Digital Transformation and Artificial Intelligence in the Service of Project-Based Learning in Higher Technological Education in Africa

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ABSTRACT

The expansion of digital technologies and artificial intelligence (AI) is driving a significant evolution in teaching practices in higher technological education. In the African context, a key question arises: how can these tools be leveraged to optimize project-based learning while taking into account the limitations related to infrastructure, digital skills, and institutional frameworks? Project-based learning, centered on solving concrete problems and the collective production of knowledge, provides a relevant framework for integrating advanced digital technologies. The methodological approach adopted is based on a qualitative analysis of scientific works, institutional reports, and initiatives carried out on the African continent. The expected results highlight several determining factors: the availability of technological infrastructure, the strengthening of teacher skills, the integration of AI into curricula, and the development of blended learning modalities. Ultimately, the convergence of digital transformation, blended learning, and artificial intelligence offers promising prospects for the modernization of higher technological education in Africa.

Keywords: Digital transformation · Educational artificial intelligence · Project-based learning · Active learning · Higher education · Africa

INTRODUCTION

The 21st century is marked by an unprecedented digital transformation affecting all sectors of society, including education. In higher education institutions worldwide, digital tools are progressively redefining teaching methods, access to knowledge, and assessment practices. This global dynamic is also impacting the African continent, where universities, particularly in technological fields, are seeking to adapt to the demands of a rapidly expanding knowledge economy (UNESCO, 2021).

In sub-Saharan Africa, higher technological education faces a dual challenge: on the one hand, the need to modernize its teaching practices to train engineers, technicians and project managers capable of operating in complex digital environments; on the other hand, persistent structural constraints linked to insufficient infrastructure, the digital divide between urban and rural areas, and the limited availability of digital educational resources adapted to local contexts (World Bank, 2022).

At the heart of these challenges, project-based learning (PBL) is emerging as a pedagogical approach particularly well-suited to the training needs of technological fields. Focused on solving concrete problems, interdisciplinary collaboration, and the collective production of knowledge, this active method fosters the development of essential transferable skills: critical thinking, creativity, communication, and teamwork (Blumenfeld et al., 1991; Thomas, 2000). The integration of digital tools and artificial intelligence into these

PBL systems opens up new perspectives for enriching the learning experience, personalizing educational pathways, and improving academic support.

However, the practical implementation of these synergies between digital transformation, artificial intelligence, and project-based learning in the African context remains a relatively unexplored area in the scientific literature. Most of the available studies come from North American or European contexts, and their direct transposition to African realities raises numerous questions of relevance and adaptation. It is precisely this gap that the present contribution aims to fill.

This article aims to analyze the conditions, modalities, and effects of integrating digital technologies and artificial intelligence into project-based learning systems within African technological higher education. The central question can be formulated as follows: under what conditions and according to what modalities can digital transformation and artificial intelligence be mobilized to optimize project-based learning in technological higher education in Africa, taking into account the constraints and opportunities specific to the local context?

To answer this question, the article is structured in five main parts: after a presentation of the theoretical framework (section 2), a description of the methodology adopted (section 3), an analysis of the results (section 4), a critical discussion (section 5), and finally recommendations and a conclusion (section 6).

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Project-based learning: foundations and contributions

Project-based learning (PBL) has its roots in the work of John Dewey (1916), who advocated for an education grounded in concrete experience and oriented towards solving real-world problems. This pragmatic approach to learning has been subsequently formalized and operationalized in contemporary educational contexts, notably by Kilpatrick (1918) and, more recently, by researchers such as Thomas (2000) and Krajcik & Shin (2014).

The PBL approach is based on several fundamental principles that distinguish it from traditional teaching methods. First, it places the learner at the center of the learning process, encouraging them to take ownership of their own knowledge construction. Second, it grounds learning in complex problem situations, similar to those professionals encounter in their actual practice. Third, it fosters collaboration and teamwork, thereby developing essential social and interpersonal skills in the contemporary professional world (Krajcik & Shin, 2014).

