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Integrating Mathematics, Data Analytics, and Technology Education: A Context-Sensitive Program Development Framework for Philippine Polytechnic Institutions

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ABSTRACT

Increasing demand for data-literate and technologically competent professionals has prompted higher education institutions to develop interdisciplinary programs that integrate mathematics, data analytics, and technology education. This study aimed to develop a context-sensitive program development framework for Philippine polytechnic institutions through the proposed Bachelor of Science in Mathematics specialized in Data Analytics, minor in Technology Education. The framework was designed to support curriculum innovation that responds to national educational priorities, workforce demands, and technological advancements. Qualitative-descriptive research design was employed using document analysis, literature review, and expert consultations involving curriculum specialists, quality assurance practitioners, and academic leaders. Data were analyzed through thematic analysis to identify the essential components of the proposed framework. Findings revealed three interconnected components of program development: Planning and Designing, which focuses on curriculum alignment, regulatory compliance, faculty preparedness, and learning resources; Feedback and Evaluation, which emphasizes stakeholder engagement, institutional policies, and quality assurance mechanisms; and Continual Improvement, which promotes benchmarking, monitoring, and evidence-based innovation to sustain program relevance and quality. Together, these components establish a systematic and iterative process for developing interdisciplinary academic programs responsive to workforce demands and technological advancement. The study concludes that effective program development in polytechnic institutions requires the integration of academic standards, industry needs, stakeholder participation, and continuous quality enhancement. The study contributes to curriculum innovation by proposing a context-sensitive program development framework for Philippine polytechnic institutions that integrates mathematics, data analytics, and technology education and supports the sustainable development, implementation, and improvement of interdisciplinary programs in technical and vocational higher education.

RESUMO

A crescente demanda por profissionais com competências em análise de dados e domínio tecnológico tem levado as instituições de ensino superior a desenvolver programas interdisciplinares que integrem matemática, análise de dados e educação tecnológica. Este estudo teve como objetivo desenvolver uma estrutura de desenvolvimento de programas sensível ao contexto para instituições politécnicas das Filipinas, por meio da proposta do Bacharelado em Matemática com especialização em Análise de Dados e minor em Educação Tecnológica. A estrutura foi concebida para apoiar a inovação curricular em resposta às prioridades educacionais nacionais, às demandas do mercado de trabalho e aos avanços tecnológicos. Foi adotado um delineamento de pesquisa qualitativo-descritivo, utilizando análise documental, revisão da literatura e consultas a especialistas, incluindo especialistas em currículo, profissionais da garantia da qualidade e líderes acadêmicos. Os dados foram analisados por meio de análise temática para identificar os componentes essenciais da estrutura proposta. Os resultados revelaram três componentes interligados do desenvolvimento de programas: Planejamento e Concepção, que se concentra no alinhamento curricular, conformidade regulatória, preparação docente e recursos de aprendizagem; Feedback e Avaliação, que enfatiza o engajamento das partes interessadas, as políticas institucionais e os mecanismos de garantia da qualidade; e Melhoria Contínua, que promove benchmarking, monitoramento e inovação baseada em evidências para sustentar a relevância e a qualidade do programa. Em conjunto, esses componentes estabelecem um processo sistemático e iterativo para o desenvolvimento de programas acadêmicos interdisciplinares responsivos às demandas do mercado de trabalho e aos avanços tecnológicos. O estudo conclui que o desenvolvimento eficaz de programas em instituições politécnicas requer a integração de padrões acadêmicos, necessidades da indústria, participação das partes interessadas e aprimoramento contínuo da qualidade. O estudo contribui para a inovação curricular ao propor uma estrutura de desenvolvimento de programas sensível ao contexto para instituições politécnicas filipinas, integrando matemática, análise de dados e educação tecnológica, além de apoiar o desenvolvimento, a implementação e a melhoria sustentável de programas interdisciplinares no ensino superior técnico e profissional.

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Introduction

The digital transformation of the global economy has elevated data to the level of a strategic resource that drives innovation, productivity, and sustainable growth. Industries across sectors, from healthcare and business to education and manufacturing, now depend on professionals capable of extracting, analyzing, and interpreting complex data sets to inform decision-making (Assur & Rowshankish, 2022; OECD, 2021). As automation and artificial intelligence continue to redefine work processes, the demand for data-literate and technologically proficient professionals has surged. World Economic Forum (2023) identified data analysis, scientists, and artificial intelligence specialists as among the most sought-after occupations, underscoring the urgent need to realign educational systems with the competencies required by an increasing digital workforce.

