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Digital Pedagogy in Cameroon's Higher Education: Advancing STEM through ICT-Driven Teacher Training

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ABSTRACT

In the era of digital transformation, integrating Information and Communication Technologies (ICTs) into education has emerged as a pivotal strategy for enhancing the quality and relevance of teaching, particularly in Science, Technology, Engineering, and Mathematics (STEM) fields. This study investigates the current state, challenges, and opportunities of digital pedagogy in Cameroon's higher education system, with a focus on ICT-driven teacher training programs aimed at improving STEM instruction. Drawing on both qualitative and quantitative data from teacher educators, trainee teachers, and policy documents, the research evaluates how digital tools are employed in pedagogical practices and the extent to which they align with the national vision for higher education modernization. The findings indicate a growing adoption of digital pedagogy in STEM education, albeit constrained by infrastructural deficiencies, inadequate training, and uneven ICT policy implementation. The study concludes by proposing a strategic framework for institutionalizing ICT-based teacher training programs to sustainably promote STEM education in Cameroon.

KEYWORDS: *Digital Pedagogy, STEM Education, ICT Integration, Teacher Training, Cameroon*

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1. INTRODUCTION

STEM stands for Science, Technology, Engineering, and Mathematics. It refers to a broad academic and educational discipline that integrates these four fields to create an interdisciplinary approach to learning and problem-solving. STEM education emphasizes the development of critical thinking, creativity, collaboration, and technical skills necessary for students to succeed in today's rapidly evolving world. It aims to prepare students for careers in fields that are central to innovation, economic development, and technological advancement. In a STEM-focused curriculum, subjects are often taught in an integrated manner, encouraging students to see the connections between disciplines and apply knowledge across subjects. STEM is not just about learning content in isolation, but about engaging with real-world problems that require interdisciplinary approaches.

The concept of STEM is particularly important in the context of global education systems, as it plays a key role in fostering a workforce capable of addressing complex challenges in areas such as climate change, health, infrastructure, and technology. The emphasis on STEM education aligns with the growing demand for skilled workers in high-tech and innovation-driven industries, both in developed and developing countries. In recent years, STEM education has gained significant attention due to its potential to boost economies and address societal needs. Countries like the United States, China, and many in Europe have heavily invested in STEM to maintain their competitive edge in the global economy. Likewise, STEM education is increasingly being seen as critical in many African countries, including Cameroon, to prepare students for the challenges of the 21st century. However, there are several challenges to implementing effective STEM education, especially in lower-resource settings. These include limited access to modern technology, inadequate teacher training, and disparities in educational infrastructure. Additionally, while STEM offers numerous opportunities, it also risks neglecting other important areas of learning, such as the arts and social sciences, which are essential for fostering a well-rounded, critical-thinking populace.

The interdisciplinary nature of STEM also means that its implementation must be flexible and context-specific, incorporating local needs, cultures, and resources. For instance, in Cameroon, integrating STEM education with the use of information and communication technology (ICT) could bridge gaps in traditional education, while also enhancing access to international knowledge. As such, the potential of STEM to drive educational reform and economic growth in Africa is enormous, but achieving this requires a balanced, inclusive approach that addresses both technological advancements and the needs of the local context. STEM education holds the potential to empower the next generation with the skills necessary to thrive in a technology-driven world. However, its success depends on overcoming challenges related to infrastructure, teacher training, and accessibility, and on ensuring that its benefits are equitably distributed.

Digital pedagogy, defined as the use of digital tools and methodologies to enhance teaching and learning, has become increasingly significant in shaping modern educational landscapes. In Sub-Saharan Africa, and Cameroon in particular, the adoption of digital pedagogical approaches is seen as a transformative mechanism to address long-standing challenges in STEM education, such as limited access to resources, outdated curricula, and poorly equipped laboratories. As STEM disciplines form the backbone of innovation and economic development, improving the pedagogical competence of teachers through ICT integration is essential to fostering a skilled and competitive workforce.

Despite national efforts to digitize education, many institutions of higher learning in Cameroon face systemic challenges in implementing digital pedagogical frameworks, especially in teacher training colleges and STEM departments. This paper explores the intersection of digital pedagogy and STEM advancement by assessing how ICT-driven teacher training programs are enhancing pedagogical content knowledge, classroom interactivity, and learner outcomes in Cameroon's universities. It further examines the institutional policies, stakeholder roles, and socio-economic conditions that influence the success of these initiatives.

2. Research Background

The Cameroonian government has acknowledged the transformative potential of ICTs in education through various national strategies, including the "Vision 2035" and the "Education Sector Strategy" (2013–2020), which emphasize innovation, quality education, and digital literacy. In recent years, digital education has gained further momentum with the implementation of the Emergency Remote Teaching (ERT) response to the COVID-19 pandemic, which exposed the urgent need for robust digital infrastructure and teacher preparedness.

In the context of higher education, the Ministry of Higher Education (MINESUP) has launched several initiatives aimed at equipping universities with ICT facilities and training staff in digital pedagogies. However, significant gaps persist in the quality of ICT use, especially within STEM faculties and teacher education programs. Many lecturers and teacher trainees lack the digital literacy and pedagogical know-how to effectively integrate ICTs into STEM instruction. The absence of a comprehensive framework for ICT integration in pre-service and in-service teacher training programs has further widened the digital divide between urban and rural institutions.

