Transforming Public Sector Capacity-Building: Lean Principles and Digital Micro-Credentials for Environmental Governance in Brazil

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Article

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Abstract

This article investigates the collaborative development and implementation of a modular, Lean-inspired professional development program for public servants in the Brazilian Ministry of Agriculture, integrating digital micro-credentials with participatory instructional design. Drawing on mixed-methods research, the study demonstrates that aligning Lean management tools with digital learning pathways enhances not only process optimization and operational efficiency, but also fosters a culture of continuous improvement and institutional learning within complex, decentralized public sector settings. Quantitative results reveal significant improvements in training completion rates, reduction of process errors, and increased engagement, while qualitative evidence highlights the value of co-constructed content, peer learning, and the democratization of access to professional development. The research also critically examines persistent barriers, such as lack of formal recognition for modular certification and digital inequalities, and contextualizes findings within global debates on educational innovation and sustainable governance. The Brazilian experience provides practical recommendations and theoretical insights for scholars, policymakers, and practitioners aiming to build resilient, adaptive, and citizen-centered public administration.

Keywords: lean management; micro-credentials; public sector innovation; sustainable governance; environmental policy

1. Introduction

Contemporary public administration faces unprecedented challenges driven by the complexities of sustainable development, the need for environmental stewardship, and the demand for efficient, citizen-oriented governance (Bruschi & Forcellini, 2019; Grech et al., 2021; Martha et al., 2021). In the global South, particularly in federative countries like Brazil, these challenges are compounded by structural inequalities, regional disparities, and institutional fragmentation that limit the state's ability to implement effective agricultural and environmental policies (Kluza et al., 2021; Melo & Rezende, 2012; Lukrafka, 2018).

Capacity-building in the public sector has long been recognized as a decisive factor in translating policy intent into impactful results (Martha et al., 2021; Radnor & Walley, 2008; Grech et al., 2021). Yet, traditional training methods, characterized by centralized content delivery, prescriptive curricula, and limited feedback loops, have been insufficient to address the adaptive, technical, and behavioral demands placed on public servants in dynamic, decentralized contexts (Bruschi & Forcellini, 2019; Klein et al., 2022). These limitations are especially acute in the management of intergovernmental transfers for agriculture and environment, where operational inefficiencies, bureaucratic inertia, and gaps between regulation and practice have been widely documented (Kluza et al., 2021; Wiharja et al., 2024; Diniz & Campos, 2020).

Emerging paradigms of lifelong learning and digital innovation have sparked the development of micro-credentialing systems, which offer modular recognition of competencies acquired through practical, context-specific learning (Selvaratnam & Sankey, 2021; Moldovan et al., 2024). Unlike

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traditional certifications, micro-credentials can be tailored to organizational needs, promote continuous upskilling, and facilitate the rapid dissemination of best practices (Morte-Nadal & Esteban-Navarro, 2022; Waithira et al., 2024). This approach aligns with global recommendations to build public sector learning ecosystems that are agile, flexible, and directly connected to organizational goals (Grech et al., 2021; Mnisi, 2023; Tan et al., 2023).

In parallel, Lean management principles, originally derived from the industrial sector, have been increasingly applied to public administration as a means to reduce waste, standardize processes, and foster a culture of continuous improvement (Womack & Jones, 1997; Teeuwen, 2011; Brunetti et al., 2020). Lean tools such as value stream mapping, root cause analysis, and visual management have been demonstrated to enhance process efficiency and service quality in both local and national governments (Bruschi & Forcellini, 2019; Hegedić et al., 2024; Diniz & Campos, 2020). Studies reveal that Lean implementation in public organizations depends on contextual adaptation, participatory design, and sustained leadership engagement (Radnor & Walley, 2008; Johnston & Fenwick, 2024).

The intersection between micro-credentialing and Lean management represents a promising frontier for public sector innovation (Martha et al., 2021; Moldovan et al., 2024). Integrating modular learning with process optimization enables the development of training pathways that are relevant, measurable, and anchored in daily operational reality (Klein et al., 2022; Mnisi, 2023). Such integration promotes not only technical skill acquisition but also the formation of collaborative networks and organizational cultures that support ongoing improvement (Waithira et al., 2024; Brunetti et al., 2020).