In response to these global shifts, higher education institutions worldwide are integrating data analytics and computational thinking into science and mathematics programs. Such integration not only enhances students' analytical and quantitative reasoning skills but also prepares them for cross-disciplinary problem-solving in modern professional environments (Horton and Hardin, 2020; Ouyang, 2024). Studies have shown that embedding technology-driven analytics into mathematics education fosters both theoretical understanding and practical application, two qualities vital for global employability (Ow-Yeong et al., 2023). These global efforts highlight a shared recognition that future-ready graduates must be proficient not only in mathematical concepts but also in the digital tools that operationalize them.

In the Philippines, educational reforms reflect similar priorities. The Commission on Higher Education (CHED) and the Department of Science and Technology (DOST) have issued policy frameworks promoting outcome-based, industry-responsive curricula across higher education institutions (CHED, 2021). Complementing this initiative, the Technical Education and Skills Development Authority (TESDA) developed the Competency Standards for Data Analytics Level III, which defines performance criteria for data collection, preparation, analysis, and visualization (TESDA, 2023). These national directives collectively advance the country's goal of cultivating a workforce equipped with both technical and analytical competencies aligned with the Fourth (4th) Industrial Revolution.

However, despite these national efforts, many polytechnic universities and colleges continue to deliver mathematics, data analytics, and technology education as discrete academic components rather than as an integrated learning pathway. This fragmentation limits the development of interdisciplinary competence, especially in institutions whose core mandate is to provide practical and industry-aligned education (Dublar , 2023; Kross and Guo, 2019). As polytechnic institutions serve as critical training grounds for applied and technical expertise, the absence of a coherent curricular model that connects mathematical theory with analytics and educational technology represents a missed opportunity for both learners and the national innovation agenda.

While curriculum development frameworks have long guided educational program design, many traditional models were developed within general education contexts and may not fully address the interdisciplinary and quality assurance demands of contemporary polytechnic institutions. One of the most influential frameworks is Tyler's Curriculum Development Model, which emphasizes the identification of educational objectives, selection and organization of learning experiences, and evaluation of learning outcomes (Tyler, 1949). Although Tyler's model provides a systematic foundation for curriculum planning, it primarily focuses on instructional design and learner outcomes, with limited emphasis on regulatory compliance, stakeholder validation, industry alignment, and continuous quality improvement processes that are essential in technical and vocational higher education settings (Teachers Institute, 2023; Golbaghi, 2025).

In contrast, the proposed Program Development Framework extends beyond curriculum design by integrating three interconnected dimensions: Planning and Designing, Feedback and Evaluation, and Continual Improvement. The framework incorporates national regulatory requirements from CHED, TESDA, and the Professional Regulation Commission (PRC), considers faculty readiness and learning-space requirements, institutionalizes stakeholder and industry participation, and embeds continuous monitoring and benchmarking mechanisms. These features make the framework particularly suitable for Philippine polytechnic institutions, where academic programs must simultaneously satisfy educational standards, workforce demands, professional licensure requirements, and institutional quality assurance systems. Consequently, the study contributes a context-sensitive and evidence-based program development framework that responds to the growing need for interdisciplinary mathematics and data analytics education within the Philippine higher education landscape.

The present study addresses this gap by conceptualizing the Program Development Framework for Bachelor of Science in Mathematics specialized in Data Analytics, minor in Technology Education (BSMath-DATEd) within the context of Philippine polytechnic education. The framework provides a structured and adaptive guide for designing and implementing interdisciplinary programs that merge mathematics, data analytics, and technology pedagogy. It is designed to be contextually relevant to polytechnic institutions with similar mandates and operational capacities while providing sufficient flexibility for local institutional adaptation. Through this initiative, the study contributes to the ongoing discourse on curriculum innovation in technical and vocational higher education by aligning local academic programs with global educational trends and workforce demands, ultimately strengthening the role of polytechnic institutions in advancing national digital transformation.