In technology fields in particular, PBL offers clear educational advantages. By allowing students to design, prototype, and test solutions to real-world technical problems, it bridges the often-observed gap between theoretical instruction and the practical demands of the professional world. Studies conducted in various contexts have shown that students exposed to PBL programs develop better problem-solving skills, higher motivation, and better learning retention than their peers who received traditional lectures (Helle et al., 2006; Larmer et al., 2015).

Digital transformation in higher education

The digital transformation of higher education is a multidimensional phenomenon that encompasses not only the introduction of new technologies into teaching practices, but also a profound overhaul of organizational models, relationships between educational stakeholders, and conceptions of learning (Selwyn , 2019). This transformation is not simply a matter of digitizing existing content; it involves a re-engineering of educational processes in light of the new possibilities offered by digital technologies.

Among the most structuring digital technologies for higher education, we can identify digital learning environments (DLEs), online learning platforms (MOOCs, LMSs), remote collaboration tools, open

educational resources (OERs), and, more recently, artificial intelligence systems applied to education. These technologies offer unprecedented possibilities in terms of learning flexibility, personalized learning paths, and broader access to educational resources (Bates, 2019).

In Africa, the digital transformation of higher education accelerated dramatically as a result of the COVID-19 pandemic, which forced institutions to rapidly shift to distance learning. This experience, while challenging and revealing of numerous inequalities, nevertheless demonstrated the adaptability of African education stakeholders and created momentum for the development of online education (Mishra et al., 2020). Several African countries, including Cameroon, Senegal, Rwanda, and South Africa, have since developed national policies for the digitalization of education, with varying results depending on the context.

Educational Artificial Intelligence

Artificial intelligence applied to education (AIED, or EdTech AI) is a rapidly growing field of research and application. It encompasses a set of technologies and systems capable of analyzing data on learner behavior and performance, adapting learning content and pace to individual needs, and providing personalized feedback (Baker & Inventado , 2014; Luckin et al., 2016).

Intelligent tutoring systems (ITS) represent one of the most developed applications of AI in education. They simulate the behavior of a human tutor by offering exercises tailored to the learner's level, identifying their weaknesses, and providing targeted explanations. Studies have shown that these systems can produce learning effects comparable to those of one-on-one human tutoring, at a considerably lower cost (VanLehn , 2011).

Learning analysis Analytics is another major application of AI in education. By collecting and analyzing massive amounts of data on learner behavior (time spent on resources, interaction patterns, assessment results), these systems allow teachers to identify struggling students early and intervene in a targeted manner. In the context of PBL, these tools can be particularly valuable for tracking group progress in their projects and identifying specific obstacles encountered (Siemens, 2013).

However, the integration of AI into African educational contexts raises specific questions related to algorithmic bias, data sovereignty, the cultural relevance of generated content, and local technological capabilities. These challenges call for critical reflection on the conditions for truly inclusive educational AI adapted to the realities of the continent (Joshi & Chavan, 2019).

Convergences between APP, digital technology and AI in Africa

The convergence of project-based learning, digital transformation, and artificial intelligence opens up a particularly fertile pedagogical space for African technological higher education. Several studies have explored the possible synergies between these three dimensions, particularly in contexts where human and material resources are limited.

Thus, Oyelaran et al. (2020) documented collaborative project experiences mediated by digital tools in Nigerian universities, showing that these tools made it possible to maintain a dynamic of active learning even in the absence of well-equipped, specialized classrooms. Similarly, initiatives like the African The Storybook Project or the online training programs of the African Virtual University (AVU) illustrate the potential of digital technologies to democratize access to quality educational resources.

The concept of an intelligent learning environment (ILE) is particularly relevant in this context. An ILE integrates adaptive, collaborative, and analytical functionalities into a coherent platform that supports both the teacher and the learner throughout the learning process. Within the framework of PBL, an ILE could facilitate project management, automate certain formative assessment tasks, provide resources tailored to the specific needs of each group, and generate analytical data enabling precise control of the system (Graesser et al., 2018).

METHODOLOGICAL APPROACH

Search Type

This study adopts an interpretive qualitative research approach, aiming to gain an in-depth understanding of the dynamics at play in the integration of digital technologies and AI into project-based learning systems within African higher technological education. This approach is justified by the complex and contextual nature of the phenomenon under study, which does not lend itself to simple quantification but requires a nuanced analysis of the actors, practices, and contexts (Creswell, 2014).