Brazilian experiences with the management of decentralized execution terms (TEDs) for agricultural policy illustrate both the obstacles and opportunities inherent in this approach (Kluza et al., 2021; Klein et al., 2022; Martha et al., 2021). Persistent bottlenecks have been attributed to insufficient standardization, limited professional recognition, and lack of effective feedback mechanisms (Bruschi & Forcellini, 2019; Grech et al., 2021; Lukrafka, 2018). Interventions that combined process mapping with participatory training design have achieved measurable reductions in errors, improved compliance, and higher staff engagement (Klein et al., 2022; Diniz & Campos, 2020; Martha et al., 2021).

The use of digital platforms for micro-credential delivery has been essential to democratizing access to professional development in geographically dispersed and resource-constrained regions (Selvaratnam & Sankey, 2021; Moldovan et al., 2024; Grech et al., 2021). Online modules, asynchronous activities, and digital badges have facilitated inclusion while enabling real-time monitoring of learning progress (Tan et al., 2023; Mnisi, 2023). Nevertheless, challenges remain regarding digital infrastructure gaps, regulatory ambiguities, and resistance to new models among senior managers (Waithira et al., 2024; Klein et al., 2022).

From a methodological standpoint, combining Lean and micro-credentials requires collaborative diagnosis, co-creation of learning resources, iterative assessment, and alignment with organizational strategies (Bruschi & Forcellini, 2019; Martha et al., 2021; Klein et al., 2022). The literature highlights the importance of participatory engagement, customization to territorial and functional realities, and a strong feedback culture (Radnor & Walley, 2008; Waithira et al., 2024; Grech et al., 2021).

Empirical research in Brazil and other contexts demonstrates that integrated capacity-building models, when grounded in evidence and collaborative practice, can lead to improved process performance, greater professional confidence, and the institutionalization of best practices (Martha et al., 2021; Brunetti et al., 2020; Hegedić et al., 2024). These models also contribute to organizational learning, fostering environments where innovation is sustained beyond the life of individual projects (Waithira et al., 2024; Grech et al., 2021; Morte-Nadal & Esteban-Navarro, 2022).

Addressing the demands of sustainable governance, particularly in the field of agricultural and environmental management, thus requires moving beyond traditional training paradigms. The integration of Lean and micro-credentialing provides a structured yet flexible pathway for public

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sector learning, aligned with contemporary principles of adaptability, co-production, and digital inclusion (Martha et al., 2021; Selvaratnam & Sankey, 2021; Moldovan et al., 2024).

This article presents a comprehensive analysis of this integrated approach, drawing on recent empirical studies, international and national experiences, and the theoretical evolution of capacity-building in the public sector (Kluza et al., 2021; Lukrafka, 2018; Tan et al., 2023). The following sections will review the state of the art in Lean and micro-credentials in public administration, detail the research methodology, examine findings from the field, and offer recommendations for practice and policy. This analysis seeks to inform both academic debate and real-world reform efforts in public health, environmental governance, and institutional development.

2. Literature Review

Recent transformations in public sector education and professional development have been marked by intense debates around institutional innovation, sustainable governance, and digital adaptation, especially in countries characterized by significant social, territorial, and organizational diversity such as Brazil. The global literature increasingly recognizes that, for public management to effectively contribute to sustainable development and the improvement of collective well-being, it must be grounded in capacity-building strategies that move beyond generic, prescriptive, or fragmented models (Bruschi & Forcellini, 2019; Martha et al., 2021; Kluza et al., 2021). In this context, two interconnected paradigms—Lean management and micro-credentialing—have emerged as central themes in contemporary academic and practical discussions. Both are now considered pivotal for the public sector's ability to respond to the dynamic demands of environmental stewardship, process efficiency, transparency, and citizen-centered service delivery.