Methods

A qualitative-descriptive design was adopted to develop the Program Development Framework for Bachelor of Science in Mathematics specialized in Data Analytics minor, in Technology Education (BSMath-DATEd) within polytechnic education contexts. This approach was deemed appropriate to capture institutional realities, professional insights, and policy considerations relevant to curriculum innovation in technical higher education (Creswell & Poth, 2018). The design emphasized understanding processes and perspectives rather than quantifying outcomes, allowing for an in-depth exploration of how mathematics, data analytics, and technology education can be systematically integrated within a single academic program (Sandelowski, 2010).

Data for the study were obtained from documentary sources and expert consultations. Documentary analysis focused on institutional records, curriculum proposals, quality assurance documents, meeting minutes, feasibility studies, and related supporting materials prepared during the development of the proposed Bachelor of Science in Mathematics specialized in Data Analytics with minor in Technology Education (BSMath-DATEd) for Academic Year 2022–2023. Documents were selected based on their direct relevance to program development, curriculum design, quality assurance, and compliance with national higher education policies and standards. To enhance the credibility and contextual relevance of the framework, consultations were conducted with nine (9) subject-matter experts purposively selected based on predetermined inclusion criteria. The panel consisted of seven (7) experts in mathematics education, one (1) computer engineering expert with knowledge of data analytics and technology integration, and one (1) quality assurance director experienced in academic program evaluation and curriculum compliance. Participants were selected because they possessed substantial experience in curriculum development, teaching and learning, data analytics, quality assurance, or educational program management and were currently affiliated with a technical-vocational institution, college, or university.

Expert consultation was conducted through structured and semi-structured discussions during the review of curriculum documents and supporting materials. Prior to participation, all experts were informed of the objectives, scope, and intended use of the study. Informed consent was obtained, and participation was entirely voluntary. Participants were encouraged to provide observations, recommendations, and clarifications regarding the proposed program framework. Notes and documentary annotations were recorded throughout the consultation process while maintaining the confidentiality and anonymity of individual responses. No personally identifiable information was included in the analysis or reporting of findings. These measures ensured integrity, transparency, and respect for research ethics within the academic setting.

Data were analyzed using thematic analysis following the procedures outlined by Braun and Clarke (2006). First, relevant documents and consultation notes were reviewed repeatedly to achieve familiarization with the data. Second, initial codes were generated by identifying recurring concepts, requirements, and institutional practices related to program development. Third, related codes were grouped into broader categories and emerging themes. Fourth, the themes were reviewed and refined to ensure coherence, consistency, and alignment with the study objectives. Fifth, themes were defined and labeled according to their conceptual contribution to the proposed framework. Finally, the themes were organized into an integrated Program Development Framework consisting of Planning and Designing, Feedback and Evaluation, and Continual Improvement.

To establish trustworthiness and validity, member checking was conducted after the coding and theme development process. The preliminary codes, categories, and thematic interpretations were presented to the participating experts for verification and confirmation. Participants were given opportunities to clarify, modify, or validate the interpretations to ensure that the findings accurately reflected their perspectives and professional insights. Feedback received during this stage was incorporated into the final framework. Triangulation of documentary evidence and expert consultations further strengthened the credibility, dependability, and confirmability of the findings. (Lincoln & Guba, 1985; Creswell & Poth, 2018)

Results and Discussion

The findings of this study revolve around the development of a structured Program Development Framework for Bachelor of Science in Mathematics specialized in Data Analytics, minor in Technology Education (BSMath-DATEd), specifically contextualized for polytechnic institutions. The results emerged from the consolidation of document analysis, stakeholder input, and validation against existing educational policies and frameworks.

The framework was analyzed thematically according to the three core dimensions: Planning and Designing; Feedback and Evaluation; and Continual Improvement. These dimensions represent interconnected stages of program development that align with institutional practices, national educational standards, and the evolving demands of data-driven industries. Thematic patterns derived from the data revealed that the integration of analytics, mathematics, and technology education requires an iterative process, beginning with compliance and design, strengthened by stakeholder feedback, and sustainable through systematic improvement. The following sections present a further discussion of the results of this study:

Proposed Program Development Framework

The Program Development Framework for Bachelor of Science in Mathematics specialized in Data Analytics, minor in Technology Education (BSMath-DATEd) represents a structured and iterative process grounded in educational policy, institutional governance, and pedagogical innovation. It comprises three interconnected components, Planning and

Designing, Feedback and Evaluation, and Continual Improvement, that collectively ensure curricular alignment, stakeholder responsiveness, and sustained program relevance in polytechnic contexts.

