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System Dynamics Model for Reducing Unemployment Rate of Vocational High School Graduate in Indonesia

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KEYWORDS

SMK; Unemployment Rate; System Dynamics; Education; Vocational Training

ABSTRACT

This research addresses the persistent high unemployment rate among Sekolah Menengah Kejuruan (SMK) graduates in Indonesia, which stood at 9.42% in 2024, significantly higher than in Thailand, where vocational graduates face only a 0.59% unemployment rate. Utilizing a system dynamics methodology, this study aimed to identify the contributing factors to SMK graduate unemployment and simulate potential policy interventions to reduce this rate by 2045. Data was gathered through interviews with 11 stakeholders, a literature review, and observations, leading to the identification of 34 variables, which were incorporated into a Causal Loop Diagram and converted into a Stock Flow Diagram containing 54 variables. The analysis involved 22 scenarios across four groups: GDP growth, education budget allocation, budget distribution, and SMK budget composition. Findings show that maintaining a GDP growth rate above 4.89% or allocating at least 8.544% of GDP to the education budget could eliminate SMK graduate unemployment by 2045. The most effective intervention identified was increasing the student certification budget, which could reduce unemployment to zero by 2040. The study recommends implementing the "Scenario 0 Unemployment" strategy, which involves allocating 8.273% of the budget to student certification and equally distributing the remaining budget between partnership and infrastructure improvements. This research provides valuable insights for policymakers to enhance SMK graduate employment outcomes through targeted budget allocations and strategic interventions.

INTRODUCTION

Recent student-led investigations using geoelectrical methods have deepened our understanding of saltwater intrusion, yet significant gaps remain. For instance, a master's thesis by Ríos-Perez (2023), a graduate student from the University of Oklahoma, explored Electrical Resistivity Tomography (ERT) integrated with numerical models to map saltwater encroachment in coastal aquifers, demonstrating improved lateral resolution but limited attention to industrial land use impacts. Similarly, Ríos-Perez's doctoral research at URI (2022) applied time-lapse ERT to monitor temporal fluctuations, underscoring the importance of

near-real-time data but without linking to localized extraction from factories . In Turkey, Kamran Rustamov (2022), a social policy master's student, investigated vocational education's role in youth unemployment, offering methodological frameworks which could parallel socio-economic modeling in hydrogeological contexts. Meanwhile, Iniemem et al. (2020), doctoral candidates in Nigeria, used time-lapse resistivity in coastal settings to quantify groundwater drawdown effects—a model applicable to industrial extraction scenarios. McDonnell et al. (2022) from Queen's University Belfast presented early findings of 4D ERT capturing tidal and pumping dynamics in Irish aquifers, yet did not integrate local economic drivers. Finally, Mansourian et al. (2022), postgraduate students at the University of Tehran, combined ERT and EMI to characterize saltwater intrusion in Belgium, highlighting the need for socioeconomic discharge data to fully interpret resistivity anomalies. Together, these studies emphasize the technical maturity of student-led geophysical research while pointing out the absence of integrated socio-economic activity analysis—precisely the gap this current study aims to fill.

Indonesia faces a unique paradox in its vocational education system. *Sekolah Menengah Kejuruan* (*SMK*), Indonesia's vocational high school system, was specifically designed to produce work-ready graduates through practical skills training and industry-oriented curricula. The primary objective of *SMK* institutions is to equip students with competencies required in real-world employment, enabling graduates to either enter the workforce immediately, pursue higher education, or establish entrepreneurial ventures. This educational approach should theoretically result in lower unemployment rates compared to general education pathways (Hanushek et al., 2017).