The roots of Lean thinking are widely acknowledged in the literature as emerging from Japanese industrial practices, most notably those of Toyota, and subsequently being adapted to a broad array of sectors, including services and public administration (Womack & Jones, 1997; Teeuwen, 2011). Lean is fundamentally oriented toward eliminating waste, streamlining value flows, and engaging all organizational actors in the relentless pursuit of improvement (Bruschi & Forcellini, 2019; Kamaruddin & Hanefah, 2023). In the public sector, these principles have been reframed to account for the specificity of bureaucratic cultures, legal frameworks, and the political nature of state action. Studies in Brazil and internationally have identified value stream mapping, process standardization, and the active involvement of employees in diagnostic and solution-generating processes as core aspects of successful Lean implementation (Brunetti et al., 2020; Diniz & Campos, 2020; Klein et al., 2022; Hegedić et al., 2024).

Despite its origins in manufacturing, Lean's central focus on value creation, as perceived by service users, makes it especially relevant for the public sector, where the final "customer" is the citizen or society itself. Literature has shown that, when Lean is adapted for governmental settings, it supports the development of a culture that values data-driven decision making, participatory management, and incremental change anchored in empirical evidence (Radnor & Walley, 2008; Lukrafka, 2018). Lean interventions in Brazilian municipalities, for example, have been linked to reductions in procedural times, error rates, and costs, as well as improvements in service quality and internal communication (Bruschi & Forcellini, 2019; Klein et al., 2022). International research reinforces that the sustainability of Lean in the public sector depends on leadership commitment, context-sensitive adaptation, the creation of feedback mechanisms, and the engagement of staff at all hierarchical levels (Johnston & Fenwick, 2024; Kamaruddin & Hanefah, 2023; Brunetti et al., 2020).

Concurrently, the literature on professional development and adult learning in public administration has increasingly emphasized the inadequacy of traditional, one-size-fits-all training programs (Grech et al., 2021; Martha et al., 2021; Morte-Nadal & Esteban-Navarro, 2022). Classic models, often delivered through centralized and prescriptive modalities, have struggled to accommodate the growing complexity of public functions, the accelerating pace of regulatory and technological change, and the need for ongoing upskilling. As a result, public servants frequently encounter a disconnect between the content of formal training and the real demands of their work

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environments, with consequences for both organizational performance and professional motivation (Klein et al., 2022; Lukrafka, 2018; Grech et al., 2021).

This backdrop has catalyzed the rise of micro-credentialing, which represents a paradigm shift in how learning, competence, and professional progression are conceptualized and recognized in the public sector (Selvaratnam & Sankey, 2021; Martha et al., 2021; Moldovan et al., 2024). Micro-credentials are defined as short, targeted certifications—often digital—that formally acknowledge the mastery of specific skills, knowledge areas, or behavioral competencies. Their modular nature makes them highly adaptable to organizational and individual needs, supporting the construction of personalized learning trajectories and enabling real-time, evidence-based validation of capabilities (Mnisi, 2023; Grech et al., 2021). They also offer flexibility for public servants in geographically dispersed or resource-constrained environments, as content can be delivered asynchronously and adapted to local priorities (Tan et al., 2023; Morte-Nadal & Esteban-Navarro, 2022).

Multiple studies, including those conducted in Brazil, Spain, and Australia, highlight the benefits of micro-credentials for democratizing access to professional development and enabling just-in-time upskilling (Martha et al., 2021; Selvaratnam & Sankey, 2021; Morte-Nadal & Esteban-Navarro, 2022). They also allow organizations to respond more effectively to changes in policy, technology, or citizen expectations by updating modules or content as new needs arise (Tan et al., 2023). Nevertheless, the literature acknowledges several persistent challenges, such as the lack of formal integration of micro-credentials into public sector career frameworks, the skepticism of traditional managers, digital divide issues, and the need for robust digital infrastructure (Waithira et al., 2024; Klein et al., 2022; Grech et al., 2021).

The intersection between Lean thinking and micro-credentialing is a promising but under-explored area in public sector studies (Bruschi & Forcellini, 2019; Martha et al., 2021; Klein et al., 2022; Waithira et al., 2024). There is growing recognition that combining these two paradigms can yield greater impact than isolated interventions, both in terms of individual learning outcomes and broader organizational transformation. Lean tools provide the analytic and procedural foundation for identifying competency gaps, streamlining work processes, and making visible the value generated at each step of service delivery (Brunetti et al., 2020; Hegedić et al., 2024). Micro-credentials, in turn, translate these insights into modular training interventions, enabling organizations to certify mastery in specific processes or tools and to reward adaptive behavior and innovation (Martha et al., 2021; Mnisi, 2023).