Table 1.
Major Themes Matrix

Major Theme	Integrative Idea, Key Points and Contributing Insights	Reference
Planning and Designing	Foundation of the framework; ensures curricular, regulatory, and institutional readiness integrating CHED PSG, TESDA standards, and PRC requirements.	Tyler (1949); Twining et al. (2020); TESDA (2023); CHED (2021); PRC (2022)
Feedback and Evaluation	Mechanisms for internal and external validation through SUC guidelines, higher education agencies, and stakeholder engagement.	Avila-Garzon and Bacca-Acosta (2025); Goren (2020); Suleiman (2023)
Continual Improvement	Establishes a culture of evidence-based innovation and benchmarking aligned with global analytics and education trends	Heilenman et al. (2018); Mukuka and Alex (2024); Signo (2025); OECD (2021)

Table 1 reflects the logical and progressive integration of the framework's three pillars. The nature of these themes demonstrates that program development is not a terminal process but a continuous institutional commitment. Each phase informs and reinforces the others, designing with compliance, evaluating through participation, and improving through innovation. This interconnection positions the program development framework as both adaptive and scalable for diverse polytechnic contexts. The findings support the view that effective curriculum and program development require a systematic process that aligns educational objectives, stakeholder needs, and institutional capacities. Traditional curriculum development models, such as Tyler's model, emphasize the identification of educational objectives, selection of learning experiences, and evaluation of outcomes (Tyler, 1949). While these principles remain relevant, contemporary higher education institutions, particularly polytechnic and technical-vocational institutions, operate within increasingly complex environments that require responsiveness to regulatory standards, technological advancements, and workforce demands (Twining et al., 2021). The emergence of Planning and Designing, Feedback and Evaluation, and Continual Improvement as major themes suggests that program development extends beyond curriculum design and must encompass governance, quality assurance, and sustainability mechanisms.

The framework likewise reflects the growing emphasis on stakeholder-centered and evidence-based educational planning. The Feedback and Evaluation component aligns with studies emphasizing that curriculum effectiveness is strengthened through continuous consultation with students, faculty members, industry partners, alumni, and regulatory agencies (Bezanilla et al., 2019; Goren, 2020). Such participatory mechanisms ensure that academic programs remain relevant to societal and labor-market needs while maintaining compliance with national educational policies. This finding is particularly important in polytechnic institutions, whose mandate requires balancing academic rigor with practical and industry-responsive competencies.

Furthermore, the Continual Improvement component reinforces the principle that curriculum innovation should be viewed as an ongoing cycle rather than a one-time institutional activity. Heileman et al. (2018) argued that curricular reforms are most effective when supported by systematic monitoring, benchmarking, and data-informed decision-making processes. Similarly, the OECD (2021) emphasized that educational institutions must continuously adapt to technological change and evolve workforce requirements to remain competitive and relevant. By embedding continual improvement within the framework, it promotes a culture of quality enhancement, innovation, and institutional learning. The integration of the three major themes therefore ensures that the framework is structurally sound, contextually relevant, and academically sustainable. Together, these components establish a comprehensive program development framework that aligns national standards, institutional goals, and industry expectations while addressing the evolving needs of Philippine polytechnic education.

Key Components of the Framework

This part translates the framework into operational components through verifiable institutional documentation, stakeholders' practices, and academic requirements. Each subtheme identifies the institutional processes and documentary proofs necessary to demonstrate compliance, implementation, and enhancement of the BSMath-DATEd. Further discussion of the components is as follows:

Planning and Designing

The first theme serves as the foundation for program creation. It ensures that all structural and curricular elements are aligned with the policy, professional regulations, and institutional capacity. It includes four key components: PSG and Curriculum Requirements, Current Trends, Faculty, and Learning Space.

Table 2 demonstrates that the Planning and Designing theme operationalizes compliance and institutional readiness through tangible documentation, curriculum alignment, faculty preparation, and infrastructure development. The findings suggest that effective program development in polytechnic education requires a comprehensive planning process that extends beyond curriculum construction to include regulatory compliance, workforce responsiveness, and organizational capacity. This supports the assertion of Twining et al. (2021) that curriculum quality in the technological era depends not only on content design but also on the alignment of institutional resources, learning outcomes, and emerging societal needs.