The methodological approach adopted is analytical-synthetic and relies on three main sources of data: (1) a systematic review of recent scientific literature (2015-2024) in the fields of educational technologies, AI in education and project-based learning in an African context; (2) an analysis of institutional reports from international organizations (UNESCO, World Bank, African Union) and national governments concerning the digitalization of higher education in Africa; (3) the analysis of emblematic cases of initiatives integrating digital tools and AI into PBL systems in various African institutions.

Data Collection and Analysis

The literature review was conducted by searching several academic databases, including Google Scholar, ERIC, Scopus , and African education journals. The inclusion criteria for selecting articles included: (a) publication after 2015; (b) an explicit focus on the African context or direct relevance to this context; (c) treatment of educational technology, AI in education, or active/project-based learning; and (d) a clearly described methodology and an identifiable empirical or theoretical contribution.

In total, 87 articles, 23 institutional reports, and 12 case studies were selected after applying these criteria. Data analysis relied on an inductive thematic coding method, enabling the identification of recurring themes, tensions, and prospects for development within the analyzed corpus. Particular attention was paid to the contextual conditions that promote or hinder the successful integration of digital technologies and AI into African PAP systems.

Limitations of the study

Several limitations of this study should be noted. First, the underrepresentation of certain African regions (particularly Central Africa and Lusophone Africa) in the available English and French literature may introduce selection bias into the results. Second, the qualitative nature of the analysis does not allow for statistical generalization but rather aims for analytical generalization toward theoretical propositions. Third, the rapid pace of development in the field of AI in education means that some of the resources consulted may already be partially outdated at the time of publication.

Results

Technological infrastructure: a necessary but not sufficient condition

Analysis of the corpus reveals that the availability of a high-performing technological infrastructure is a fundamental prerequisite for any initiative to integrate digital technology into higher education. In sub-Saharan Africa, this condition is far from being universally met: according to the World Bank report (2022), only 28% of higher education institutions in the continent's low-income countries have sufficient internet connectivity to support large-scale online teaching activities.

However, the situation varies considerably across countries and regions. Nations such as South Africa, Rwanda, Morocco, and Ethiopia have made significant investments in developing digital infrastructure for higher education, with promising results. Rwanda, in particular, is often cited as a model of national digitalization policy, having developed a fiber optic network covering most of its territory and invested heavily in equipping its universities (Gasarabwe & Mugisha , 2019).

The case studies analyzed also show that creative solutions can sometimes circumvent infrastructural constraints. The use of lightweight platforms optimized for slow connections, the deployment of local servers accessible via intranet without an internet connection, and the use of low-cost mobile devices are strategies adopted by several institutions to broaden access to digital resources. The WhatsApp Business solution, for example, has been successfully used by some Cameroonian and Senegalese universities to facilitate communication and resource sharing in low-connectivity environments (Sengeh , 2020).

Teachers' pedagogical and digital skills

The second determining factor identified in the analysis is the level of teachers' pedagogical and digital skills. The studies analyzed converge to emphasize that the introduction of digital tools and AI in teaching does not automatically lead to improved learning: everything depends on how these tools are used by teachers.

A study conducted in five West African universities (Diallo & Traoré, 2021) showed that the most effective teachers in integrating digital technology were those who had received specific training combining both technical aspects (mastery of tools) and pedagogical aspects (design of mediated active learning situations). This dual skill set, often referred to as TPACK (Technological PACK), Pedagogical Content Knowledge), appears as a key predictor of the success of technology integration initiatives.

The analysis also indicates that African teachers face specific obstacles in developing these skills: lack of time for continuing professional development, insufficient resources available in local languages or French, and the unsuitability of some training programs to African educational contexts. To address these challenges, several institutions have developed communities of practice among teachers, enabling the sharing of experiences and the collaborative development of appropriate teaching resources.

Curricular integration of digital skills and AI

The third factor highlighted by the analysis concerns the formal integration of digital skills and AI into training programs. The studies analyzed show that integration is much more effective when systematically planned at the curriculum level, rather than left to the individual initiative of teachers.