This integration is reflected in recent empirical research from Brazil, which shows that capacity-building programs aligned with Lean mapping and modular certification can significantly improve completion rates, reduce administrative errors, and foster communities of practice within public organizations (Martha et al., 2021; Klein et al., 2022; Waithira et al., 2024). Participatory instructional design—wherein public servants themselves help co-create the content and structure of learning modules—has proven particularly effective in strengthening engagement, relevance, and learning transfer (Bruschi & Forcellini, 2019; Martha et al., 2021). Furthermore, the creation of shared digital repositories of micro-credentials and best practices supports the dissemination of innovation and the institutionalization of successful routines across diverse organizational units and territories (Tan et al., 2023; Moldovan et al., 2024).

International comparative studies reinforce these findings. For example, research on government agencies in Italy, Spain, Kenya, and Indonesia suggests that integrating Lean and modular learning supports the formation of organizational cultures that value continuous improvement, peer learning, and results-based management (Brunetti et al., 2020; Morte-Nadal & Esteban-Navarro, 2022; Waithira et al., 2024; Wiharja et al., 2024). In Spain, modular learning was credited with improving knowledge transfer and alignment between training and institutional goals, while Lean adoption facilitated the removal of procedural bottlenecks (Morte-Nadal & Esteban-Navarro, 2022). Studies in Italy and Brazil highlight that participatory approaches and iterative evaluation cycles are essential for overcoming cultural and structural resistance to change (Bruschi & Forcellini, 2019; Brunetti et al., 2020).

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Nonetheless, the literature remains cautious regarding the risks of superficial adoption or "toolbox" approaches to Lean and micro-credentials (Kamaruddin & Hanefah, 2023; Klein et al., 2022; Lukrafka, 2018). Scholars warn that meaningful transformation requires not only technical solutions, but also changes in mindsets, incentive structures, and institutional values (Grech et al., 2021; Martha et al., 2021). There is consensus that leadership commitment, integrated digital infrastructure, and the alignment of professional development with performance evaluation systems are preconditions for sustainable success (Radnor & Walley, 2008; Johnston & Fenwick, 2024).

Within the Brazilian context, the implementation of Lean and modular capacity-building models has shown particular relevance in the management of Terms of Decentralized Execution (TEDs) for agricultural and environmental policy (Kluza et al., 2021; Klein et al., 2022). Persistent challenges in this domain—such as procedural delays, errors in documentation, and insufficient intergovernmental coordination—have been linked to a lack of standardization, inadequate professional development, and limited feedback loops (Bruschi & Forcellini, 2019; Klein et al., 2022). The literature documents positive outcomes when Lean mapping and micro-credential-based training are used to align competencies with the operational realities of public service delivery, including reductions in error rates and the creation of collaborative learning environments (Martha et al., 2021; Klein et al., 2022).

The literature further discusses the role of digital transformation in enabling and scaling these innovations (Tan et al., 2023; Grech et al., 2021). The adoption of cloud-based platforms, digital badges, and analytics for tracking learning progress have enabled not only greater inclusion of staff from remote or resource-scarce environments, but also real-time adjustment of content and process (Selvaratnam & Sankey, 2021; Moldovan et al., 2024). However, researchers highlight the continued need for investment in digital infrastructure, regulatory adaptation, and strategies to address digital literacy gaps (Waithira et al., 2024; Mnisi, 2023).

In summary, the current body of literature strongly supports the assertion that integrating Lean and micro-credentialing is a promising pathway for advancing sustainable, adaptive, and equitable governance in the public sector (Martha et al., 2021; Brunetti et al., 2020; Hegedić et al., 2024). Such integration fosters a learning ecosystem that aligns capacity-building with operational needs, incentivizes innovation, and supports the continuous improvement required for effective environmental and public health policies. The next section will detail the methodology adopted for the empirical analysis presented in this article, building on the theoretical foundation established here.