Table 2.
Planning and Design Key Information Matrix

Key Components	Emerging Theme	Documentation	Reference
PSG and Curriculum Requirements	Curriculum Compliance	CHED PSG for BS Mathematics; Curriculum Description, Institutional Mandate	CMO No. 48 series of 2017; Republic Act No. 9289
	Outcome-Based Educational Design	OBTL -Outcome-Based Teaching and Learning (Course Syllabi), Course description, Learning outcomes	Twining et al. (2020)
	PRC Professional Requirements	Proof of integration of 18 Professional Education units required for Licensure Examination for Teachers (LET)	PRC (2022)
Current Trends	Integration of Data Analytics in Mathematics	Updated OBTL including Data Analytics Competency Standards	Ouyang (2024); TESDA (2023)
	Alignment to Industry 4.0	Partnership MOAs with industries partners related to or needing data analytics	Assur and Rowshankish (2022)
Faculty	Digital Literacy and Analytics Proficiency	Faculty Matrix (with Educational Attainment, Training Certificates, Seminar Participation logs)	Mukuka and Alex (2024)
	Continuous Capacity Building	Institutional Faculty Manual, Faculty Development Plan, Hiring Guidelines	Kross and Guo (2019)
Learning Space	Instructional Space	Classroom Dimension, Library (Structure, Plans, Details, etc)	Agyemang Adarkwah et al. (2025)
	Technology-Enhance Facilities	Educational Technology Room, Multimedia Room, Computer Laboratories, Content Creation Room, Software and Data Source	Dublar (2023); Assur and Rowshankish (2022)

The inclusion of CHED Program Standards, TESDA Competency Standards, and PRC professional education requirements highlights the importance of integrating academic, technical, and professional expectations within a single program framework. Consistent with Outcome-Based Education (OBE) principles, curriculum development must ensure that learning outcomes reflect the competencies expected by industry, professional bodies, and higher education regulators (Biggs & Tang, 2011). The incorporation of 18 units of Professional Education further strengthens the program's dual purpose of preparing graduates for data analytics-related careers while providing eligibility for teacher licensure. This dual pathway enhances graduate mobility and employability by enabling students to pursue opportunities in both the analytics industry and educational sector. The emergence of Current Trends as a major component reflects the increasing influence of Industry 4.0 and digital transformation on higher education. Studies have emphasized that mathematics and data analytics programs must continuously adapt to technological advancements and workforce requirements to remain relevant (Assur & Rowshankish, 2022; Ouyang, 2024). The integration of data analytics competencies and industry partnerships within the framework demonstrates an effort to bridge theoretical mathematical knowledge with practical applications, a characteristic widely recognized as essential in technical and vocational education settings.

Equally important is the inclusion of Faculty and Learning Space components, which acknowledge that successful curriculum implementation depends on institutional capacity. Mukuka and Alex (2024) noted that educators' digital competence significantly influences the effectiveness of technology-integrated instruction. Similarly, contemporary learning environments require access to technology-enhanced facilities, laboratories, and digital resources that support experiential and applied learning (Agyemang Adarkwah et al., 2025). These findings indicate that program quality is influenced not only by curriculum content but also by the preparedness of faculty members and the availability of appropriate learning infrastructure.

Collectively, the subthemes align institutional capacities with regulatory expectations and industry demands, fulfilling the framework's goal of structured and evidence-based planning. The Planning and Designing phase therefore serves as the foundation of the framework by ensuring that curriculum requirements, professional competencies, faculty readiness, and technological resources are systematically aligned to support effective program implementation and long-term sustainability.

Feedback and Evaluation

The second theme provides systematic mechanisms to ensure that the program is responsive to stakeholder needs and adheres to national and institutional quality standards. It includes three subthemes: Regulatory Agency for Higher Education, SUC Policies and Guidelines, and Stakeholders' Evaluation.

Table 3 presents a comprehensive feedback ecosystem that combines regulatory validation, institutional compliance, and participatory evaluation. The findings indicate that effective program development in polytechnic institutions requires not only compliance with external standards but also continuous engagement with internal and external stakeholders. This supports the view that quality assurance in higher education is most effective when institutional decision-making is informed by evidence, stakeholder participation, and systematic review processes (Suleiman, 2023).

