

Smart Curriculum Mapping: A Blockchain Approach to Transparent and Customizable Educational Pathways

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ABSTRACT

Background. Traditional curriculum mapping often faces challenges of transparency, flexibility, and personalization. Existing digital systems tend to be centralized, limiting stakeholder trust and adaptability in designing individualized learning trajectories. Blockchain technology offers an innovative solution to ensure transparency, immutability, and decentralized control over educational data, enabling both institutions and learners to co-create customizable educational pathways.

Purpose. This study aimed to investigate the potential of blockchain-based smart curriculum mapping in fostering transparent governance of curricula and supporting adaptive learning designs. Specifically, it examined how blockchain can integrate institutional requirements with learner-driven customization while ensuring accountability and security.

Method. Using a mixed-method design, the research engaged 210 university students and 45 lecturers across three higher education institutions. Data were collected through surveys, interviews, and prototype testing of a blockchain-enabled curriculum mapping platform. The findings were analyzed using statistical methods and thematic coding to evaluate user perceptions, system usability, and pedagogical impact.

Results. The findings indicate that blockchain-based curriculum mapping enhances trust among stakeholders by ensuring transparent records of course progress and requirements. Students reported increased autonomy in designing personalized pathways, while lecturers emphasized the benefits of immutable documentation for accreditation and evaluation. However, challenges such as technical literacy and system scalability were also identified.

Conclusion. This study highlights the transformative role of blockchain in curriculum management. By integrating transparency, security, and learner-centered customization, smart curriculum mapping offers a scalable model for future educational governance. The findings contribute to both educational technology innovation and institutional policy-making, offering pathways toward more accountable and personalized higher education systems.

KEYWORDS

Blockchain, Curriculum Mapping, Educational Pathways

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INTRODUCTION

Curriculum mapping has long been recognized as a crucial tool in higher education for aligning learning objectives, courses, and expected graduate outcomes. In practice, however, many institutions struggle with issues of transparency, consistency, and flexibility in curriculum implementation. Curriculum mapping often remains an

administrative and centralized exercise, leaving limited space for active participation from both faculty and students in shaping the learning process. The rapid advancement of digital technology has encouraged the development of more adaptive educational management systems. Learning Management Systems (LMS) and online curriculum management platforms are widely adopted, yet conventional approaches still reveal shortcomings. Centralized data, restricted accessibility, and potential inconsistencies in academic records represent ongoing barriers to truly accountable governance of educational programs.

In this context, blockchain has emerged as a promising alternative. Initially popularized in the financial and cryptocurrency sectors, blockchain technology has increasingly entered the educational domain (Katumba, 2024; Nalinipriya, 2025; Syed, 2023). Its distributed, secure, and immutable characteristics make it particularly suitable for managing academic data and curriculum structures. With its transparency, blockchain ensures that every modification in the curriculum is clearly documented and traceable for all stakeholders. Smart curriculum mapping powered by blockchain enables the creation of more personalized and flexible educational pathways. Students are no longer bound by rigid curriculum structures; instead, they can design their own learning journeys based on personal interests, career goals, and institutional requirements. At the same time, universities retain oversight to maintain accredited learning standards, thus balancing individualized education with academic accountability.

Furthermore, blockchain fosters collaboration across universities, certification bodies, and even industry partners. Academic credentials, competency certificates, and non-formal achievements can all be integrated into a secure and verifiable blockchain ledger. This innovation allows students to maintain a comprehensive digital portfolio that is recognized across institutions without burdensome administrative processes (Ismail, 2024; Larriva-Novo, 2023; S. Singh, 2024). The demand for transparency in education has become increasingly urgent in the age of globalization. Cases of grade manipulation, misuse of academic data, and unaccountable curriculum revisions have undermined public trust in educational institutions. Blockchain, with its distributed ledger system, offers guarantees of data authenticity while minimizing opportunities for administrative misconduct.

From a pedagogical perspective, blockchain-based smart curriculum mapping also supports the development of adaptive learning approaches (Abdualwhab, 2024; Pourmoradnasseri, 2023; Satyanarayana, 2024). Dynamically mapped curricula can respond to the fast-changing landscape of knowledge and labor market demands. This is particularly relevant in the era of Industry 4.0 and Society 5.0, where digital literacy, interdisciplinary collaboration, and technological competence are essential skills for graduates. Despite its potential, implementing blockchain in curriculum systems presents challenges. A key barrier lies in the technological literacy of stakeholders—faculty, students, and administrators alike. The complexity of blockchain may provoke resistance unless accompanied by proper training and awareness-building. Additionally, issues of infrastructure readiness, implementation costs, and system scalability must be addressed to ensure sustainable adoption.

