propose a phased approach compatible with rural constraints. The expected contribution lies in this shift in scale: starting from classroom situations rather than a general promise of modernisation.

2. Methodology

2.1. Research design and fieldwork

The research adopts a convergent mixed-methods design, in the sense that quantitative and qualitative data were collected during the same period, analysed separately and then linked

during the interpretation phase (Creswell & Plano Clark, 2018). The quantitative component describes the equipment, usage patterns, obstacles and teachers’ sense of preparedness. The qualitative component documents how these tools are integrated into lesson preparation, pupil activity and day-to-day decision-making. This combination was necessary: a percentage measures the frequency of an obstacle, but does not explain how a teacher continues the lesson when a battery runs out or when the network connection is lost.

The survey took place from October 2025 to May 2026 in ten secondary schools in the Boma Bungu area. The schools were selected using a reasoned approach to ensure a mix of status, distance from the centres they serve and presumed internet availability. The unit of quantitative analysis is the teacher responsible for at least one lesson in life and earth sciences or biology. As a comprehensive and up-to-date database of all teachers in the area was not available, no probabilistic sample size calculation was presented. Forty accessible teachers were approached and 36 returned a usable questionnaire, representing a response rate of 90.0 per cent: $(36 / 40) \times 100$.

The qualitative data comprises ten semi-structured interviews, eight of which were with teachers and two with school heads, as well as two focus groups of six pupils. Participants were selected to ensure a contrast in terms of length of service, access to devices, digital training and level of usage. Structured observation was carried out at the ten schools, focusing on: electricity supply, dedicated internet connection, functional devices, projection equipment, computer labs, secure storage and the availability of content that can be used offline.

Table 1: Data collection methodology and contribution from each source.

Source	Sample size or unit	Information collected	Method of analysis
Teachers' questionnaire	36 life and earth sciences teachers	Access, usage, constraints, training and digital preparation	Frequencies, percentages, mean, Cronbach's alpha, chi-squared
Observation sheet	10 secondary schools	Power, connectivity, equipment, laboratory, storage and content	Data collection and comparison between schools
Individual interviews	8 teachers and 2 managers	Practices, trade-offs, training, maintenance and expectations	Thematic analysis
Focus groups	12 pupils in two groups	Access, understanding, equity and perceptions of usage	Thematic analysis and comparison of viewpoints

Source: Field survey, academic year 2025–2026.

2.2. Instruments, variables and quality of measurements

The questionnaire comprised four sections. The first described access to smartphones and school computers. The second listed six uses: preparation on a mobile phone, offline videos, sharing documents via WhatsApp, projection, simulation and digital quizzes. The third section presented seven constraints with multiple-choice answers. The final section assessed digital preparation across six items rated on a scale from 1, 'not at all capable', to 4, 'completely capable': recognising the usefulness, using the device with ease, selecting a resource, designing an activity, managing the class and assessing using a digital tool.

The content was reviewed in light of the national curriculum and the TPACK framework, then discussed with two teaching methodology trainers and a science teacher. This stage aimed to ensure clarity, disciplinary relevance and alignment with professional terminology. The internal consistency of the readiness scale was assessed using Cronbach's alpha (Cronbach, 1951). The value obtained, $\alpha = .95$, indicates a

high degree of homogeneity amongst the six items. However, it does not prove either perfect unidimensionality or construct validity; in a small sample, a high value may also reflect the similarity of the statements.

Regular use, the dependent variable, corresponds to at least one educational use per week or during each relevant lesson. Previous digital training was coded as 1 when a participant reported having undertaken structured training, however brief, on the educational use of a device or resource; informal peer support was not counted. Multiple-choice responses were analysed separately, meaning that their total exceeds 100 per cent.

2.3. Quantitative and qualitative analysis

The data were entered into a spreadsheet and then verified by checking the accepted values. Proportions were calculated using the number of respondents, $n = 36$, as the denominator. For example, smartphone ownership is $(30 / 36) \times 100 = 83.3$ per cent. The average level of preparedness corresponds to the average of the six items, and then to the average of the individual scores.