Table 3.
Feedback and Evaluation Key Information Matrix

Key Components	Emerging Theme	Documentation	Reference
Regulatory Agency for Higher Education	CHED Alignment	CHED Evaluation reports; Compliance Checklist	CHED (2021)
	DOST Research and Innovation Linkages	DOST Research Agenda; DOST-MPC collaborative projects.	Avila-Garzon and Bacca-Acosta (2025)
	National Quality Assurance Framework	Institutional Quality Assurance Certifications; Accreditation Reports	Suleiman (2023)
SUC Policies and Guidelines	Internal Academic Procedures	SUC Manuals, Local Procedure on Creation and Revision of Curriculum or Programs	CHED (2021)
	Compliance Reports	Internal Quality Audit Reports; Governance Reports; Other External Agency's Requirements report	OECD (2021)
	Administrative Oversight	Administrative and Academic Council Resolutions; Communication Letters; Other Internal Circulars or Communications	Goren (2020)
Stakeholders' Evaluation	Students and Teachers' Feedback	Feasibility Study Results and Report	Goren (2020)
	Alumni and Industry Feedback	Minutes of Meeting; Alumni Tracer Study; Consultative Meeting Results	Okafor (2025)
	Collaborative Validation	Comparative Report from other SUCs; Possible MOA and Internship; TESDA's Feedback	Avila-Garzon and Bacca-Acosta (2025)

The emergence of Regulatory Agency for Higher Education as a major subtheme highlights the important role of national agencies in ensuring program relevance, quality, and accountability. The alignment of CHED policies, DOST priorities, and institutional requirements reflects a coordinated approach to curriculum development that responds to both educational and workforce needs. Previous studies have emphasized that regulatory frameworks provide institutions with standards that promote consistency, comparability, and continuous enhancement of academic programs (OECD, 2021). In the context of technical and vocational higher education, such alignment is particularly important because educational programs must remain responsive to rapidly changing technological and industrial environments. The inclusion of SUC Policies and Guidelines further demonstrates that curriculum development is strengthened through institutional governance and internal quality assurance mechanisms. Administrative oversight, compliance reports, curriculum review procedures, and quality audits create a structured system for monitoring program implementation and identifying areas for improvement. This finding supports the work of Goren (2020), who emphasized that institutional policies and governance structures contribute significantly to maintaining educational quality and organizational effectiveness. By integrating external requirements with internal procedures, the framework promotes consistency between policy intentions and actual implementation practices.

Stakeholders' Evaluation emerged as a critical component of the framework, reflecting the growing recognition that educational programs should be developed through collaborative and participatory processes. The inclusion of students, faculty members, alumni, industry representatives, and partner institutions ensures that curriculum decisions are informed by multiple perspectives and evolving societal needs. This finding is consistent with stakeholder-driven approaches to higher education, which emphasize the importance of consultation and feedback in improving curriculum relevance and graduate preparedness (Bezanilla et al., 2019; Avila-Garzon & Bacca-Acosta, 2025). Recent evidence further suggests that emerging educational technologies, including AI-supported learning environments, influence students' learning behaviors, autonomy, and engagement, highlighting the importance of incorporating learner experiences into curriculum evaluation and program enhancement processes (Ignacio, 2026). Stakeholder participation therefore strengthens institutional accountability by ensuring that program decisions remain responsive to both educational innovation and workforce expectations.

The framework's strength therefore lies in institutionalizing feedback loops that connect regulatory oversight, institutional governance, and stakeholder participation. Aligning CHED and DOST directives with SUC implementation creates an integrated quality assurance system that supports both academic excellence and workforce relevance. Through structured compliance and participatory evaluation, the Feedback and Evaluation component sustains the BSMath-DATEd program's responsiveness, accountability, and long-term viability, enabling polytechnic institutions to continuously adapt to national priorities and stakeholder expectations.

Continual Improvement

The third theme, Continual Improvement, represents the self-renewing phase of the framework. It encompasses benchmarking, innovation, and policy adaptation to sustain program relevance and quality. The emergence of this theme suggests that curriculum development should not be viewed as a static or one-time undertaking but rather as a dynamic process that requires ongoing evaluation and refinement. This finding supports contemporary perspectives in higher education that emphasize continuous quality enhancement as a critical component of institutional effectiveness and educational sustainability (OECD, 2021; Signo, 2025).