3. Methodology

The methodological approach of this research was anchored in a design-based, mixed-methods paradigm, recognized in contemporary literature as particularly suitable for the complex and adaptive environment of public sector innovation. The selection of this methodology is justified by the intricate challenges of promoting capacity-building and sustainable governance in a federative and regionally diverse context like Brazil, where agricultural and environmental policies require not only technical knowledge but also adaptive, iterative learning and organizational reflexivity. In line with recommendations from Brunetti et al. (2020), Bruschi & Forcellini (2019), and Martha et al. (2021), the research design foregrounded cycles of collaborative diagnosis, intervention, evaluation, and iterative refinement, integrating both qualitative and quantitative techniques to generate robust, context-sensitive evidence for both academic and policy audiences.

The fieldwork was situated within the Ministry of Agriculture, specifically targeting teams and managers engaged with the Terms of Decentralized Execution (TEDs), a key instrument for the implementation of federal agricultural policies at state and municipal levels. The decision to focus on TEDs stems from their relevance for public resource allocation, rural development, and the achievement of broader environmental and sustainability goals, as outlined by Kluza et al. (2021) and Klein et al. (2022). The program was operationalized in collaboration with academic partners specializing in public administration, digital learning, and process improvement, ensuring an

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interdisciplinary perspective and access to state-of-the-art instructional design and evaluation frameworks (Grech et al., 2021; Martha et al., 2021; Selvaratnam & Sankey, 2021).

Participant selection followed a purposive sampling strategy, aiming for representation across diverse regional realities, administrative levels, and functional responsibilities within the Ministry. Invitations were first extended to those directly responsible for TED management, but were expanded to include support staff, policy advisors, and technical analysts to capture the multi-layered nature of public sector operations. This approach aligns with the guidance from Radnor & Walley (2008) and Bruschi & Forcellini (2019) that high-quality design-based research in public settings requires a diversity of perspectives, particularly where process innovation and learning transfer are central goals.

Data collection was structured around four interlinked components. The first consisted of a comprehensive documentary analysis, examining legal frameworks, operational guidelines, process manuals, audit findings, and workflow diagrams related to TEDs, as recommended by Diniz & Campos (2020) and Lukrafka (2018). This allowed for the identification of bottlenecks, regulatory ambiguities, and contextual variables shaping the operational environment. The second component involved a series of semi-structured interviews and focus groups with managers and staff at different hierarchical levels. These sessions explored perceived barriers to process improvement, institutional learning needs, experiences with previous training initiatives, and openness to new digital and modular approaches (Klein et al., 2022; Martha et al., 2021).

The third component harnessed digital platform analytics, capturing real-time data on participant engagement with micro-credential modules, completion rates, usage of interactive resources, and time spent on task. These data were essential for understanding learning behaviors in geographically dispersed, digitally mediated environments, as highlighted by Selvaratnam & Sankey (2021) and Moldovan et al. (2024). The fourth and final component included pre- and post-intervention surveys and structured participant observations during workshops, training sessions, and Lean process mapping activities. These instruments enabled both the measurement of knowledge and skill gains, and the direct observation of group dynamics, adaptation processes, and the practical application of Lean tools in real work contexts (Bruschi & Forcellini, 2019; Mnisi, 2023).

The instructional intervention itself was conceived as a modular, blended learning pathway, integrating digital micro-credentials with synchronous and asynchronous activities. The content and structure were co-created with participants in a series of workshops, utilizing Lean tools such as value stream mapping, standardized work protocols, and visual management boards to align learning objectives with actual operational challenges. The modules included topics such as fundamentals of TED management, error reduction in documentation, digital compliance, participatory problem-solving, and continuous improvement for sustainability. Each module culminated in a competency-based assessment, and successful participants received a digital micro-credential, consistent with best practices documented by Martha et al. (2021), Selvaratnam & Sankey (2021), and Moldovan et al. (2024). The flexibility of the blended model enabled participants to engage with learning materials at their own pace, a particularly important feature for staff working in remote or under-resourced settings (Tan et al., 2023; Grech et al., 2021).

Implementation occurred over two main cycles, each lasting six months. The process began with a baseline survey and process audit, followed by the rollout of digital modules and synchronous coaching sessions. Institutional leadership played a key role in endorsing the initiative, providing political and administrative support, and ensuring the integration of results into ongoing policy and management discussions (Brunetti et al., 2020; Klein et al., 2022). Throughout the cycles, participant feedback was actively solicited via surveys, interviews, and online discussion forums, enabling rapid adjustment of module content, sequencing, and pedagogical strategies. Lean “kaizen” events, held at the midpoint and conclusion of each cycle, created opportunities for direct, practice-oriented problem-solving, allowing for the real-time application and validation of new tools and approaches.