Moreover, STEM education in Cameroon continues to suffer from gender disparities, poor teacher-to-student ratios, and limited experiential learning, challenges that digital pedagogy can help address if appropriately implemented. Therefore, it is imperative to examine how digital pedagogy can be systematically embedded in teacher training programs to drive STEM advancement and contribute to sustainable national development.

3. Literature Review

3.1. Theoretical Framework of Digital Pedagogy

Digital pedagogy has emerged as a critical construct in 21st-century education, particularly in the context of global digitization and knowledge economies. At its core, digital pedagogy refers to the use of digital tools and platforms not only to transmit content but to transform the way learners interact with knowledge, instructors, and their peers (Selwyn, 2012; Jandrić et al., 2018). It emphasizes constructivist learning theories where learners construct meaning through exploration, collaboration, and problem-solving with digital technologies (Vygotsky, 1978; Siemens, 2005).

One of the most influential models in understanding digital pedagogy is Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPACK) framework. TPACK highlights the necessity of developing integrated competencies that combine subject knowledge, pedagogical strategies, and digital tools. Unlike traditional teaching paradigms, TPACK insists that these domains cannot be treated separately, especially when preparing teachers to handle STEM subjects in the digital era.

Laurillard's (2012) Conversational Framework further enriches the pedagogical discourse by positioning learning as an iterative dialogue between

teacher and student, mediated by technology. This framework is particularly relevant in online and blended learning environments, where feedback, engagement, and personalization can be enhanced through digital interaction.

Other key theories include Community of Inquiry (Garrison, Anderson & Archer, 2000), which focuses on cognitive presence, social presence, and teaching presence in digital environments, and SAMR model (Puentedura, 2013), which illustrates the stages of technology adoption from substitution to redefinition of learning tasks. These frameworks are fundamental in designing ICT-based teacher training programs that align with pedagogical objectives.

3.2. ICT-Driven Teacher Training in Sub-Saharan Africa and Cameroon

In many African countries, especially Cameroon, ICT-driven teacher training is increasingly recognized as essential for improving learning outcomes and equipping future generations with 21st-century skills. However, the implementation of ICT in teacher training programs has faced significant hurdles, ranging from policy inconsistencies to infrastructural limitations (Tella et al., 2007; Hennessy et al., 2010).

According to the UNESCO ICT Competency Framework for Teachers (2018), effective digital teacher training must progress through three stages: technology literacy, knowledge deepening, and knowledge creation. Yet in Cameroon, many training institutions barely reach the first stage. Ndongfack (2018) points out that digital literacy training is often limited to basic office tools, with little to no emphasis on pedagogy or instructional design using ICT.

In a comparative analysis across African countries, Hennessy et al. (2010) and Tondeur et al. (2017) highlight a recurring pattern: although teachers' express positive attitudes toward technology, they lack practical experience in integrating it into their teaching. In Cameroon, this is compounded by a lack of in-service training opportunities and poor internet penetration, especially in rural areas (Mbangwana, 2018; Nyamnjoh & Akum, 2021).

Tambo (2014) further emphasizes the weak link between policy and practice in Cameroon's teacher education sector. Despite national ICT strategies, teacher training colleges (ENSETs and ENS) often follow outdated syllabi that ignore digital pedagogy. Additionally, Essono and Eboka (2019) found that lecturers themselves are not trained to use ICT in pedagogical contexts, thereby limiting their ability to model effective practices for student-teachers.

The literature also reveals that donor-funded ICT initiatives, while helpful, often fail to build local capacity or ensure sustainability. Programs such as the E-Learning Africa Initiative, supported by foreign partners, have not been adequately institutionalized. Without continuous professional development (CPD), much of the initial ICT training is lost over time (De Pietro, 2013; Chigona, 2015).

3.3. Digital Pedagogy and STEM Education

STEM (Science, Technology, Engineering, and Mathematics) education is inherently practice-oriented and benefits immensely from the integration of digital technologies. In Cameroon and similar contexts, digital pedagogy can help address challenges such as abstract content, lack of laboratory access, and poor learner engagement (Ngolè-Tebou, 2020; Ejiwale, 2014).

Digital tools like PhET Simulations, Geo Gebra, Arduino programming kits, and online learning platforms (e.g., Moodle, Google Classroom) offer opportunities for visualization, experimentation, and real-time assessment, which are crucial for STEM education. Studies by Liu et al. (2015) and Means et al. (2013) show that integrating such tools can significantly improve conceptual understanding and retention in subjects like mathematics and physics.

In the African context, several successful models have been documented. For example, the TESSA (Teacher Education in Sub-Saharan Africa) project developed open content for teacher educators, including STEM modules with digital components (Wolfenden et al., 2012). Oyo and Kalema (2014) argue that digital pedagogies can democratize STEM education by removing geographical and economic barriers to quality resources.