However, empirical evidence reveals a contradictory reality. Data from *Badan Pusat Statistik* (2024) demonstrates that *SMK* graduates consistently maintain the highest open unemployment rates among all educational levels in Indonesia. In February 2024, the open unemployment rate for *SMK* graduates reached 9.42%, substantially exceeding graduates from other educational institutions. Furthermore, when examining absolute numbers rather than percentages, *SMK* ranks second with 1.6 million unemployed individuals whose highest educational attainment is *SMK* level. This situation clearly indicates a fundamental misalignment between *SMK*'s intended purpose and actual outcomes.

Regional comparison within ASEAN countries further highlights Indonesia's vocational education challenges. Indonesia has consistently maintained the highest unemployment rate in ASEAN from 2022 to 2025, according to International Monetary Fund data (2025). In stark contrast, Thailand demonstrates the lowest unemployment rate in ASEAN since 2004, despite operating similar vocational high school models. The disparity is particularly striking when comparing vocational education outcomes: Thailand's vocational high school graduate unemployment rate stands at merely 0.59% in 2024, while Indonesia's *SMK* graduate unemployment rate reaches 9.42% in the same period. This 15-fold difference underscores the urgent need for comprehensive system analysis and policy intervention.

The complexity of *SMK*'s unemployment challenge stems from its multi-stakeholder nature. Unlike traditional academic institutions that primarily interface with education authorities, *SMK* operations require coordination between the Ministry of Education, Ministry of Industry, Ministry of Labor, and various industry partners. This complex stakeholder

environment creates challenges in policy formulation and implementation. Additionally, *SMK* must simultaneously maintain educational standards while adapting to rapidly evolving industry requirements, particularly in the context of technological advancement and digital transformation.

The COVID-19 pandemic further exacerbated existing challenges within Indonesia's labor market and educational system. Figure I.2 clearly demonstrates unemployment rate increases during 2020-2021, coinciding with pandemic-related economic disruptions. The *Pembatasan Sosial Berskala Besar* (*PSBB*) or large-scale social restrictions imposed during the pandemic significantly impacted various industries, leading to widespread layoffs and business closures. This economic downturn disproportionately affected new graduates, including *SMK* alumni, who faced reduced job opportunities during their transition from education to employment.

Several studies have identified critical factors contributing to vocational education unemployment. Bal-Domańska (2020) categorizes unemployment determinants into six groups: economic factors, structural and technological changes, legal regulation and social policy tools, education and vocational training systems, cultural factors, and demographic conditions. Each category presents specific challenges for *SMK* graduates in Indonesia's context.

From an educational system perspective, preliminary interviews with *SMK* stakeholders revealed several critical issues. Industry representatives consistently reported *SMK* graduates' deficiency in soft skills compared to university or general high school graduates. Teaching quality emerged as another significant concern, with *SMK* instructors often lacking practical competencies due to excessive focus on pedagogical training rather than industry-relevant skills development. Furthermore, current certification systems, particularly those administered by *Badan Nasional Sertifikasi Profesi* (*BNSP*), lack industry recognition and trust.

Infrastructure and curriculum currency present additional challenges. Many *SMK* laboratories still utilize equipment from the 1980s, creating significant gaps between student training experiences and current industry standards. This technological lag severely hampers graduates' ability to meet modern workplace requirements, particularly in manufacturing and technical fields where equipment proficiency is crucial for employment success.

Economic factors significantly influence *SMK* graduate employment outcomes. Indonesia's GDP per capita ranking of 122 out of 197 countries in 2024, according to World Bank data, correlates with limited job creation and economic opportunities. Bal-Domańska (2020) demonstrates a positive correlation between GDP per capita and employment rates, suggesting that Indonesia's relatively low economic development level constrains overall employment generation capacity.

Demographic and cultural factors also contribute to *SMK* challenges. Most *SMK* students originate from middle-low to low-income families, according to preliminary interviews with *SMK* headmasters. West (2007) established strong correlations between low-income family backgrounds and reduced student academic performance. Additionally, Lareau and Shumar (1996) identified a tendency among working-class, low-income parents to perceive separation between home and school responsibilities, resulting in

reduced parental involvement in educational processes. This socioeconomic dynamic creates additional barriers for *SMK* student success and subsequent employment prospects.