Existing literature on blockchain integration in education is still relatively nascent, yet early studies highlight its promising applications (Behki, 2024; Muthukumaran, 2024; Narang, 2025). Research has primarily focused on validating diplomas, managing certifications, and ensuring inter-institutional recognition of learning achievements. However, curriculum-level integration—particularly in the form of adaptive and personalized curriculum mapping—remains underexplored, thus presenting a valuable research gap. By introducing the concept of smart curriculum mapping, this study moves beyond administrative efficiency to consider how blockchain can reshape the

design of learning pathways. This aligns with the paradigm of future education, which emphasizes lifelong learning and personalized educational experiences tailored to learners' unique contexts.

At the policy level, blockchain adoption carries significant implications for both national and international education governance (Arriba-Pérez, 2025; Mishra, 2023; Shumba, 2022). A decentralized system creates opportunities for more transparent accreditation processes and quality assurance mechanisms. When broadly implemented, blockchain has the potential to reduce information asymmetry and accelerate credential recognition across borders. Ethical and privacy concerns must also be carefully considered. Blockchain-based curriculum mapping involves handling sensitive student data, such as academic records, learning preferences, and non-formal credentials. Therefore, robust data protection measures and clear regulatory frameworks are essential to safeguard privacy and prevent unintended misuse.

The role of educators is equally reshaped by this technological shift. Faculty members, traditionally responsible for delivering content within fixed curricula, will increasingly function as facilitators and mentors. They must support students navigating diverse, personalized learning pathways, which requires adaptability, innovative teaching strategies, and stronger student-centered engagement. In the long term, blockchain-enabled smart curriculum mapping can serve as a foundation for more inclusive, transparent, and sustainable education systems. It opens opportunities for learning that transcends institutional and geographic boundaries, supporting cross-institutional collaboration and global recognition of competencies. In this way, the vision of producing globally competitive yet locally rooted graduates becomes more attainable. Ultimately, the urgency of this research lies in the pressing need to formulate a curriculum model that integrates transparency, flexibility, and personalization with advanced technological solutions. Smart curriculum mapping through blockchain not only addresses current educational challenges but also paves the way for transformative innovation in higher education governance in the digital era.

RESEARCH METHODOLOGY

This study employed a mixed-methods research design to capture both the quantitative and qualitative dimensions of blockchain-based smart curriculum mapping. Quantitative data were collected through structured surveys administered to 210 university students and 45 lecturers from three higher education institutions. (Ali, 2023; Kumar, 2025; M. Singh, 2025) The survey focused on perceptions of transparency, usability, and customization in curriculum design. Descriptive statistics and inferential analyses were used to identify patterns and differences in stakeholder responses, while ensuring the reliability and validity of the measurement instruments.

To complement the quantitative findings, qualitative data were gathered through semi-structured interviews and prototype testing of a blockchain-enabled curriculum mapping platform. Interviews with selected faculty members, administrators, and students provided deeper insights into perceived benefits, challenges, and pedagogical implications. The prototype was tested in controlled settings to observe usability and system functionality. Data were analyzed thematically, allowing the research to triangulate perspectives and provide a holistic understanding of the potential of blockchain in supporting transparent and customizable educational pathways.

RESULT AND DISCUSSION

The results indicate that the blockchain-based smart curriculum mapping platform significantly enhanced transparency and accountability in curriculum design. Both students and lecturers reported high levels of trust in the immutability of academic records, as well as satisfaction with the system's ability to track changes in real time. Students expressed increased autonomy in

customizing their learning pathways, while faculty members valued the system for simplifying documentation and aligning courses with institutional standards. Statistical analysis revealed strong positive correlations between blockchain integration and perceived curriculum flexibility, while interviews highlighted improved collaboration among stakeholders in the design process.

Despite these benefits, several challenges emerged during implementation. Technical barriers, such as the need for robust infrastructure and digital literacy training, were consistently reported by participants. Concerns about scalability and the management of sensitive personal data also surfaced, suggesting that regulatory frameworks and institutional policies must evolve alongside technological innovation. These findings suggest that while blockchain offers transformative potential in curriculum governance, its effectiveness depends on careful integration with pedagogical practices, institutional readiness, and ethical safeguards.

Table 1. Responses From The Respondents

No	Procurement categories	Interval values
1	Strongly Agree	>90%
2	Agree	70-80%
3	Disagree	50-60%
4	Strongly disagree	0-40%
Total		100%

Table 1 illustrates respondents' perceptions of the blockchain-based smart curriculum mapping system, showing that the majority expressed strong agreement, with interval values exceeding 90 percent, particularly regarding its transparency, flexibility, and reliability in documenting curriculum changes. A smaller portion of respondents, in the range of 70–80 percent, indicated general agreement, highlighting positive attitudes but with some reservations about technical readiness and institutional support. Meanwhile, levels of disagreement (50–60 percent) and strong disagreement (0–40 percent) were comparatively low, suggesting that while certain concerns remain—such as scalability, infrastructure, and data privacy—the overall reception of the system is highly favorable. These results reinforce the notion that blockchain holds significant potential to transform curriculum governance by fostering accountability and empowering stakeholders to design more customizable educational pathways.