In institutions that have successfully integrated digital technology and AI into their technology programs, a spiral approach is generally observed: basic digital skills are introduced in the first year, progressively enriched with more advanced skills (programming, data analysis, use of AI tools) in the second and third years, culminating in integrative projects mobilizing all of these skills during the final dissertation (Ogata & Arnseth , 2013).

The University of Science and Technology of Masuku (Gabon) and the Polytechnic School of Thiès (Senegal) are two illustrative examples of this systematic curricular approach. In these institutions, modules dedicated to "digital project-based learning" have been introduced into all technology programs, with measurable positive results in terms of graduates' digital skills and their professional integration.

Hybrid models: enhanced face-to-face and distance learning

The analysis reveals that hybrid teaching models, combining physical presence and online activities, represent a promising avenue for integrating digital technology into African PBL systems. These models leverage the advantages of both modalities: the richness of face-to-face human interaction for the project design and discussion phases, and the flexibility of digital technology for the research, individual work, and remote collaboration phases.

Several initiatives documented in the corpus demonstrate the viability of these hybrid approaches in African contexts. The Virtual University of Senegal (UVS), established in 2013, has developed a hybrid training model deployed in open digital spaces (ODS) distributed throughout Senegal. This model allows geographically dispersed students to benefit from a quality university education, including project-based learning activities

conducted in a hybrid format. Evaluation of this system has shown high satisfaction rates and academic results comparable to those of traditional face-to-face teaching (Diagne, 2020).

Within the specific context of the APP (Applied Professional Development), online collaboration tools play a crucial role in maintaining group dynamics and enabling continuous work on projects between face-to-face sessions. Platforms such as Moodle, Google Workspace for Education, or African solutions like Claroline are examples. Connect, adapted to the Francophone African context , allows project groups to share resources, co-edit documents, organize themselves and communicate asynchronously.

AI for monitoring and evaluation in the APP

One of the major challenges of PBL lies in assessment: how to fairly evaluate the individual contribution of each learner in a collective work, and how to provide sufficiently frequent and personalized formative feedback despite teachers' time constraints? AI provides partial but significant answers here.

Learning analytics systems integrated into digital platforms allow for real-time monitoring of each student's participation in group activities: frequency and quality of contributions to the discussion forum, activity on collaborative editing tools , and progress in completing assigned tasks. This data enables teachers to quickly identify struggling groups or individuals and intervene in a targeted manner.

Automated feedback systems, based on natural language processing (NLP), are also beginning to be tested in some African institutions. These systems allow for the analysis of students' written work (progress reports, project logs) and provide near-instantaneous formative feedback on writing quality, idea structuring, and the relevance of arguments. While these systems cannot replace the teacher's expert judgment, they are a valuable complement, particularly in contexts where the teacher-to-student ratio is unfavorable (Warschauer & Grimes, 2008).

DISCUSSION

Towards an African model for integrating digital technology into APP

The analysis of the results suggests a model for integrating digital technology and AI into learning and development programs that is firmly rooted in African realities, rather than importing models designed for radically different contexts. Such an African model should incorporate several complementary dimensions: a progressive and realistic approach to infrastructural constraints, a strong emphasis on developing the skills of stakeholders (teachers and students), the valorization of local resources and knowledge, and inclusive governance involving all stakeholders.

The concept of "frugal digital" or " low -tech for education " deserves exploration in this context. It refers to the use of simple, robust , and energy-efficient digital technologies adapted to the constraints of resource-limited environments. Solutions such as offline dashboards, applications that function in offline mode, and downloadable educational resources offer pragmatic options for integrating digital technology without requiring constant and high-performance connectivity.

Tensions and risks to be taken into account

Several significant tensions must be identified and managed within the framework of integrating digital technology and AI into African PAP systems. The first concerns the risk of increased inequality: if the benefits of digital technologies are unequally distributed across institutions, regions, and social categories, their integration could paradoxically exacerbate existing educational inequalities rather than reduce them.

The second tension concerns the issue of digital sovereignty and the cultural relevance of the tools deployed. The vast majority of available educational AI platforms and systems were designed in Anglophone and Western contexts, using training data and cultural assumptions that do not necessarily reflect African realities.