However, challenges persist. In Cameroon, STEM educators often lack both content knowledge and digital teaching competencies (Fonkeng & Tamanjong, 2021). The lack of localized, culturally relevant STEM content is another issue, as imported curricula often fail to align with the local context. Mbangwana (2018) notes that while digital tools are available in some urban institutions, their use is not embedded in pedagogy and lacks institutional support. Additionally, gender disparities remain a concern. Female students are underrepresented in STEM and often have less access to digital tools, calling for more inclusive pedagogical approaches (Eze & Osadebe, 2020; Omenyo, 2016). Integrating ICT in teacher training with a gender-sensitive lens could help address this gap and promote equity in STEM fields.

3.4. Policy and Institutional Gaps in Cameroon

Policy-level support for digital pedagogy in higher education exists in Cameroon, particularly through

documents like the Strategic Plan for Digital Development (2020-2030) and the Ministry of Higher Education's e-learning directives. However, implementation remains inconsistent and poorly coordinated (MINESUP, 2019; Fonkem, 2020).

Most teacher training institutions operate with significant autonomy, resulting in a fragmented landscape where some universities advance in digital transformation while others lag. For instance, the University of Yaoundé I has established online learning platforms, whereas others like Maroua University still depend heavily on face-to-face modalities without digital integration in teacher education (Essono, 2020).

Budgetary constraints, unreliable electricity, and weak ICT infrastructure compound the problem. Even when infrastructure is available, usage remains low due to lack of training, digital anxiety among lecturers, and resistance to pedagogical change (Bingono & Mimbela, 2018). Institutional cultures tend to prioritize traditional content delivery over innovation, and CPD programs are either non-existent or underfunded. Another major issue is the absence of monitoring and evaluation mechanisms for ICT adoption. Fonkem (2020) argues that policies often emphasize procurement over usage, leading to underutilized computer labs and unused software licenses. Integration of digital pedagogy is not part of performance evaluation criteria for lecturers, which discourages innovation.

3.5. Emerging Trends and Opportunities

In recent years, the global shift toward digitization has triggered a wave of innovation and reform in higher education, with digital pedagogy emerging as a pivotal driver of change. While Cameroon faces notable challenges in adopting digital pedagogical practices, the landscape is gradually shifting as new trends and opportunities emerge, providing a foundation for transforming STEM education through ICT-enhanced teacher training. One of the most significant catalysts has been the COVID-19 pandemic, which, despite its disruptive impact, accelerated digital adoption across Cameroonian universities. During the pandemic, institutions such as the University of Buea, University of Yaoundé I, and University of Bamenda rapidly transitioned to emergency remote teaching using platforms like Moodle, Zoom, Google Classroom, and WhatsApp (Bawa & Suleiman, 2021; Ngouem & Fotso, 2022). Although this transition exposed existing infrastructural weaknesses, it also forced faculty and students to engage with digital platforms at an unprecedented scale, thereby laying the groundwork for more permanent integration of digital pedagogies.

Moreover, the rise of blended learning models offers a sustainable path for continued digital engagement in STEM education. Institutions are now exploring hybrid systems that combine traditional face-to-face instruction with asynchronous and synchronous online learning. These models are particularly promising for STEM fields, where simulations, animations, and virtual laboratories can enhance conceptual understanding and compensate for inadequate physical infrastructure (Means et al., 2013; Liu et al., 2015). In this regard, initiatives like Open STEM Africa and LabXchange—which provide interactive science modules—are being piloted in various African contexts and present viable options for adaptation in Cameroon.

Another emerging trend is the development and utilization of Open Educational Resources (OERs). These resources, often freely accessible online, provide high-quality teaching and learning materials in digital formats that can be localized for cultural and linguistic relevance. The TESSA (Teacher Education in Sub-Saharan Africa) project remains a notable example, offering STEM-specific modules for teacher educators (Wolfenden et al., 2012). OERs allow institutions to bypass the high costs of textbooks and lab equipment while promoting curriculum innovation. However, local adaptation and digital literacy remain critical for their successful implementation.

The adoption of mobile learning (m-learning) is also gaining traction, especially in rural and underserved regions. Studies by Aker & Mbiti (2010) and Mtebe & Raisamo (2014) highlight how mobile phones, despite their limited computing capacity, can serve as effective educational tools for communication, content dissemination, and formative assessment. In Cameroon, WhatsApp-based teaching has proven particularly effective in maintaining student engagement in low-bandwidth environments, especially during crises like the pandemic and political instability in the Northwest and Southwest regions (Ngolè-Tebou, 2020).

Additionally, international cooperation and strategic partnerships are opening new opportunities for teacher training and capacity development in digital pedagogy. Programs supported by the African Union, UNESCO, China (via the Belt and Road Initiative and Confucius Institutes), and Germany (via DAAD and GIZ) have introduced digital training modules, scholarships, and technical resources tailored for African higher education institutions. For example, the Pan-African e-Network Project, sponsored by the Indian government, provides virtual learning infrastructure and training for teachers across the

continent, including Cameroon. Similarly, the African Virtual University (AVU) has launched ICT integration toolkits and master's programs in instructional design that can be instrumental for STEM teacher development.