The association between training and regular use was examined using Pearson's chi-squared test. The null hypothesis assumes independence between the two variables. Expected frequencies are calculated as $E_{ij} = (\text{row total} \times \text{column total}) / N$, and the test statistic as $\chi^2 = \sum (O_{ij} - E_{ij})^2 / E_{ij}$. The decision threshold is set at 5 per cent. Cramér's V describes the strength of the association; for a 2×2 table, $V = \sqrt{(\chi^2 / N)}$. The expected frequencies, all of which are greater than 5, allow for the use of the chi-squared approximation.

The interviews and focus groups were summarised and then coded using a thematic analysis inspired by Braun and Clarke (2006). An initial reading identified units relating to uses, barriers, effects on comprehension and solutions. The codes were then grouped, compared across participant categories and cross-referenced with the observations. Discrepancies were retained, particularly regarding pupils' use of mobile phones. Convergence did not imply that the two components had to yield the same answer: a discrepancy between ownership and use, for example, became in itself a finding to be interpreted.

2.4. Ethical considerations and limitations of the protocol

School management were informed of the study's objectives and procedures. Participation was voluntary; responses were anonymised using codes. Pupils were asked not to reveal any personal information during group discussions, and comments

were reported by theme to minimise the risk of identification. The data were used solely for the stated analysis.

The protocol has several limitations. The purposive sampling and small sample size do not allow for statistical extrapolation to the whole of Muanda or Kongo Central. Practices are partly self-reported and may be overestimated. A one-off observation of equipment does not measure its availability throughout the year. Finally, the analysis of learning focuses on perceptions and practices, not on a standardised test of pupils' attainment. The results are therefore of an analytical and local nature.

3. Results

3.1. Access to devices and state of infrastructure

Thirty out of 36 teachers, or 83.3 per cent, own a smartphone. This level of individual equipment contrasts with institutional access: only six respondents, or 16.7 per cent, can use a computer belonging to the school. Of the ten schools observed, three have a power supply deemed reliable enough to prepare or project teaching materials; only one has a dedicated internet connection; two have at least one working computer; and two have a projector. One school has a television. Two schools have a room designated as a life and earth sciences laboratory, but the scientific equipment there remains limited. Three schools store content offline and three have a secure room or cupboard.

Table 2: Resources observed in the ten schools.

Resource or condition	Schools concerned	Percentage
Relatively reliable power supply	3	30.0%
Dedicated internet connection	1	10.0%
At least one working computer	2	20.0%
Working projector	2	20.0%
Television suitable for use in a lesson	1	10.0%

Science laboratory or classroom	2	20.0%
Teaching resources stored offline	3	30.0%
Secure storage for equipment	3	30.0%

Source: School surveys, 2025–2026; N = 10.

This table reveals that the teacher's mobile phone often constitutes the de facto digital infrastructure. This situation results in a form of cost personalisation: the cost of data, top-ups and wear and tear on the device are borne by the individual. The interviews also show that the mere existence of a computer does not guarantee its accessibility. The device may be reserved for administrative use, have a flat battery, or lack suitable software and content. Conversely, a school without a permanent internet connection can still conduct a digital lesson if the file has been downloaded elsewhere, transferred to a memory card and projected using a portable power source.

3.2. Educational uses: digital technology primarily as a preparatory tool

Fourteen teachers, or 38.9 per cent, report regular educational use. The most common activity is lesson preparation on a mobile phone: 24 respondents, or 66.7 per cent, look up a definition, an image, a diagram or a video. Eleven teachers, 30.6 per cent, use a video available offline and nine, 25.0 per cent, occasionally share a document via WhatsApp. Projection is used by only five respondents, simulations by three and digital quizzes by two.

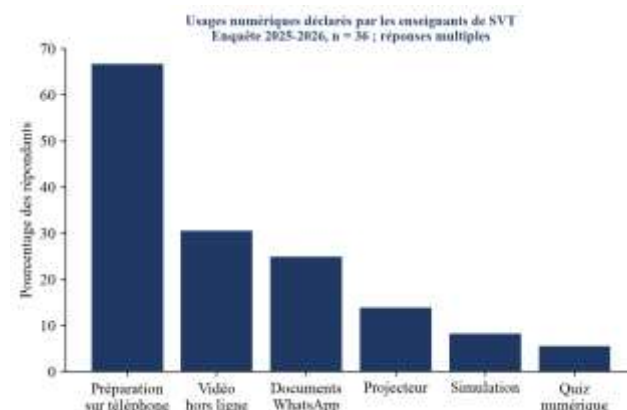


Figure 1: Digital uses reported by Life and Earth Sciences teachers.