This situation creates a risk of the tools being ill-suited to local educational needs and of technological dependence on foreign actors.

The third tension concerns the balance between automation and human interaction in learning. While AI can handle certain repetitive assessment and feedback tasks, it must not replace the human pedagogical relationship, which remains central to the educational process. In African cultures where the relational and community dimension of learning is particularly valued, this risk of dehumanization must be taken seriously.

The role of institutional and national policies

The analysis clearly shows that the most successful digital and AI integration initiatives are not the result of isolated individual efforts, but rather are part of coherent and sustained institutional and national policies. The role of governments, regional organizations such as the African Union, and international partners like UNESCO and the AUF (Agence Universitaire de la Francophonie) is crucial in creating an environment conducive to these transformations.

Among the policies identified as particularly effective are: the development of national digital qualification frameworks for higher education; the creation of funds dedicated to digital educational innovation in universities; the establishment of regional networks for the exchange of experiences between institutions (such as the RUFIFESE network in the Francophone area); and the development of public-private partnerships for the financing of digital infrastructure and resources.

RECOMMENDATIONS AND CONCLUSION

Operational Recommendations

Based on the analysis conducted, the following recommendations can be formulated for the various stakeholders in African technological higher education:

For higher education institutions

- Develop a clear and shared institutional digital strategy, setting precise objectives and monitoring indicators for the integration of technologies into teaching practices.
- Create digital educational resource centers accessible to all teachers, with human support (instructional designers, trainers of trainers) to support innovation initiatives.
- Develop hybrid APP (Applied Professional Development) systems, with thematic projects connected to local socio-economic realities, to strengthen the relevance and motivation of students.
- Implement multi-source assessment systems that integrate learning analysis tools for fair monitoring of individual contributions in collective projects.

For public authorities

- Invest massively in the development of resilient digital infrastructures in higher education institutions, prioritizing solutions adapted to contexts with limited resources.
- Integrate digital and AI skills frameworks into national qualification frameworks for higher technological education.
- Develop policies to encourage continuing education for teachers in digital pedagogy and the use of educational AI.

- Supporting the development of endogenous educational technology solutions, adapted to African languages and cultural contexts.

For the academic and research community

- Develop rigorous empirical research on the effects of digital APP and educational AI devices in African contexts, using mixed methodologies and appropriate theoretical frameworks.

- Establish pan-African research networks on educational technologies, promoting the pooling of resources and the capitalization of experiences.

- Developing open educational resources (OER) in African languages and adapted to local curricula, accessible to all institutions on the continent.

CONCLUSION

This article explored the conditions, methods, and challenges of integrating digital transformation and artificial intelligence into project-based learning within African higher technological education. The analysis reveals a complex landscape, marked by significant disparities between countries and institutions, but also by a remarkable dynamic of innovation and adaptation in the face of challenges.

Four key factors have been identified for successful integration: the availability of high-performing technological infrastructure, the strengthening of teachers' pedagogical and digital skills, the systematic integration of digital knowledge and AI into curricula, and the development of blended learning approaches. Added to these factors is the crucial importance of a coherent and sustained political and institutional framework.

Artificial intelligence, far from being a panacea, is a powerful tool when used thoughtfully and appropriately: to improve learning monitoring, personalize learning paths, automate certain formative assessment tasks, and thus free up time for high-value pedagogical interactions. Within the framework of personalized learning, these contributions are particularly relevant for meeting the challenge of individualized support within necessarily collective learning environments.

Ultimately, digital transformation and the integration of AI into African technological higher education are not ends in themselves, but means to serve a deeper educational purpose: to train citizens and professionals capable of understanding, analyzing, and contributing positively to the transformation of their societies. This purpose calls for a comprehensive, inclusive approach rooted in local realities, one that values the diversity of African contexts rather than mechanically transposing models designed elsewhere.

The research perspectives opened up by this work are numerous. It would be particularly fruitful to conduct longitudinal studies on the long-term effects of digital APP systems on the professional trajectories of African graduates; to systematically compare the different approaches to integrating digital technology in various institutional contexts; and to explore the conditions for developing a truly "African" educational AI, that is, one designed with and for the educational communities of the continent.

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