Data analysis followed established principles for mixed-methods research. Qualitative materials from interviews, focus groups, and observations were subjected to thematic analysis, using both

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inductive and deductive coding to surface recurring patterns, explanatory factors, and context-specific insights (Martha et al., 2021; Johnston & Fenwick, 2024).

Quantitative data from surveys and digital platform analytics were analyzed using descriptive and inferential statistics to assess changes in knowledge, skills, process efficiency, and error rates before and after the intervention (Mnisi, 2023; Grech et al., 2021). Special attention was paid to triangulation, systematically comparing findings from different sources and stakeholder perspectives to maximize the reliability and validity of conclusions (Bruschi & Forcellini, 2019; Klein et al., 2022). Cases of divergence or negative results were carefully examined and, where possible, attributed to contextual factors such as variations in digital infrastructure, leadership engagement, or local organizational culture (Waithira et al., 2024).

Ethical considerations were fully observed at all stages of the research. Participation was voluntary, informed consent was obtained, and all personal or organizational data were anonymized and securely stored, in accordance with national and international guidelines for research in public administration (Klein et al., 2022; Martha et al., 2021). The research protocol was reviewed and approved by the relevant university ethics committee, ensuring compliance with the highest standards of academic integrity and participant protection (Tan et al., 2023).

In summary, the methodology combined design-based, participatory approaches with rigorous mixed-methods evaluation to produce a robust, context-sensitive analysis of the integration of Lean and micro-credentialing in Brazilian public sector professional development. This methodological rigor provides a strong foundation for the subsequent analysis of findings, institutional barriers, and broader policy implications, fully in line with international standards for research in the field.

4. Results and Discussion

The implementation of a modular, Lean-inspired, micro-credentialed professional development program within the Ministry of Agriculture yielded a complex set of results that illuminate both the transformative potential and the persistent challenges of educational innovation in the public sector. The empirical evidence collected through a robust combination of quantitative and qualitative instruments not only validates several claims found in the international literature but also brings to light new insights regarding the interplay between process optimization, digital learning, and institutional culture in Brazilian federal administration.

One of the most salient outcomes observed during and after the intervention was a substantial increase in participant engagement and learning retention, as measured by digital platform analytics and post-module assessments. Quantitative data indicated completion rates for digital modules consistently above 85%, a significant improvement compared to previous centralized, in-person trainings, which often struggled to surpass 60%. Qualitative feedback collected through reflection journals, open-ended survey responses, and follow-up interviews confirmed that participants found the modular, digital structure more accessible and relevant to their day-to-day professional needs. This is especially important in a context marked by significant regional disparities, where staff in remote or under-resourced offices have historically been excluded from mainstream capacity-building opportunities due to travel, scheduling, or infrastructural barriers (Grech et al., 2021; Tan et al., 2023).

Another notable finding relates to the effectiveness of participatory instructional design—an approach strongly recommended in both Lean and adult learning literatures (Martha et al., 2021; Bruschi & Forcellini, 2019). By involving frontline staff in co-creating the content, sequence, and real-world applications of each micro-credential module, the project fostered a sense of ownership and agency. Participants repeatedly emphasized, both in surveys and group discussions, the value of seeing their operational realities reflected in the learning materials and assessments. This alignment between training and work context not only enhanced motivation but also promoted learning transfer, as evidenced by the successful application of Lean tools to specific, previously intractable bottlenecks in TED management.

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The program's impact on operational efficiency is underscored by multiple data points. Digital platform analytics revealed that the average time required to complete core administrative processes related to TED management fell by approximately 20% across participating units. This finding was corroborated by managerial reports and workflow data, which documented reductions in error rates (particularly in digital documentation and compliance activities), improved adherence to deadlines, and greater consistency in regulatory interpretation. The integration of Lean instruments—such as value stream mapping, standardized checklists, and visual workflow boards—was repeatedly cited by both managers and staff as central to these improvements, echoing international studies that link process mapping and error reduction with organizational learning (Bruschi & Forcellini, 2019; Diniz & Campos, 2020; Klein et al., 2022).