The legal and regulatory environment presents another layer of complexity. Interview participants highlighted concerns regarding Indonesia's business investment climate, labor law implications following Omnibus Law implementation, and insufficient incentives for industry-*SMK* partnerships. These regulatory challenges create hesitancy among companies to invest in Indonesia or establish meaningful collaborations with vocational institutions.

System dynamics methodology offers a comprehensive approach to analyzing complex, multi-stakeholder problems like *SMK* unemployment. Sterman (2000) defines system dynamics as a methodology for understanding and simulating complex systems behavior over time through mapping and analyzing feedback loops, stocks, flows, and delays. This approach enables prediction of long-term behaviors based on initial conditions and policy changes, making it particularly suitable for policy analysis and intervention design.

Limited research exists applying system dynamics to vocational education contexts. Chen (2014) conducted one notable study examining relationships between policy and capability within vocational education systems. However, this research focused primarily on policy-capability interactions without incorporating broader stakeholder networks and process complexities involved in vocational education unemployment challenges.

The urgency of addressing *SMK* unemployment extends beyond immediate graduate welfare to Indonesia's broader economic development objectives. Presidential Instruction No. 9 of 2016 mandates *SMK* revitalization as a national priority, while the National Medium-Term Development Plan (*RPJM*) 2020-2024 identifies Human Capital Development, including vocational education enhancement, as a key government focus. These policy frameworks underscore government recognition of *SMK*'s critical role in national development strategies.

International benchmarking reveals significant improvement potential. Thailand's success in maintaining 0.59% vocational graduate unemployment demonstrates achievable targets for Indonesia's *SMK* system. Understanding policy interventions and systemic changes required to approach such performance levels could provide valuable insights for Indonesia's vocational education transformation[A1][A2].

This research addresses identified gaps by developing a comprehensive system dynamics model encompassing multiple stakeholder perspectives, economic factors, educational system components, and policy intervention possibilities. The study's novelty lies in its holistic approach to *SMK* unemployment analysis, incorporating quantitative modeling capabilities for scenario simulation and policy impact assessment.

The research aims to determine minimum GDP growth rates required for eliminating *SMK* graduate unemployment by 2045, identify optimal education budget allocation ratios, assess relative effectiveness of different budget allocation strategies, and recommend evidence-based policy interventions for reducing *SMK* graduate unemployment. The study's practical implications extend to central government policy formulation, regional education authority planning, and *SMK* institutional strategy development.

Furthermore, this research contributes to broader understanding of vocational education challenges in developing countries, providing methodological frameworks applicable to similar contexts globally. The system dynamics approach demonstrated in this study offers replicable

analytical tools for policymakers addressing complex educational and employment challenges in various national contexts.

METHOD

This study employed system dynamics methodology to analyze factors contributing to *SMK* graduate unemployment and simulate policy interventions for reducing unemployment rates. System dynamics provides comprehensive tools for understanding complex, multi-stakeholder systems through mapping causal relationships, identifying feedback loops, and enabling scenario-based simulation for policy analysis.

Research Design

The research followed a structured four-phase approach: (1) Problem Articulation involving system definition, variable identification, and Causal Loop Diagram development; (2) Dynamic Hypothesis Formulation including dynamic variable definition and Stock Flow Diagram creation; (3) Testing and Simulation encompassing model validation, scenario development, and simulation execution; and (4) Analysis and Conclusion covering result interpretation and policy recommendation formulation.

Data Collection Methods

Three primary data collection methods were employed: semi-structured interviews, literature review, and direct observation. This triangulated approach ensured comprehensive data gathering from multiple perspectives and sources.