Source: 2025–2026 survey, $n = 36$; multiple responses allowed.

The interviews reveal three distinct levels. At the first level, digital technology enriches the teacher's teaching materials, without being visible to the pupils. At the second level, the device is used as an illustrative aid: an image is passed round the class or a video is shown to a small group. At the third level, which is less common, pupils observe, make a prediction, use an animation, record a result and compare it with an observation. The transition from the first to the third level requires not so much technical sophistication as careful preparation of the task and the possibility of collective viewing.

The educational value most frequently attributed to digital technology is the visualisation of biological phenomena that are difficult to observe, cited by 31 teachers (86.1 per cent). This is followed by lesson documentation (80.6 per cent) and contextualisation (75.0 per cent). Participants mentioned comparing a scientific representation with organisms, soils or water samples available in the local environment. Collaboration (55.6 per cent) and assessment (50.0 per cent) were identified less frequently. Groups of pupils confirmed the value of moving images for following the stages of a process, but pointed out that visibility becomes poor when a small screen is shown to the whole class.

3.3. Material, financial and professional constraints

Electricity ranks first among the constraints, cited by 30 teachers (83.3 per cent). Data costs were cited by 28 respondents (77.8 per cent), a lack of equipment by 27 (75.0 per cent), insufficient training by 24 (66.7 per cent), network instability by 23 (63.9 per cent) and maintenance by 21 (58.3 per cent). Finally, 15 teachers (41.7 per cent) highlighted a lack of content relevant to the curriculum, the pupils' language level or the realities of Kongo Central.

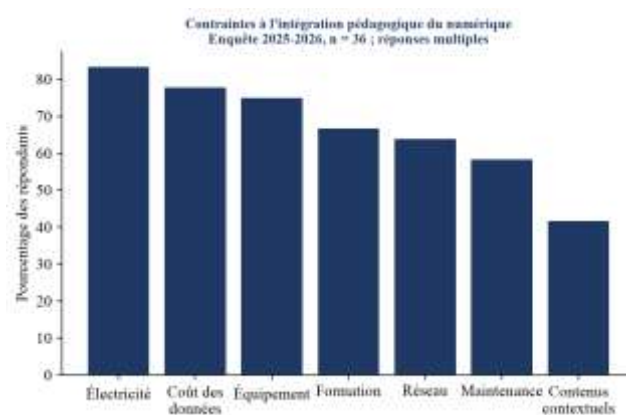


Figure 2: Barriers to the integration of digital technology into teaching.

Source: 2025–2026 survey, $n = 36$; multiple responses.

These constraints form a chain. A teacher may know how to select a video but decide against it if downloading it uses up a significant portion of their data allowance. A school may receive a projector but then stop using it following a cable or battery failure. A file available online may not be suitable for the curriculum or may use language that is too abstract. Participants therefore do not describe a single obstacle, but rather an interdependence between energy, access, the relevance of content and support.

The management of mobile phones in the classroom gives rise to particular tension. Some teachers fear distraction, cheating, unauthorised filming and inequality amongst learners. Others consider that a total ban deprives the school of a device that is already present. The groups of learners instead propose supervised use: one device per group, a specific task, a limited duration and a joint presentation of findings. This compromise does not resolve the issue of data protection, but it avoids confusing the social availability of the mobile phone with unrestricted individual use during the teaching session.

3.4. Digital readiness and the impact of training

The average score for digital preparedness is 2.13 out of 4, with an inter-individual standard deviation of 0.64. Teachers feel more confident in recognising the usefulness of a resource or launching content than in designing an activity, organising class participation and assessing learning. The need for training therefore relates less to the basic handling of the phone than to its educational application.

Fifteen teachers have undertaken structured digital training. Of these, ten report regular use, compared with four of the 21 who have not received training. The cross-tabulation reveals a substantial association.

Table 3: Previous digital training and regular educational use.

Previous training	Regular use: yes	Regular use: no	Total
Yes	10	5	15
No	4	17	21
Total	14	22	36

Source: 2025–2026 survey.