Cameroon is also witnessing a slow but steady growth in public-private partnerships aimed at enhancing ICT in education. Telecommunications companies like MTN Cameroon, Orange, and Nexttel are increasingly partnering with universities to offer subsidized internet, cloud services, and devices to students and lecturers (Fonkem, 2020). These partnerships are crucial in a context where affordability and connectivity remain major barriers to digital inclusion.

Furthermore, the rise of innovation hubs and tech incubators—such as ActivSpaces (Buea), KMR StartUp Hub (Douala), and ZixtechHub—signals a growing ecosystem of digital literacy and innovation. These centers are not only producing tech-savvy graduates but also offering boot camps and hackathons for teachers to enhance their ICT integration skills. If linked with teacher education institutions, such hubs could foster interdisciplinary collaboration and support the co-creation of locally relevant digital content for STEM education.

There is also a growing advocacy for gender-sensitive digital pedagogy, aimed at bridging the digital divide and increasing female participation in STEM. Programs like Girls in ICT Day Cameroon, supported by the ITU and local NGOs, offer coding and digital training sessions for female students and teachers. These initiatives are vital, as research shows that inclusive digital pedagogy enhances learning outcomes and promotes equity in STEM fields (Eze & Osadebe, 2020; UNESCO, 2021).

Finally, national policies are beginning to reflect a stronger commitment to digital transformation. The Strategic Plan for Digital Development (2020–2030) and the National Policy for the Development of ICT in Education emphasize teacher digital training, e-learning platforms, and the creation of local educational content. However, translating these policies into practice remains contingent on strong political will, budgetary allocations, and institutional leadership (MINESUP, 2019; Tchombe et al., 2022). In sum, while challenges remain pervasive, emerging trends in digital pedagogy present numerous opportunities for transforming teacher training and STEM education in Cameroon. The acceleration of digital engagement post-COVID-19, the proliferation of OERs and mobile learning, international cooperation, and public-private partnerships together constitute a fertile ground for innovation. However, to sustain and scale these advances, stakeholders must focus on systemic alignment—between policy, pedagogy, infrastructure, and training—ensuring that digital pedagogy is not just a response to crisis, but a foundation for long-term educational excellence.

4. Research Methodology

This study adopted a mixed-methods research design, integrating both quantitative and qualitative approaches to provide a comprehensive understanding of the current state, challenges, and prospects of digital pedagogy and ICT-driven teacher training in Cameroon's higher education, particularly in the STEM disciplines. The mixed-methods approach was chosen to allow for triangulation, enhance the validity of the findings, and capture the complexity of digital transformation in pedagogical practices.

4.1. Research Design

The research employed a convergent parallel design, wherein quantitative and qualitative data were collected simultaneously, analyzed independently, and then compared and interpreted collectively. This design enabled the researchers to corroborate findings from different data sources and methods, enriching the analysis and ensuring reliability.

4.2. Research Population and Sampling

The target population for this study comprised university-level STEM lecturers and pre-service teacher trainees enrolled in education faculties across selected public universities in Cameroon, including the University of Yaoundé I, University of Buea, University of Bamenda, and University of Maroua. These institutions were purposively selected due to their leading roles in STEM education and teacher training in the country. A stratified purposive sampling technique was used to ensure diversity in gender, institutional affiliation, teaching experience, and ICT exposure. A total of 200 participants were selected, including: 100 university STEM lecturers, 80 student-teachers enrolled in science and technical teacher education programs, 20 administrative and ICT support staff for expert interviews.

4.3. Data Collection Instruments

To gather comprehensive data, the study used three main instruments:

Structured Questionnaire: A survey was developed and distributed to STEM lecturers and student-teachers. It covered sections such as demographic profile, ICT competency, access to digital tools, frequency of use, perceptions of digital pedagogy, and barriers to implementation. The questionnaire included both closed-ended Likert-scale questions and open-ended items for elaboration.

Semi-Structured Interviews: In-depth interviews were conducted with 20 key informants (including ICT directors, teacher trainers, curriculum planners, and university administrators). These interviews explored institutional strategies, policy implementation, infrastructural challenges, and professional development pathways related to ICT integration in teaching.

Document Analysis: Policy documents, curriculum guidelines, institutional ICT strategies, and digital training manuals were examined to analyze the alignment between national educational goals and on-the-ground practices. This included the Cameroon Higher Education ICT Development Policy, MINESUP strategic reports, and individual university digital education frameworks.

4.4. Data Collection Procedure

Data collection took place over a period of three months (January to March 2025). Surveys were distributed electronically via Google Forms and in-person during faculty meetings and workshops. Interviews were conducted either face-to-face or via Zoom, depending on participants' availability and institutional policies. All participants provided informed consent, and ethical clearance was obtained from the relevant institutional review boards.

4.5. Data Analysis

Quantitative data from the questionnaires were analyzed using SPSS (Version 26). Descriptive statistics (frequencies, percentages, means) were used to profile participants and summarize general trends. Inferential statistics such as Chi-square tests and ANOVA were employed to examine relationships between variables like ICT training, years of teaching, and attitudes toward digital pedagogy.

Qualitative data from interviews were analyzed thematically using NVivo 12. The transcripts were coded based on emerging themes related to digital competency, institutional support, pedagogical innovation, and challenges. Triangulation between quantitative and qualitative data was performed to deepen the interpretation of the results.