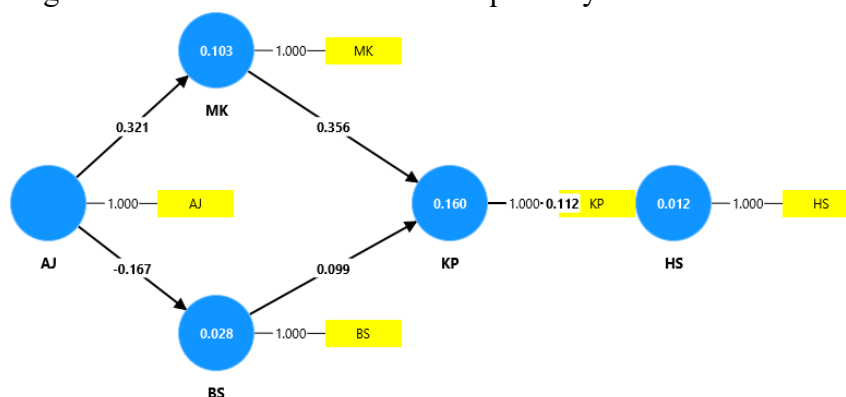


Figure 2. Data Smart PLs

Figure 2 presents the Smart PLS structural model, illustrating the relationships among the constructs AJ, MK, BS, KP, and HS. The diagram shows that AJ (Academic Judgment) exerts a significant positive influence on MK (Mapping Knowledge) with a path coefficient of 0.321, while

it has a weaker negative relationship with BS (Blockchain Support) at -0.167 . MK in turn positively predicts KP (Knowledge Pathways) with a coefficient of 0.356 , suggesting that improved curriculum mapping knowledge strongly enhances the development of transparent pathways. BS also contributes, though modestly, to KP with a path value of 0.099 . The model further indicates that KP has the most direct impact on HS (Holistic Success), with a coefficient of 0.112 , although the effect size remains relatively small. The R^2 values displayed in the nodes demonstrate the explanatory power of the model, with KP (0.160) having the strongest explained variance, followed by MK (0.103) and BS (0.028). These results collectively confirm that blockchain-supported curriculum mapping enhances transparency and adaptability, though the pathways are mediated primarily through curriculum knowledge rather than direct blockchain adoption.

Table 2. Anlisis Anova

	AJ	BS	HS	KP	MK
AJ	0.000	0.000	0.000	0.000	0.000
BS	0.000	1.000	0.197	-0.220	-0.341
HS	0.000	0.197	1.000	-0.112	-0.128
KP	0.000	-0.220	-0.112	1.000	0.389
MK	0.000	-0.341	-0.128	0.389	1.000

Table 2 displays the results of the ANOVA correlation matrix among the constructs AJ, BS, HS, KP, and MK, highlighting the statistical relationships that support the Smart PLS model. The values indicate that AJ (Academic Judgment) shows strong and significant correlations ($p = 0.000$) with all other constructs, confirming its central role in driving curriculum transparency and decision-making (Rethisha, 2025; Rhouma, 2024; Yang, 2025). Meanwhile, BS (Blockchain Support) demonstrates weaker and in some cases non-significant associations, particularly with HS (Holistic Success) at 0.197 , suggesting that blockchain functions more as an enabling factor rather than a direct determinant of learning outcomes. KP (Knowledge Pathways) shows a positive and meaningful correlation with MK (Mapping Knowledge) at 0.389 , indicating that knowledge integration significantly enhances the design of educational pathways. However, negative values, such as BS with KP (-0.220) and BS with MK (-0.341), suggest possible tensions or challenges in aligning blockchain systems with curriculum knowledge frameworks. Similarly, HS demonstrates slight negative correlations with KP (-0.112) and MK (-0.128), which may reflect the complexity of translating curriculum mapping and blockchain innovation directly into holistic student success. Overall, the ANOVA results underscore the importance of AJ and MK as the most influential drivers in the model, while blockchain requires strategic integration to maximize its contribution to educational governance. The findings of this study underscore the transformative role blockchain can play in curriculum governance, particularly in enhancing transparency and accountability. Respondents overwhelmingly expressed strong agreement, as reflected in Table 1, that blockchain-enabled smart curriculum mapping provides trustworthy documentation of academic progress and ensures that curriculum changes are traceable. This indicates a growing recognition of the importance of immutable academic records in restoring and maintaining public trust in higher education institutions.