The expected frequencies are 5.83, 9.17, 8.17 and 12.83 respectively. The resulting chi-squared statistic is $\chi^2(1, N = 36) = 8.35$, with $p = .004$. The null hypothesis of independence is rejected at the 5 per cent significance level. Cramér's V is .48, indicating a statistically significant association in the sample. The odds ratio, $(10 \times 17) / (5 \times 4) = 8.50$, suggests that the likelihood of regular use is higher amongst trained teachers. This result does not demonstrate causality: those who are already motivated may be more likely to seek out training, and access to equipment may influence both variables.

The interviews clarify the nature of useful training. One-off sessions focusing on computer functions are considered less transferable than workshops where the teacher prepares a real lesson, tests a resource, anticipates a technical fault and receives feedback. Peer support appears to prolong this effect. Training therefore likely works in conjunction with other factors: basic access, preparation time, encouragement from management, and the opportunity to experiment without penalty in the event of technical difficulties.

3.5. Convergence of results

Analysing the data leads to three observations. Firstly, personal access is greater than school-based access, but it primarily supports preparation outside the classroom. Secondly, teachers clearly recognise the potential of digital technology for visualising and documenting; the main obstacle is not a principled opposition. Thirdly, uses that transform learners' activities are the rarest, as they require a combination of infrastructure, teaching skills and organisation.

These findings point to incomplete digital preparation rather than a complete absence of it. Practices already exist, but they remain scattered, dependent on individual expenditure and

vulnerable to the slightest technical failure. The challenge now is to make them collective, reliable and pedagogically explicit.

4. Discussion: challenges and constraints

4.1. From personal mobile phone to learning tool

The first significant finding is the gap between ownership and use. More than eight in ten teachers own a smartphone, but fewer than four in ten use it regularly for teaching purposes, and only a minority utilise digital simulations or assessments. This discrepancy is consistent with the study by Farhana et al. (2024) among biology teachers: a favourable attitude is not enough when school access, training and curricular guidelines are lacking. It also suggests that we should not assume that devices are immediately available for learning.

Personal mobile phones serve a genuine reference function. They can improve the accuracy of a diagram or provide an alternative example. However, unless the resource forms part of a set of instructions, is observed and discussed, it has little impact on the structure of the lesson. The TPACK framework helps to articulate this transition: technological knowledge must be integrated with life and earth sciences content and an appropriate teaching strategy (Mishra & Koehler, 2006). In a large class, showing an animation of respiration on a small screen is technically possible but pedagogically ineffective. Projecting the same file, pausing the animation at selected moments, asking for a prediction and then having pupils construct a diagram transforms its role.

This is particularly evident when dealing with invisible or dynamic phenomena. A simulation can support understanding if it allows certain variables to be manipulated, provides feedback and remains linked to a scientific problem (Smetana & Bell, 2012). It becomes misleading if the pupil mistakes the model for reality. The teacher must therefore make clear what the representation retains, omits or simplifies. This guidance justifies prioritising teaching methodology over the purchase of software.

4.2. A chain of vulnerabilities rather than an isolated shortcoming

The constraints reported correspond to the first-order obstacles described by Ertmer (1999), but their combination is more instructive than their classification. Power determines recharging; recharging determines transmission; the connection enables downloading; cost determines its frequency; maintenance determines the lifespan of the system as a whole. An investment focused on a single link is therefore fragile. The local findings extend the analysis of Voufo et al.

(2024), who argue that the digital readiness of Congolese schools depends simultaneously on the environment, the school's capacity and the teachers' skills.

This chain also explains why the 'all-online' option would be ill-suited. An open educational resource may be legally accessible whilst remaining physically out of reach. Indeed, the UNESCO Recommendation on Open Educational Resources emphasises the capacity of stakeholders to create, adapt, share and sustain these resources, and not merely to make them available online (UNESCO, 2019). In the Boma Bungu area, a lightweight, offline library aligned with the curriculum could be more effective than a feature-rich platform requiring a constant internet connection.

Maintenance deserves to be a central priority. School equipment in rural areas is subject to dust, humidity, power fluctuations and a shortage of spare parts. Without an inventory, a designated person in charge, a minimal budget and a local repairer, the equipment quickly becomes unusable. The total cost includes purchase, electrical protection, storage, battery replacement, cables, updates and training. UNESCO (2023) rightly recommends assessing long-term costs and sustainability before any roll-out.