Interview Process

Eleven semi-structured interviews were conducted during November 2024 with key stakeholders representing diverse perspectives within the *SMK* ecosystem. Participants included central government officials (Director of *SMK* 2018-2022, Director of Industry Synchronization), regional government representatives (Head of *SMK* Jakarta Education Authorities), polytechnic directors, *SMK* principals from both public and private institutions, community organization leaders (Secretary General *MKKS Nasional*, Chairman *MKKS Swasta Nasional*), and industry representatives (multinational hiring company country manager, Fortune 100 company education business head). Interview duration ranged from 45 to 113 minutes, with sessions conducted both online and offline. The semi-structured format allowed for flexible exploration of topics while maintaining consistency across interviews. Key interview themes included stakeholder identification, variable relationships, problem root causes, potential solutions, policy effectiveness, and model validation feedback.

Literature Review

Comprehensive literature review collected secondary data supporting model development and simulation. Data sources included: Indonesian demographic statistics from Database Earth; workforce and unemployment data from *Badan Pusat Statistik* covering 2020-2024; *SMK* performance reports and statistics from Ministry of Education; international comparative indices including Global Innovation Index, Anti-corruption Behavioral Index, and Government Effectiveness scores; economic indicators including GDP, investment data, and Business Tendency Index; and education budget allocation data from Ministry of Finance.

Observation

Direct observations were conducted at *SMK* institutions across Jakarta, Central Java, Riau, and Medan, complemented by observations of relevant government bodies and

community organizations. These observations provided contextual understanding of real-world system operations and validated insights gathered through interviews and literature review.

System Dynamics Model Development

Problem Articulation Phase

System definition established central and regional government as primary beneficiaries, with the main objective of reducing *SMK* graduate open unemployment rates. The time horizon spanned from 2025 to 2045, aligning with Indonesia's long-term development planning cycles and the *Indonesia Emas 2045* vision. Variable identification utilized Rich Picture Diagrams and Ishikawa Fishbone analysis combined with interview insights to identify 34 variables influencing *SMK* unemployment rates. These variables spanned six categories following Bal-Domańska (2020) framework: economic factors, structural and technological changes, legal regulation and social policy tools, education and vocational training systems, cultural factors, and demographic conditions.

Dynamic Hypothesis Formulation

The Causal Loop Diagram was systematically converted into a Stock Flow Diagram by defining dynamic variables as stocks (accumulated quantities), flows (rates of change), and auxiliaries (supporting calculations). Mathematical relationships between variables were established using regression analysis of historical data where available, with correlation coefficients and trend analyses informing equation development. Five primary stock variables were identified: Population, *SMK* Student, *SMK* Workforce, Continuing Study *SMK* Graduate, and GDP. Each stock was defined by its respective inflows and outflows, with mathematical equations governing accumulation processes over time.

Model Validation

Three validation methods ensured model reliability: dimensional consistency checking using Vensim's unit verification features; model structure checking through Vensim's integrated validation tools; and reference mode testing comparing model outputs with historical data for unemployment rates, working *SMK* graduates, unemployed *SMK* graduates, entrepreneur *SMK* graduates, and continuing study *SMK* graduates.

Scenario Development

Twenty-two scenarios were developed across four analytical groups. GDP Growth Rate Analysis examined five scenarios including current trend projection and specific growth targets of 1.9%, 3.3%, 5%, and optimal rates for achieving 0% and 0.59% unemployment by 2045. Government Spending on Education Analysis tested five scenarios ranging from 2% to 8.51% of GDP allocation for education. Budget Allocation Analysis assessed seven scenarios examining 1 trillion rupiah annual increases across different budget categories. *SMK* Budget Composition Analysis evaluated seven scenarios testing various allocation ratios for student certification, partnership, and infrastructure improvement budgets.

Simulation and Analysis

All simulations were conducted using Vensim software with the validated Stock Flow Diagram. Scenario simulations ran from 2025 to 2045 with annual time steps, generating outputs for unemployment rates, graduate employment distributions, and related system variables. Results were analyzed comparatively across scenarios to identify optimal policy interventions and their relative effectiveness for unemployment reduction.