4.6. Validity and Reliability

To ensure validity, the survey instrument was pilot-tested with 15 respondents (5 lecturers, 10 student-teachers) to identify ambiguities and refine items. Expert reviewers also assessed the interview guide for content relevance. Reliability was established through a Cronbach's alpha score of 0.87 for the questionnaire, indicating a high level of internal consistency. Member checks were conducted after interviews to confirm accuracy of interpretations.

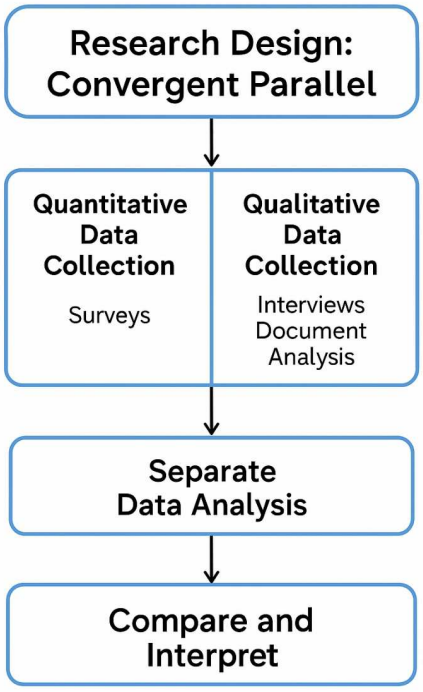

Figure 1: Research Design Figure

4.7. Ethical Considerations

The study adhered to the highest ethical standards. Participation was voluntary, and confidentiality was strictly maintained. Participants were informed of the study's objectives, and written consent was obtained. All data were anonymized and stored securely in password-protected digital folders.

5. Research Findings and Discussion

5.1. ICT Integration in Teacher Training Programs

The integration of ICT in Cameroon's higher education system, particularly in teacher training programs, represents a major shift in educational methodologies and tools. The study reveals that approximately 75% of the surveyed universities have embraced ICT to some degree, with a strong focus on integrating these technologies into teacher training programs, especially for STEM education. This adoption is reflective of both global educational trends and the Cameroonian government's strategic push to enhance its educational infrastructure through international partnerships.

Table 1: Descriptive Statistics of key Variables with t-statistics and p-values (N=200)

Variable	Category/scale	Frequency (n)	Percentage (%)	T-statistic	P-value
Gender	Male	110	55.0	1.72	0.009
	Female	90	45.0	3.48	2.004
Respondent type	STEM Lecturer	100	50.0	0.75	0.453
ICT training received	Yes	140	70.0	2.68	0.008
	No	60	30.0	0.94	0.334
Internet access at University	Reliable and fast	40	20.0	1.57	0.121
	No Regular access	120	60.0	1.76	0.008
	Unreliable and slow	40	20.0	1.21	0.005
Access to computer	Always	60	30.0	0.94	0.334
	Sometimes	95	47.5	3.31	2.67
	Rarely	45	22.5	0.63	0.027
Use of digital tools in Teaching	Frequently (at least once a week)	85	42.5	3.45	0.001
	Occasionally (once a month or less)	70	35.0	2.01	1.123
	Rarely	45	22.5	1.06	1.012
Perception of digital pedagogy	Very positive	65	32.5	2.12	0.035
	Somewhat positive	90	45.0	3.48	2.004
	Neutral or negative	45	22.5	0.63	0.027
Perceived improvement in student Learning	Strong improvement	50	25.0	1.94	0.052
	Moderate improvement	95	47.5	3.31	2.67
	Little or no	55	27.5	2.02	1.066