4.3. Training in a context-specific approach to Life and Earth Sciences

The link between training and regular use supports the research hypothesis. Its strength, $V = .48$, is sufficiently significant to justify action, but the cross-sectional design prevents us from asserting that training alone leads to use. The result is consistent with Hillmayr et al. (2020), who identify teacher support as a moderator of the effectiveness of digital tools, and with Hennessy et al. (2010), who emphasise the role of professional support in sub-Saharan contexts.

Generic training in office software does not fully meet the observed need. Teachers ask how to choose a scientifically accurate video, pause an animation at the right moment, engage a large class, check for understanding, and continue if the battery runs out. Training in digital teaching methods for life and earth sciences can be based on specific topics: germination, photosynthesis, the human body's systems, water pollution, local biodiversity and erosion. For each topic, the trainer should link together a learning objective, a practical activity that can be carried out, an optional digital resource, a written record and a brief assessment.

The literature on teacher change highlights that confidence and beliefs evolve through experiences of success, dialogue amongst peers and school culture (Ertmer & Ottenbreit-

Leftwich, 2010; Tondeur et al., 2017). Support must therefore extend beyond the initial workshop. One resource teacher per group of schools, peer observations and a low-cost monthly meeting may prove more useful than a one-off training session involving a large number of participants.

4.4. Equity, local relevance and scientific purpose

Digital technology in schools can bridge a knowledge gap, but it can also widen disparities. A compulsory activity using personal mobile phones favours learners who are equipped, connected and authorised to use the family device. A collective approach, with assigned roles, better safeguards access. It also allows for scientific discussion rather than merely individual use of the technology. Schools must provide a non-digital alternative so that no pupil is excluded.

Cultural and environmental relevance is not simply a matter of translating a few menus. It involves linking concepts to the environments familiar to pupils. Photographs taken in the local area can be used to classify organisms, document erosion, compare water uses or track changes in a plot of land. Such material must be used with consent and without exposing individuals or sensitive personal details. Digital technology then becomes a means of producing local data, rather than merely receiving images from elsewhere.

This approach preserves the epistemological specificity of Life and Earth Sciences. Pupils must learn to distinguish between observation, interpretation and models; to evaluate a source; to recognise uncertainty; and to test an explanation against the facts. The national curriculum provides a solid foundation for this approach (MEPSP, 2019). The screen is only relevant if it reinforces these processes. A seed being germinated, a leaf being observed, a water level reading or a simple cross-section can remain at the heart of the lesson; photography, video or spreadsheets extend the experience.

4.5. Scope and limitations of the results

Consistency between the questionnaire, observations and interviews strengthens the interpretation, but it does not remove the limitations. The ten schools do not represent all rural situations in Kongo Central. The statistical association is based on 36 people and its margin of uncertainty remains wide. Usage data were not verified by a continuous logbook. Nor does the study measure any learning gain attributable to a specific tool.

These limitations suggest the need for further empirical research. A pragmatic experiment could compare, within the same teaching sequence, three approaches: the usual activity, a practical activity using a printed resource, and a practical

activity enriched by offline content. Conceptual learning, the quality of work produced, the participation of girls and boys, preparation time and actual cost would be measured. A one-year follow-up would also make it possible to document breakdowns, repairs and dropouts – aspects often missing from short-term evaluations.

5. Outlook, recommendations and conclusion

5.1. A gradual approach for the Boma Bungu sector

The results do not argue in favour of either waiting for perfect infrastructure or rushing to distribute devices. Instead, they call for a five-stage approach. The assessment first identifies the life and earth sciences lessons that would genuinely benefit from such support, as well as the specific constraints of each school. This is followed by a limited but reliable energy and hardware foundation: solar charging, protection against voltage fluctuations, a robust computer or tablet, and a shared projection system. An offline library is then compiled from verified content, organised according to the curriculum and accompanied by a teaching guide for each lesson plan. TPACK training transforms these resources into activities. Finally, monitoring assesses usage, learning outcomes, costs and technical failures before any expansion takes place.