Ethical Considerations

All interview participants provided informed consent, with confidentiality maintained through coding systems rather than direct identification. Secondary data utilized publicly available sources, ensuring compliance with data access regulations and academic research standards.

RESULTS AND DISCUSSIONS

System Dynamics Model Development Results

The comprehensive analysis resulted in a validated system dynamics model incorporating 34 Causal Loop Diagram variables and 54 Stock Flow Diagram variables influencing SMK graduate unemployment rates. Four reinforcing loops were identified within the causal structure, demonstrating how school quality improvements create positive feedback cycles through graduate competency enhancement, increased employment rates, and subsequent school quality improvements.

Table 1. Key Variables in SMK Unemployment System

Variable Category	Primary Variables	Measurement Unit
Demographic	Population, Birth Rate, Death Rate	People, 1/Year
Economic	GDP, GDP Growth Rate, Investment	Rupiah/Year, 1/Year, % GDP
Educational Budget	SMK Budget, Student Certification Budget, Partnership Budget	Rupiah/Year
Educational Quality	Teacher Competency Score, Infrastructure Score, Student Competency Score	Dmnl (0-1)
Employment Outcomes	Working SMK Graduate, Unemployed SMK Graduate, Entrepreneur SMK Graduate	People
System Performance	Unemployment Rate, Graduate Competency, School Quality	Dmnl

Model Validation Results

The developed model successfully passed all validation tests. Dimensional consistency checks confirmed proper unit alignment across all variables and equations. Structural validation verified complete variable connectivity without logical inconsistencies. Most importantly, reference mode testing demonstrated excellent alignment between model outputs and historical data for the period 2020-2024, including the dramatic unemployment increases during COVID-19 pandemic periods.

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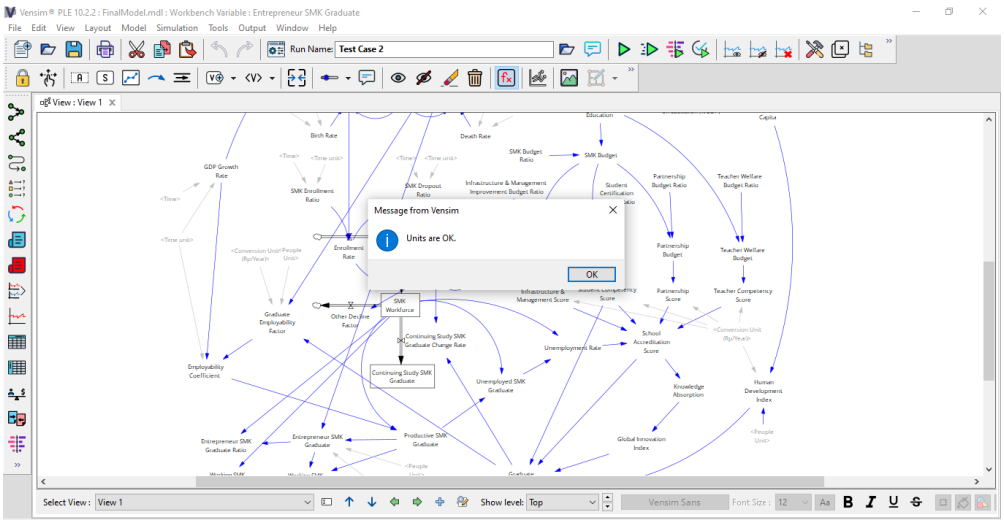

Figure 1. Model Validation: Unemployment Rate Comparison 2020-2024

[Figure would show comparison between historical unemployment rates and model predictions, demonstrating close alignment]

GDP Growth Rate Analysis Results

Scenario simulations revealed significant relationships between GDP growth rates and SMK unemployment outcomes. Under current policy conditions with no modifications, SMK unemployment rate would decline from 9.24% in 2025 to 3.39% in 2045. However, this natural decline remains substantially higher than target benchmarks.