Beyond efficiency, the intervention contributed to the institutionalization of collaborative learning and knowledge sharing. The process manuals, digital checklists, and workflow diagrams developed during the participatory workshops were not only adopted by multiple units but also served as the basis for ongoing "kaizen" cycles—structured, iterative improvement processes embedded into the organizational routine. Several managers reported that the collaborative approach helped break down traditional silos, foster peer mentoring, and create informal communities of practice, in line with recommendations from Waithira et al. (2024) and Johnston & Fenwick (2024). The democratization of knowledge—supported by open access to digital resources and the recognition of diverse learning paths through micro-credentials—was a recurring theme in participant feedback and has clear implications for organizational resilience and adaptive capacity.

Despite these positive outcomes, several institutional and structural barriers were encountered that limited the full realization of the program's potential. Chief among these was the lack of formal recognition of micro-credentials within the Ministry's human resource management and career progression systems. While digital badges and modular certificates were widely valued as symbols of professional achievement and learning, their lack of official status meant that many participants saw limited tangible benefit beyond personal satisfaction. This challenge is consistent with international experiences and signals the need for policy reform to fully embed modular certification in public sector incentive structures (Selvaratnam & Sankey, 2021; Martha et al., 2021).

Another persistent barrier concerned the digital divide and varying levels of technological literacy among staff. Although the blended learning model and asynchronous digital modules substantially increased access for those in remote regions, a minority of participants—particularly older employees and those in offices with unreliable internet connectivity—struggled to engage fully with the online platform. Technical support and additional coaching helped mitigate some of these issues, but the feedback highlights that digital transformation in public sector learning must be accompanied by sustained investment in infrastructure, ongoing digital literacy training, and the simplification of interfaces to ensure inclusion (Tan et al., 2023; Grech et al., 2021; Moldovan et al., 2024).

The presence of hierarchical and cultural resistance to innovation also emerged as a critical theme in both quantitative and qualitative data. Some senior managers expressed skepticism regarding the rigor and sustainability of digital, modular training models, reflecting a broader attachment to traditional classroom-based or lecture-centric approaches. This resistance manifested in delayed uptake in some units, uneven engagement, and reluctance to grant formal time or institutional credit for participation in the new program. The literature on Lean implementation in the public sector identifies similar dynamics, emphasizing that leadership commitment, transparent communication, and visible short-term wins are essential for overcoming institutional inertia (Brunetti et al., 2020; Kamaruddin & Hanefah, 2023; Klein et al., 2022).

Comparative insights from international literature and case studies provide additional context for these findings. Research from Italy, Spain, and Indonesia, for example, demonstrates that the integration of Lean tools and modular certification is most successful when it is supported by comprehensive policy frameworks, strong digital foundations, and active engagement of both leadership and staff in design and evaluation (Brunetti et al., 2020; Morte-Nadal & Esteban-Navarro,

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2022; Wiharja et al., 2024). In Brazil, the contextual adaptation of global best practices—particularly the emphasis on participatory design and iterative feedback—proved central to achieving meaningful impact, supporting the notion that "one size fits all" approaches are inadequate for complex, multi-level public administration systems (Kluza et al., 2021; Klein et al., 2022).

The results also highlight the critical role of continuous evaluation and rapid adaptation. The use of real-time analytics, participant feedback, and ongoing process audits enabled the research team and institutional partners to identify emerging barriers, adjust module content, and refine implementation strategies in response to user needs. This responsiveness is a hallmark of both design-based research and Lean philosophy, reinforcing the argument that sustainable innovation in public sector learning is best achieved through iterative, feedback-driven processes rather than top-down mandates (Martha et al., 2021; Radnor & Walley, 2008).

At a broader level, the program's impact on sustainable governance and public health outcomes is linked to improvements in the technical capacity and adaptive competence of public servants engaged in environmental policy implementation. By aligning professional development with real operational needs—validated through process mapping and participatory design—the initiative supported more effective resource allocation, greater compliance with regulatory requirements, and enhanced responsiveness to local demands and territorial specificities (Kluza et al., 2021; Martha et al., 2021; Klein et al., 2022). These gains are of particular relevance to transdisciplinary journals and the global movement toward integrating public health, environmental management, and administrative reform.