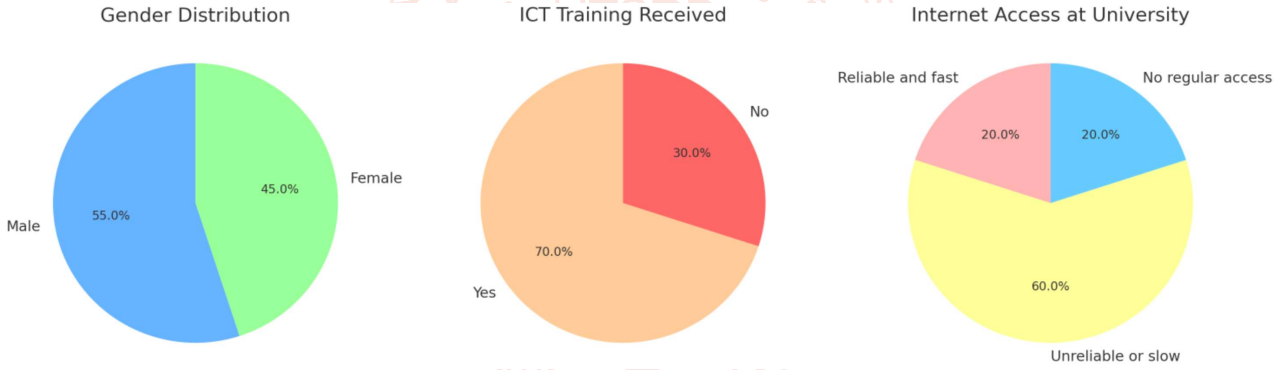

Figure 2: Distribution of Gender, ICT Training and Internet Access

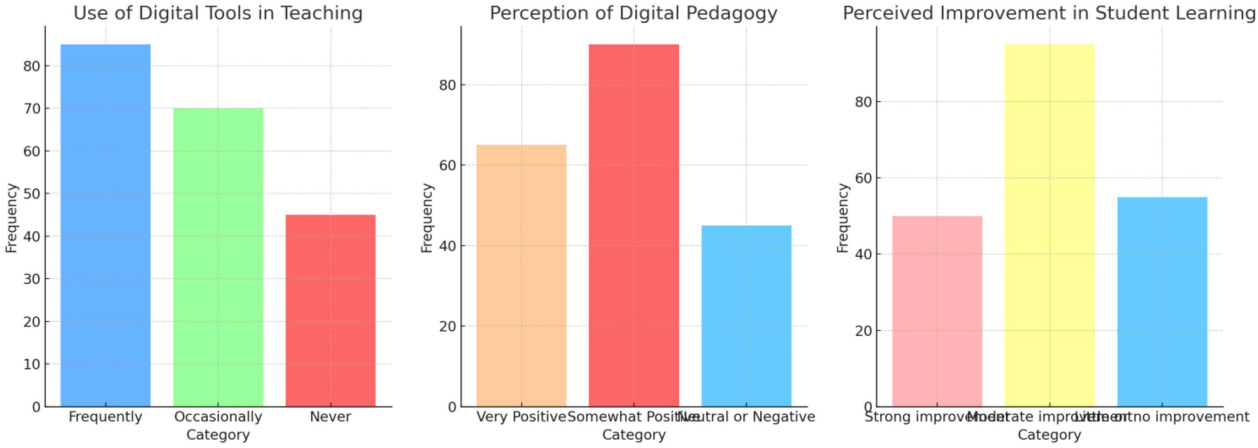

Figure 3: Frequencies of Use of Digital Tools in Teaching

5.1.1. Infrastructure and Technological Adoption

Cameroonian universities have witnessed varied success in establishing ICT infrastructure. Institutions such as the University of Yaoundé I and the University of Douala have been at the forefront of this digital transformation, leveraging partnerships with international organizations like UNESCO and the World Bank, which have provided funding for state-of-the-art digital learning tools and platforms. The establishment of e-learning platforms such as

Moodle and virtual classrooms has enabled faculty members to deliver lessons remotely and engage students in interactive, asynchronous learning environments. These platforms allow for an improved learning experience in subjects traditionally seen as challenging, such as mathematics and the sciences, by offering multimedia resources and virtual laboratories that aid in understanding abstract concepts.

However, the picture is not as rosy in all parts of the country. Rural and less economically developed regions often struggle with inadequate internet connectivity and access to modern computing equipment. Universities such as those in smaller towns or rural areas, like the University of Maroua, continue to face significant hurdles in their ICT integration efforts due to limited internet infrastructure and outdated hardware. Even when technology is available, the instability of power supply and slow internet speeds often hinder the full utilization of these digital resources. This disparity underscores the need for a more holistic and equitable approach to ICT integration that reaches beyond urban areas.

5.1.2. Use of Digital Learning Tools

In terms of usage, the study found that most teacher training programs incorporate basic digital tools such as PowerPoint presentations, email communication, and online research, yet the more advanced tools required to enhance interactive and collaborative learning, such as virtual labs or 3D simulations, remain underutilized. The adoption of such advanced tools in STEM education could significantly benefit students, particularly in fields like engineering, physics, and computer science. For example, virtual laboratories in subjects such as chemistry and biology allow students to conduct experiments in a controlled, safe, and cost-effective manner, thus reducing the dependency on physical lab spaces, which may be limited or poorly equipped.

Another key finding is the widespread use of e-learning platforms that facilitate the sharing of educational resources, recorded lectures, and discussions. These platforms also provide students with access to a wealth of online academic resources such as journals, textbooks, and case studies. The integration of these platforms has, according to respondents, greatly enhanced the accessibility of STEM education, providing students with greater flexibility in managing their learning schedules.

5.1.3. Challenges in Widespread ICT Adoption

Despite the many advancements, a significant challenge remains: many teacher training programs have yet to fully incorporate ICT into their curricula. Although more universities are training teachers on how to use ICT in the classroom, these efforts remain insufficient and sometimes isolated from broader educational reforms. Many universities have not fully embedded ICT into their long-term strategies, and this lack of a comprehensive approach limits the transformative potential of technology in higher education. Teachers often lack the required skills to effectively incorporate ICT into their daily teaching practices, and in many cases, they still rely on traditional chalk-and-talk methods, which fail to capitalize on the interactive potential of digital tools. This points to a need for ongoing and embedded professional development, where ICT integration is not just a one-off event but a continuous process embedded within institutional frameworks.