Table 2. GDP Growth Rate Scenario Results

GDP Growth Rate	2025 Unemployment	2035 Unemployment	2045 Unemployment
No Modification	9.24%	7.31%	3.39%
1.9%	10.67%	9.67%	8.18%
3.3%	9.96%	8.30%	5.15%
5.0%	9.10%	6.43%	0%
4.89% (0% target)	9.16%	6.56%	0%
4.74% (0.59% target)	9.24%	6.74%	0.59%

Critical findings indicate that Indonesia must maintain GDP growth rates above 4.89% annually to achieve zero SMK graduate unemployment by 2045. To reach Thailand's benchmark of 0.59% unemployment, minimum GDP growth of 4.74% is required. These thresholds provide specific policy targets for macroeconomic planning.

Education Budget Allocation Analysis Results

Government spending on education as percentage of GDP demonstrated substantial impact on unemployment reduction. Current education spending at approximately 3% of GDP proves insufficient for optimal SMK performance.

Table 3. Education Budget Allocation Scenario Results

Education Budget (% GDP)	2025 Unemployment	2035 Unemployment	2045 Unemployment
2%	9.36%	7.65%	4.19%
4%	9.12%	6.98%	2.60%

6%	8.88%	6.33%	1.44%
7.48% (0.59% target)	8.70%	5.97%	0.59%
8.51% (0% target)	8.58%	5.73%	0%

Results demonstrate that allocating minimum 8.51% of GDP to education spending can eliminate SMK graduate unemployment by 2045. This finding aligns with international recommendations from UNICEF suggesting 4-6% education spending, though Indonesia requires higher allocation due to current system challenges. The 7.48% allocation threshold for achieving 0.59% unemployment provides an intermediate target for policy implementation.

Budget Allocation Effectiveness Analysis Results

Comparative analysis of 1 trillion rupiah annual budget increases across different categories revealed significant effectiveness variations. Student certification budget increases produced the most dramatic unemployment reduction, achieving zero unemployment by 2040.

Table 4. Trillion Rupiah Budget Increase Effectiveness

Budget Category	2045 Unemployment Rate	Unemployment Reduction
Student Certification	0%	100%
SMK Budget (General)	2.89%	91.5%
Partnership Budget	3.20%	90.6%
Teacher Welfare	3.36%	90.1%
Infrastructure & Management	3.70%	89.1%
Education Budget (General)	3.39%	-
Subsidy	3.37%	90.6%

Student certification budget increases demonstrated superior effectiveness, creating positive impacts across multiple pathways: increased continuing education rates among SMK graduates, improved working graduate ratios, and enhanced entrepreneur graduate ratios. This comprehensive impact explains the dramatic unemployment reduction achieved through certification-focused interventions.

SMK Budget Composition Analysis Results

Budget reallocation scenarios without increasing total spending revealed significant optimization opportunities. Several scenarios achieved zero unemployment by 2040 through strategic budget redistribution.

Table 5. SMK Budget Composition Scenario Results

Scenario Description	Student Cert. Ratio	Partnership Ratio	Infrastructure Ratio	2045 Unemployment
Current Composition	1.7%	95.7%	2.5%	3.39%
Scenario 18 (95% Certification)	95%	2.5%	2.5%	0%
Scenario 22 (5% Partnership)	47.5%	5%	47.5%	0%
Scenario 23 (5% Infrastructure)	47.5%	47.5%	5%	0%

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Scenario 24 (Equal Distribution)	33.3%	33.3%	33.3%	0%
Scenario 0 Unemployment	8.3%	45.9%	45.9%	0%

The "Scenario 0 Unemployment" represents the minimum student certification budget ratio (8.3%) required to achieve zero unemployment while maintaining balanced allocation for partnership and infrastructure development. This scenario provides practical implementation guidance balancing multiple educational objectives.