Notwithstanding these successes, several research limitations must be acknowledged. The voluntary nature of participation and the pilot scale of the intervention limited the sample size and may have introduced selection bias. Those who engaged most actively were often the most motivated or digitally literate, which could overstate the program's generalizability to the entire workforce. The reliance on self-reported data and digital analytics also poses risks of measurement bias, although these were partially mitigated by triangulation with independent process audits and managerial reports. Finally, the relatively short duration of the evaluation window—twelve months across two cycles—limits the ability to assess long-term sustainability, institutionalization, and potential spillover effects into broader policy domains.

Despite these constraints, the evidence suggests that the strategic integration of Lean philosophy and micro-credentialing can generate significant, scalable improvements in public sector professional development, operational performance, and organizational learning. The participatory, modular, and digitally enabled model not only increased access and equity but also fostered a culture of continuous improvement, collaborative problem-solving, and evidence-based decision making. The lessons learned reinforce the centrality of leadership engagement, digital equity, and policy alignment to achieving sustainable impact.

In summary, this research advances the field by demonstrating that public sector education and capacity-building initiatives grounded in Lean and modular certification are not only feasible but also desirable in diverse, federative contexts like Brazil. The findings call for a holistic, systems-based approach to innovation—one that aligns instructional design, digital transformation, and institutional strategy with the broader objectives of sustainable development and public health. The recommendations that follow address these imperatives and point the way forward for scholars, practitioners, and policymakers interested in building resilient, adaptive, and citizen-centered public administration.

5. Conclusion

This research has demonstrated that the integration of Lean management principles and modular micro-credentialing into the professional development systems of the Brazilian Ministry of Agriculture offers a compelling model for advancing institutional learning, process optimization, and sustainable public sector governance. The participatory, iterative, and data-driven methodology not only improved operational outcomes—such as reductions in process time, error rates, and service

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bottlenecks—but also contributed to the formation of collaborative cultures within public organizations. These cultures are more resilient, responsive, and capable of adapting to evolving policy demands, technological advances, and the challenges associated with environmental stewardship and decentralized program delivery.

By prioritizing the co-construction of training modules and emphasizing digital flexibility, the program addressed long-standing barriers to professional development in the public sector, including geographic inequity, limited access to traditional training, and the mismatch between generic educational content and specific operational needs. The participatory instructional design and the use of digital analytics allowed for ongoing adaptation and refinement, supporting both immediate learning transfer and the long-term institutionalization of new routines and best practices.

The findings underscore the necessity of embedding capacity-building efforts within broader strategies for digital transformation, policy reform, and human resource development. While the implementation of modular micro-credentials and Lean-based approaches generated significant improvements, their potential for lasting impact will depend on the alignment with formal career progression frameworks, sustained investment in digital infrastructure, and leadership engagement across all administrative levels. The Brazilian case suggests that participatory and context-sensitive innovation, rather than top-down mandates or imported best practices, provides the most promising pathway for strengthening public sector education and, by extension, for advancing sustainable development goals.

Future research should build on these results by conducting longitudinal studies that assess the durability and scalability of such interventions across diverse policy domains and institutional settings. Comparative analyses between different ministries, sectors, and countries could further illuminate the contextual factors that facilitate or hinder the diffusion of Lean and modular learning paradigms. There is also a pressing need for studies exploring the integration of micro-credentialing with national and regional accreditation systems, the evolution of digital literacy among public servants, and the mechanisms by which collaborative learning translates into measurable improvements in environmental and public health outcomes.

Ultimately, this work reaffirms the value of combining evidence-based management, participatory design, and digital innovation to meet the increasingly complex demands of modern public administration. As global challenges related to sustainability, health, and governance become ever more interlinked, the capacity to continuously learn, adapt, and collaborate across institutional boundaries will be central to the legitimacy and effectiveness of the public sector. The lessons from this Brazilian experience offer valuable guidance for scholars, practitioners, and policymakers seeking to design and implement robust, human-centered approaches to public sector education and institutional change.

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