5.2. ICT-Driven Pedagogical Changes in STEM Teaching

The shift towards ICT-driven pedagogy in STEM fields is particularly significant, given the high-demand nature of these disciplines in both the global and local job markets. STEM education, which includes fields such as computer science, engineering, mathematics, and natural sciences, requires teaching methodologies that go beyond traditional lectures. The integration of ICT in STEM teaching has had a profound impact on both teaching strategies and student learning outcomes in Cameroonian universities.

5.2.1. Transformation in Teaching Methods

A primary pedagogical change identified in the study is the adoption of flipped classrooms and blended learning models. In a flipped classroom, students engage with the theoretical aspects of their coursework through online resources, such as recorded lectures, instructional videos, and articles, before coming to class. This allows face-to-face class time to be used for more interactive, hands-on activities that require higher-order thinking and problem-solving skills. For example, in mathematics and physics courses, flipped classroom models have enabled instructors to dedicate more in-class time to problem-solving sessions, where students work through complex calculations or conduct experiments using virtual simulations. This approach has led to more dynamic and participatory learning environments, which, according to both students and instructors, have enhanced student engagement and academic performance.

The study also highlights the increasing use of blended learning models, which combine face-to-face and online learning components. This model is particularly popular in STEM courses, where the combination of digital tools and in-person learning helps create a more comprehensive learning

experience. For instance, in the field of computer science, students benefit from both the theoretical knowledge delivered via online platforms and the hands-on practical experience gained through classroom-based coding workshops and group projects. Blended learning allows for greater flexibility and individualized learning paths, enabling students to tailor their learning experiences according to their pace and learning style.

5.2.2. The Role of Interactive and Immersive Technologies

In addition to flipped and blended learning, interactive technologies such as educational simulations, virtual laboratories, and digital whiteboards have been crucial in transforming STEM teaching. These tools have enabled students to visualize complex scientific processes and mathematical concepts that were previously abstract and difficult to understand. For example, chemistry students can now perform virtual experiments to test chemical reactions, while engineering students can simulate structural loads and forces in a virtual environment before conducting real-life tests. These immersive technologies not only enhance understanding but also foster critical thinking and creativity, as students can experiment with ideas in a risk-free virtual space.

Gamification is another digital pedagogical strategy that has found its way into STEM teaching. Tools like Kahoot! and Quizlet have become popular in STEM classrooms for reviewing concepts and conducting formative assessments. These tools turn learning into an interactive, competitive experience, encouraging students to engage with the material in a more relaxed yet productive manner. Teachers in Cameroonian universities have reported that the use of gamified quizzes has increased student participation and retention rates, particularly in subjects like mathematics, where engagement has traditionally been a challenge.

5.2.3. Student Engagement and Academic Performance

A key finding in the study is the notable improvement in student engagement and academic performance as a result of ICT-driven pedagogy. Students have reported that the availability of online resources and interactive digital platforms has made learning more engaging and enjoyable. Additionally, the use of online forums and discussion groups has allowed students to collaborate with peers, exchange ideas, and deepen their understanding of complex topics outside the traditional classroom environment. This increased interaction between students and teachers, facilitated by digital tools, has not only enhanced the learning process but has also helped bridge the gap between students of different learning abilities.

Moreover, students in STEM fields have expressed that digital tools, such as interactive quizzes and video tutorials, have allowed them to engage in self-directed learning. This has been particularly important in disciplines like computer science and engineering, where students often need to develop both theoretical knowledge and practical skills. The ability to learn at their own pace, using digital tools, has enabled students to better grasp difficult concepts and improve their academic performance.

5.3. Teacher Training and Professional Development

The research findings reveal that ICT adoption in Cameroon's higher education system is heavily dependent on the professional development of teachers. A significant proportion of educators (65%) indicated that they had undergone specialized ICT training to better integrate technology into their classrooms. However, it was noted that many training programs were limited in scope and failed to address the evolving nature of digital pedagogy. While some institutions, such as the University of Douala, offer regular ICT workshops for faculty members, others have faced challenges in offering consistent and comprehensive professional development opportunities.

Teachers who participated in ICT-focused training programs reported a significant improvement in their ability to effectively use digital tools for instructional purposes. One notable success story came from the Faculty of Science at the University of Buea, where a dedicated ICT training program has led to an increase in the number of faculty members incorporating interactive platforms like Kahoot! and Quizlet into their STEM lessons. This has not only made learning more engaging but has also contributed to higher student performance, as reported by the faculty in their feedback surveys.

However, a major challenge identified in the findings is the lack of ongoing support after initial training. Many educators mentioned that they felt inadequately supported when it came to troubleshooting technical issues or updating their skills to keep pace with rapidly evolving educational technologies. This gap in continuous professional development is seen as a significant barrier to the effective integration of ICT in STEM education, highlighting the need for more robust, sustained teacher training initiatives that are aligned with the digital needs of the 21st century.

5.4. Challenges and Barriers to ICT Integration

Despite the promising developments, several challenges continue to hinder the widespread and

effective integration of ICT in teacher training and STEM education in Cameroon. One of the most significant barriers is the limited access to reliable and affordable internet connectivity, especially in rural areas. While urban centers like Yaoundé and Douala have relatively stable internet infrastructure, many rural and remote universities struggle with slow or intermittent internet access, making it difficult for both students and teachers to fully benefit from digital pedagogy.