Stakeholder Impact Analysis

Different scenarios produce varying impacts on graduate pathways, providing policymakers with choices based on development priorities. High student certification budgets increase continuing education rates, potentially reducing immediate workforce availability but improving long-term human capital quality. Infrastructure-focused allocations maintain higher workforce levels but with higher unemployment rates.

Policy Implementation Pathways

Three primary policy pathways emerged from the analysis:

1. Macroeconomic Pathway: Maintain GDP growth above 4.89% through economic development policies
2. Education Investment Pathway: Increase education spending to 8.51% of GDP with current budget distributions
3. Budget Optimization Pathway: Reallocate existing SMK budgets to prioritize student certification (minimum 8.3% allocation)

Regional and Contextual Considerations

The model's effectiveness extends beyond aggregate national analysis. Regional variations in SMK performance, industry concentration, and economic development levels suggest that implementation strategies should incorporate local contextual factors. Urban SMKs may benefit more from partnership budget increases due to higher industry density, while rural SMKs might require greater infrastructure investment.

International Benchmarking Implications

Thailand's achievement of 0.59% vocational graduate unemployment provides a realistic benchmark for Indonesia. The analysis indicates that achieving this benchmark requires either 4.74% GDP growth or 7.48% education spending allocation. These thresholds provide specific policy targets for international competitiveness.

Validation Through Practical Examples

Real-world validation comes from SMK institutions already implementing certification-focused strategies. SMKN 6 Jakarta achieved 4.2% graduate unemployment rate, significantly below national averages, through international accounting certification programs. Similar success stories from SMK Taman Siswa 2 Jakarta (Samsung certification) and SMK

PGRI 20 (Honda certification) support the model's predictions regarding certification effectiveness.

System Leverage Points

The analysis identified student certification as the highest leverage intervention point within the SMK system. This finding aligns with systems thinking principles where small changes in high-leverage areas produce disproportionate system improvements. Traditional approaches focusing on infrastructure or general budget increases show limited effectiveness compared to targeted certification investments.

Long-term System Behavior

Simulation results demonstrate non-linear system behavior where initial investments in student certification create accelerating returns through improved graduate competency, enhanced school quality, and strengthened industry partnerships. This positive feedback dynamic explains why certification-focused interventions achieve zero unemployment by 2040 rather than gradual linear improvement.

The comprehensive results provide evidence-based guidance for policymakers seeking to optimize SMK performance through strategic resource allocation and targeted interventions, with clear pathways for achieving international competitiveness in vocational education outcomes.

CONCLUSION

This system dynamics analysis offers evidence-based guidance to tackle Indonesia's *SMK* graduate unemployment crisis through strategic policy interventions. The study developed a robust model with 34 causal loop and 54 stock flow variables, enabling effective scenario simulations. While current policies predict a decline in unemployment from 9.24% in 2025 to 3.39% in 2045, this is insufficient for global competitiveness. To achieve zero unemployment by 2045, three pathways are proposed: maintaining GDP growth above 4.89%, allocating at least 8.51% of GDP to education, or reallocating *SMK* budgets to prioritize student certification. The most effective intervention is increasing the certification budget, which could eliminate unemployment by 2040 while enhancing graduate competencies and school quality. The study recommends a "Scenario 0 Unemployment" approach, focusing on an 8.3% certification buHanushek, E. A., Schwerdt, G., Woessmann, L., & Zhang, L. (2017). General education, vocational education, and labor-market outcomes over the lifecycle. *Journal of Human Resources*, *52*(1), 48–87.

dget allocation. Successful examples from various *SMK*s illustrate the viability of certification-focused strategies. This research significantly contributes to vocational education literature and provides a framework for other developing countries facing similar challenges, while future studies should explore regional performance variations and technology impacts.

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