The inclusion of benchmarking, curricular analytics, and iterative review processes reflects the growing need for evidence-based curriculum management. Heileman et al. (2018) argued that curricular reforms are most effective when supported by systematic mechanisms that measure program performance, identify areas for improvement, and evaluate the impact of curricular innovations. In the context of data analytics education, such mechanisms are particularly important because technological advancements and industry requirements evolve rapidly, requiring educational institutions to regularly reassess program content, learning outcomes, and instructional strategies. Through benchmarking against national and international standards, institutions can ensure that academic offerings remain competitive and aligned with emerging workforce competencies.

The findings also highlight the critical role of faculty members and institutional leaders in fostering a culture of innovation and organizational learning. Faculty development initiatives, curriculum review activities, and strategic planning processes create opportunities for continuous reflection and improvement. Mukuka and Alex (2024) emphasized that educator readiness and digital competence are essential factors influencing successful technology integration and educational innovation. Consequently, continual improvement extends beyond curriculum revision and includes the ongoing development of human resources, instructional practices, and institutional capabilities.

Furthermore, the integration of quality audits, monitoring systems, and policy reviews demonstrates that continual improvement functions as a bridge between evaluation and innovation. Rather than serving merely as compliance requirements, these processes generate evidence that informs future decision-making and strategic program enhancement. This finding aligns with OECD's (2021) framework for educational innovation, which emphasizes adaptability, responsiveness, and digital transformation as key characteristics of future-ready educational institutions. Through systematic review and data-informed planning, institutions are better positioned to anticipate changes in technology, labor market demands, and educational policy environments.

Continual Improvement therefore transcends compliance by transforming evaluation into a mechanism for innovation and institutional learning. The process ensures that each program cycle becomes an opportunity for enhancement rather than simply a validation exercise. By embedding continuous review, benchmarking, and evidence-based decision-making within the framework, it remains adaptive, self-correcting, and responsive to emerging educational and industry trends. This component ultimately strengthens the framework's long-term sustainability and positions it as a globally competitive model for program development in Philippine polytechnic higher education.

The Model

The integration of all thematic components culminates in Figure 1, representing the continuous process of curriculum planning, validation, and improvement in polytechnic education.

Figure 1.