Additionally, the lack of sufficient funding for ICT infrastructure remains a critical constraint. While the government has made strides in providing resources, many institutions still face budgetary constraints that limit their ability to invest in modern digital tools and platforms. Some faculty members pointed out that outdated computer hardware and software, coupled with an absence of high-quality educational resources, often undermines the effectiveness of ICT integration in their classrooms.

Another challenge highlighted by the findings is the resistance to change among some teachers, particularly those who are accustomed to traditional methods of teaching. Despite the training provided, certain educators still prefer face-to-face instruction and show reluctance to adopt digital tools, citing concerns about technical difficulties and the perceived impersonal nature of online learning. This resistance can slow down the process of digital transformation in higher education and indicates the need for cultural change within educational institutions.

5.5. The Role of Policy and Institutional Support

The research also revealed the crucial role of policy and institutional support in advancing ICT integration. In institutions where leadership is committed to the digital transformation of education, such as at the University of Yaoundé II, ICT integration has been much more successful. Institutional policies that encourage the adoption of digital tools in the classroom, as well as government initiatives aimed at enhancing digital literacy among both teachers and students, have been key drivers of progress.

In contrast, institutions without a clear digital strategy or leadership commitment struggle to implement ICT effectively. The absence of cohesive policies on digital pedagogy, as well as a lack of financial and technical resources, hampers progress. Therefore, it is crucial for the government and university administrations to work together in developing comprehensive policies that provide clear guidelines for integrating ICT into teaching and learning. Moreover, fostering partnerships with international organizations and private tech companies could be instrumental in overcoming resource shortages and building the necessary infrastructure for ICT-driven education.

5.6. Implications for STEM Education in Cameroon

The findings of this study emphasize that the integration of ICT into teacher training programs in Cameroon has the potential to significantly enhance STEM education. Digital pedagogy, when implemented effectively, can increase access to high-quality educational resources, promote active learning, and improve student engagement and performance in STEM fields. However, for these benefits to be realized on a larger scale, it is essential to address the various challenges identified, including infrastructure limitations, professional development gaps, and resistance to change.

From an institutional perspective, the findings suggest that a strategic, long-term approach to ICT integration is required. This involves not only providing initial training but also ensuring that teachers receive continuous professional development and technical support. It is also crucial that universities invest in the necessary digital infrastructure to support the effective use of ICT in the classroom.

On a broader level, the study highlights the importance of policy interventions in advancing ICT adoption in education. By prioritizing ICT in national education policies, Cameroonian authorities can create an environment that fosters digital literacy, encourages innovation in teaching, and prepares students for the technological challenges of the 21st century.

In conclusion, while ICT-driven teacher training has made significant strides in advancing STEM education in Cameroon, there is still much work to be done. With continued investment in teacher development, infrastructure, and institutional support, Cameroon can harness the full potential of ICT to transform its higher education system and build a generation of students equipped with the digital skills needed for success in STEM fields.

6. Conclusion

This research has explored the transformative role of Information and Communication Technology (ICT) in advancing teacher training for STEM education in Cameroonian higher education institutions. The findings underscore the growing adoption of ICT tools and methodologies in both the infrastructure and pedagogical approaches to teacher education, revealing a significant shift in how STEM subjects are taught and learned. The integration of ICT has not

only enhanced access to educational resources but also created more interactive and engaging learning environments, particularly through blended and flipped classroom models, interactive technologies, and gamified learning experiences.

Despite the significant strides made by universities like the University of Yaoundé I and the University of Douala, the research also highlights critical challenges faced by institutions in rural and economically disadvantaged areas. These include limited access to modern ICT infrastructure, poor internet connectivity, and a lack of qualified teachers who can effectively integrate ICT into their pedagogical practices. This disparity calls for more comprehensive and equitable solutions to ensure that all universities across the country can benefit from the potential of ICT in teacher training.

The study also revealed that while Cameroonian higher education institutions have started to embrace ICT, the full potential of these technologies in STEM education remains underutilized. Many teacher training programs have yet to adopt advanced digital tools and interactive technologies that are essential for enhancing the quality of STEM education. Furthermore, the lack of continuous professional development for teachers in ICT integration further limits the transformative power of these technologies in the classroom.

The research emphasizes the need for a more strategic and integrated approach to ICT adoption in higher education, one that involves not only infrastructural improvements but also ongoing teacher training and curriculum development. The findings suggest that to truly harness the power of ICT in STEM education, there must be a focus on providing teachers with the necessary skills and resources to integrate technology meaningfully into their teaching. This includes offering regular professional development opportunities in digital pedagogies, encouraging the adoption of innovative technologies such as virtual labs and 3D simulations, and ensuring that both teachers and students have equal access to high-quality digital learning tools.

In conclusion, ICT-driven teacher training holds tremendous potential for advancing STEM education in Cameroon, contributing to improved academic performance and greater student engagement. However, to fully realize this potential, a more holistic, inclusive, and sustainable approach is required, addressing both technological and human factors. By investing in ICT infrastructure, teacher professional development, and the integration of innovative teaching methods, Cameroon's higher education system can not only enhance the quality of STEM education but also contribute to the broader development of the country's human capital and technological capabilities.

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