Figure 3: A phased approach to integrating digital technology into Life and Earth Sciences.

Source: developed by the author based on the results and the TPACK framework.

This scenario is in line with recent national policy directions. In July 2026, the Congolese strategy on open educational resources set out plans for 2026–2030 to establish a platform, produce resources, provide training and carry out monitoring (MINEDU-NC, 2026b). The Digital Pact signed in April 2026 also provides for infrastructure, equipment and educational platforms (MINEDU-NC, 2026c). For the Boma Bungu sector, implementation would be best started with offline and collaborative uses, accompanied by simple indicators, rather than an immediate reliance on an internet connection.

5.2. Allocation of responsibilities

The Boma Higher Institute of Education (ISP Boma) can act as a bridge between policy and practice. In initial teacher training, every trainee biology teacher should produce at least one lesson plan combining environmental observation, a low-resource digital tool and a fallback solution. Teaching placements could include a module dedicated to the alignment of technology and pedagogy. In continuing professional development, the Institute could host a small repository of validated resources and organise travelling workshops with schools in the Muanda 2 sub-division.

School management teams are responsible for ensuring that equipment is available, traceable and repairable. A usage log, a quarterly stock-take, a person in charge of equipment and a set of lending rules are sufficient to get started. The sub-division can coordinate the purchase of consumables, maintenance and the sharing of mobile equipment between neighbouring schools. External partners should fund a functional package rather than an individual device: power supply, protection, support, training, resources and maintenance.

Table 4: Proposed action matrix for digital teaching of Life and Earth Sciences.

Timeframe	Priority action	Lead person	Monitoring indicator
0 to 6 months	Compile an inventory of equipment, energy resources, skills and priority teaching sequences	Headteachers and Life and Earth Sciences teachers	Inventory validated in each school
0 to 12 months	Build an offline library aligned with the curriculum	ISP Boma and the teaching support team	Number of resources approved with activity sheets
6 to 18 months	Install shared charging and projection kits	Sub-division, schools and partners	Monthly kit availability rate
6 to 24 months	Deliver training through life and earth sciences lessons and organise mentoring	ISP Boma and resource teachers	Lessons prepared, observed and reviewed

12 to 36 months	Assess learning outcomes, equity, cost and maintenance before scaling up	ISP Boma and educational services	Annual report based on classroom data
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Source: Proposal arising from this study.

5.3. Principles of implementation

Four principles should guide decision-making. The first is simplicity: choose the simplest tool capable of achieving the objective. The second is complementarity: maintain observation and hands-on activities where feasible. The third is equity: do not make participation conditional on owning a device or having a data plan. The fourth is verifiability: document the source of a resource, its alignment with the curriculum and its observable effects.

These principles lead to practical choices. A video must be short, downloaded in advance, scientifically verified and accompanied by questions. A simulation must be preceded by a prediction and followed by a comparison with the real-world phenomenon. A local photograph must be taken with the subject's consent and be dated. A group of pupils must be assigned roles so that the person holding the device does not monopolise the task. Finally, a lesson must provide for continuity on paper or through hands-on activities in the event of a technical failure.

5.4. General conclusion

The teaching of Life and Earth Sciences in the Boma Bungu area faces less of a choice between tradition and modernity than a problem of adaptation. Digital technology is already present, particularly via the teacher's mobile phone, but it remains peripheral to pupils' activities. Its potential is recognised for visualisation, documentation and contextualisation; its effective use is limited by electricity supply, data costs, equipment, training and maintenance.

The observed link between training and regular use confirms the importance of professional development, though this does not allow for a causal interpretation. Training alone will not suffice if resources are inaccessible; providing equipment alone will not suffice if its use lacks a pedagogical purpose. The appropriate response is systemic and phased. It combines a reliable minimum power supply, shared equipment, offline content, training focused on life and earth sciences lessons, and locally organised maintenance.

From this perspective, digital technology replaces neither the teacher nor the fieldwork. It helps us to see what the eye cannot see directly, to keep a record, to compare data and to discuss a model. The Boma Bungu environment remains a primary scientific resource. The challenge lies in linking this local experience to broader concepts and information in a way that is equitable, sustainable and intellectually stimulating. It is on this condition that the digital transition can become an educational transformation rather than a mere accumulation of devices.

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