Proposed Program Development Model

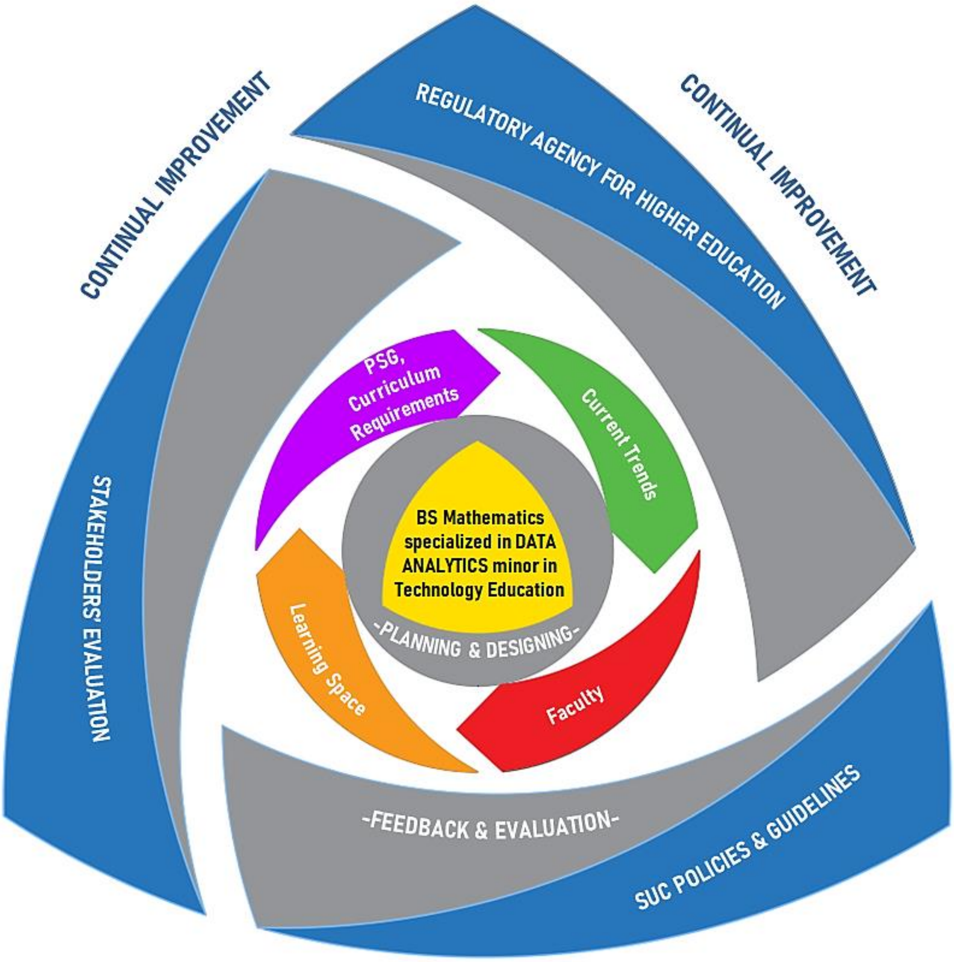

Figure 1 illustrates the dynamic relationship among Planning and Designing, Feedback and Evaluation, and Continual Improvement. Rather than functioning as isolated stages, these components operate as an interconnected cycle in which evaluation informs improvement and improvement guides future planning. This iterative structure reflects contemporary quality assurance and curriculum innovation principles that emphasize evidence-based decision-making, stakeholder engagement, and continuous organizational learning. Through this cyclical process, polytechnic institutions can maintain curriculum relevance while adapting to emerging technological, educational, and workforce developments.

Conclusion and Recommendations

This study addressed the need for a structured and context-sensitive approach to developing interdisciplinary academic programs in Philippine polytechnic institutions. Specifically, it developed a program development framework for integrating mathematics, data analytics, and technology education through the proposed Bachelor of Science in Mathematics specialized in Data Analytics, minor in Technology Education. The findings revealed that effective program development requires the integration of three interconnected components: Planning and Designing, Feedback and Evaluation, and Continual Improvement. Together, these components provide a systematic process for ensuring curriculum quality, regulatory compliance, stakeholder responsiveness, and long-term program sustainability.

The findings further highlight that successful curriculum innovation in mathematics and data analytics depends on the alignment of national educational standards, faculty competencies, learning infrastructure, industry requirements, and quality assurance mechanisms. The integration of CHED Program Standards, TESDA Competency Standards, and PRC professional education requirements strengthens the framework's capacity to prepare graduates for both professional practice and teacher education pathways. Likewise, the incorporation of stakeholder participation and continuous quality enhancement mechanisms reinforces institutional accountability and program relevance. These findings demonstrate that curriculum development in technical and vocational higher education should be viewed as a cyclical and evidence-based process that continuously adapts to emerging technological, educational, and workforce demands.

The study contributes to curriculum development literature by proposing a context-sensitive program development framework for Philippine polytechnic institutions. The framework extends traditional curriculum development models by integrating regulatory compliance, stakeholder engagement, institutional readiness, and continual improvement within a single program development process. As such, it provides a practical guide for the sustainable development, implementation, and enhancement of interdisciplinary programs in mathematics, data analytics, and technology education.

Based on the findings, it is recommended that the framework be pilot-tested and implemented in polytechnic institutions to assess its applicability and effectiveness in actual academic settings. Future studies may employ quantitative or mixed method approaches to evaluate its reliability, scalability, and impact on student outcomes, faculty development, and institutional performance. Longitudinal investigations may likewise be conducted to examine the influence of continual improvement processes on curriculum quality, graduate employability, and organizational adaptability. Furthermore, collaboration among CHED, TESDA, PRC, and higher education institutions should be strengthened to promote policy alignment, resource sharing, and the development of interdisciplinary programs responsive to national priorities and industry needs. Continuous evaluation and contextual refinement of the framework are encouraged to ensure its sustained relevance within an increasingly data-driven and technology-oriented educational landscape.

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Statements and Declarations Section

This study adhered to all ethical guidelines for research involving human participants. The authors declare that they have no conflicts of interest in relation to this research. AI assistance was used solely to improve wording, grammar, and language translation, and was not involved in data collection. The authors also confirm contribution to the paper as follows: study conception and design: Reynaldo C. Rivera, Jr; data collection, and framework designing: Josephine L. Obispo; analysis and interpretation of results and draft manuscript preparation: Deo James B. Roxas. All authors reviewed the results and approved the final version of the manuscript.

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