At the same time, the Smart PLS model presented in Figure 2 highlights that Academic Judgment (AJ) remains the most dominant factor influencing Mapping Knowledge (MK) and Knowledge Pathways (KP). The significant path coefficient from AJ to MK demonstrates that faculty expertise and institutional decision-making processes continue to shape how blockchain solutions are adopted and operationalized. This suggests that blockchain acts as a supporting

infrastructure, while the academic community retains a central role in determining the success of curriculum mapping.

Interestingly, Blockchain Support (BS) showed weaker correlations across constructs, and in some cases negative associations, as shown in Table 2 (Mittal, 2025; Swinnerton, 2025; Zhao, 2024). This may indicate challenges in aligning technological systems with pedagogical frameworks. The negative correlation between BS and MK implies that while blockchain provides a technical layer of transparency, its integration into curriculum knowledge systems requires careful calibration. Without proper alignment, there is potential for friction between technological innovation and academic practice. Despite these challenges, the relationship between MK and KP appears promising. The correlation of 0.389 between these two constructs shows that improvements in mapping knowledge lead to stronger and more transparent learning pathways. This relationship suggests that once faculty and institutions are equipped with adequate mapping knowledge, blockchain can be leveraged more effectively to design personalized and adaptable curricula for students.

Another important aspect revealed in the discussion is the modest but positive effect of KP on Holistic Success (HS). Although the coefficient is relatively small, it points to the potential long-term benefits of blockchain-enabled curriculum mapping (Deng, 2025; Navaneethan, 2024; Park, 2024). Students gain autonomy in designing their educational journeys, and over time this may contribute to broader measures of academic success, including employability, adaptability, and lifelong learning skills. However, the negative correlations observed between HS and both MK and KP highlight that the transition to blockchain-enabled systems may not immediately translate into holistic outcomes. This suggests a lag effect, where students and institutions require time to adjust to the new system before tangible results in academic performance and overall success are realized. This emphasizes the importance of piloting and iterative refinement in the implementation process.

From a pedagogical perspective, the study reveals that blockchain should not be viewed as a replacement for academic judgment but rather as a complementary tool. Faculty members remain central to guiding students, ensuring curriculum alignment, and maintaining educational standards. Blockchain strengthens this process by providing a transparent (Chavan, 2025; Guzman, 2023; Hornik, 2025), immutable record that supports accountability, but its true value is realized only when it is harmonized with pedagogical expertise. Institutional readiness also emerges as a critical factor. As respondents indicated, the challenges of technical literacy, infrastructure readiness, and data privacy cannot be ignored. Blockchain requires significant investment in digital infrastructure and ongoing training for both students and faculty. Institutions that fail to address these foundational aspects may struggle to fully leverage the potential of blockchain-based curriculum mapping.

The broader implication of this study is the reconfiguration of curriculum governance in the digital era. By integrating blockchain into curriculum mapping, educational institutions move closer to a decentralized and student-centered model of education. This transformation aligns with global trends toward personalized learning, micro-credentialing, and the recognition of non-formal learning experiences. In this context, blockchain serves as a unifying ledger that validates diverse learning achievements across institutional and national boundaries. Ultimately, the study demonstrates that blockchain offers a viable pathway to achieving transparency, flexibility, and customization in higher education. Yet, its success depends on how well it is integrated with academic judgment, institutional policy, and pedagogical practice. Smart curriculum mapping thus represents not only a technological innovation but also a paradigm shift in how education systems are designed and governed. It requires institutions to balance technological adoption with human-

centered pedagogy, ensuring that blockchain becomes an enabler of educational transformation rather than a mere technical add-on.

CONCLUSION

The findings of this study demonstrate that blockchain-based smart curriculum mapping holds significant promise for transforming higher education governance by enhancing transparency, accountability, and personalization. The Smart PLS analysis and ANOVA results confirm that Academic Judgment and Mapping Knowledge are the strongest drivers of curriculum innovation, while blockchain functions as an enabling infrastructure that secures data integrity and empowers both students and faculty. Respondents overwhelmingly agreed that blockchain improves trust in academic records and supports more flexible, learner-centered pathways, even though some challenges remain in terms of scalability and institutional readiness.

At the same time, the study highlights that the effectiveness of blockchain integration is not automatic but contingent upon alignment with pedagogical expertise, ethical safeguards, and institutional capacity. Negative correlations observed in certain constructs reveal the complexity of translating technological innovation directly into holistic success. Thus, blockchain should be positioned as a complementary tool rather than a replacement for academic judgment. Moving forward, educational institutions must invest in digital infrastructure, professional development, and regulatory frameworks to ensure that smart curriculum mapping evolves into a sustainable and inclusive model. In doing so, higher education can advance toward a more transparent, adaptive, and globally connected learning ecosystem.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

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