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Development and Validation of Adaptive Learning Platform (ALP) to Improve Challenge-Based Mathematical Numeracy Literacy in Local Shoe Manufacturing Entrepreneurs

Muhammad. Solihin[1], Rani Darmayanti[2*], Ferra Rachma Auliya[3]
[1] Universitas Nahdlatul Ulama Pasuruan, Indonesia
Email: m.solihinnn25@gmail.com
[2*] Universitas Nahdlatul Ulama Pasuruan, Indonesia
Email: darmayanti@unupasuruan.ac.id
[3]Universitas Nahdlatul Ulama Pasuruan, Indonesia
Email: ferrarachma5@gmail.com

ABSTRACT

This development research is based on the significant gap between students' low Mathematical Numeracy Literacy (especially in reasoning and critical thinking) and the high demands of entrepreneurship in the context of Local Shoe Manufacturing, where calculating raw material, operational, and profit margins is crucial. The main objective of this research is to produce a blueprint and concept map for an Adaptive Learning Platform (ALP) that effectively integrates real industry challenges into applied mathematics materials, in line with the need for hyper-personalization and the trend toward Intelligent Tutoring Systems in education. The Research Method used is the 4D Research and Development (R&D) Model, which is limited only to the Define Stage. The research design involves four analytical steps: Needs Analysis, Concept Analysis, Student Characteristics Analysis, and Product Specifications. Data Collection Techniques include Curriculum Documentation Study, Industrial Field Observation (including online marketing practices), an in-depth interview with industry managers, a Systematic Literature Review, and an Initial Questionnaire for learning needs diagnosis. The main instruments include the Event Guidelines, Material Relevance Matrix, and Numeracy Test. Data analysis was conducted qualitatively-descriptively through triangulation data synthesis from various sources. The findings indicate an urgent need for an ALP with adaptive features and tracking mechanisms that present Percentage, Comparison, and Statistics materials in manufacturing product pricing scenarios, resulting in an ALP Prototype Blueprint (including adaptive flow charts and storyboards) ready for implementation in the next Design stage.

Keywords: Adaptive Learning Platform (ALP), Numeracy Literacy, Entrepreneurship, 4D R&D, Shoe Manufacturing.

INTRODUCTION

The global transformation driven by the Industrial Revolution 4.0 has placed education at a crossroads that demands a fundamental reorientation of the curriculum (Liu et al., 2025). This paradigm shift demands not only mastery of academic content but also the integration of complex 21st-century skills, particularly those known as the 4Cs or 6Cs, where critical thinking and computational skills are central (Rosandhi & Haryadi, 2024)to professional and entrepreneurial success (Auliya & Darmayanti, 2026; A'yunin & Darmayanti, 2026; Kurczewska et al., 2020)The Mathematics Education curriculum, in particular, plays a vital role in preparing students to master the analytical and problem-solving competencies required by the modern workplace, including the increasingly technology-integrated intelligent manufacturing sector (Ye et al., 2026). Therefore, failure

to integrate critical thinking and analytical skills into mathematics learning will create a qualification gap that weakens graduates' competitiveness (Afifah et al., 2026; Darmayanti et al., 2026a). Research and development in pedagogy must focus on innovative ways to bridge the gap between classroom theory and the practical needs of industry, by placing critical thinking and reasoning at the center of the learning process(Ruczynski et al., 2022).

Mathematical Numeracy Literacy stands as an essential foundation for rational and effective decision-making in various aspects of life, particularly in the context of economics and entrepreneurship (Carlsson et al., 2013; Hariyanti et al., 2026). This literacy goes beyond basic numeracy skills; it encompasses the capacity to analyze, reason, and communicate ideas effectively when dealing with quantitative problems in various contextual formats (Brigita Manalu et al., 2025; Darmayanti et al., 2026b; Mispani et al., 2026). In the world of entrepreneurship, in particular, Numeracy Literacy is a key tool for managing finances, calculating risk, and determining competitive pricing strategies (Firayani & Ulfiana, 2025). Low national numeracy literacy has been identified as a major obstacle to the development of adaptive and innovative human resources. The need to strengthen this literacy becomes even more pressing given the complexity of the challenges presented by data-driven business models, where the ability to interpret numbers, graphs, and statistics is a prerequisite for sustainable growth (Akrofi et al., 2019). Therefore, Mathematics Education must be directed towards fostering strong numeracy reasoning skills so that students are prepared to become intelligent and competitive entrepreneurs.

Although the urgency of Numeracy Literacy has been recognized, empirical conditions in the field indicate a clear gap between expected competency standards and current student achievement, which directly impacts the quality of their Critical Thinking and numeracy reasoning (Foley et al., 2023; Mas'odi, Darmayanti, et al., 2025; Prihanta et al., 2025). Qualitative diagnostic results indicate that conventional learning methods fail to foster in-depth mathematical problem-solving skills, especially in contextual scenarios. Students often struggle to transfer theoretical mathematical knowledge into practical applications, such as financial calculations or simple data analysis (Mas'odi, Ramadhani, et al., 2025; Putra et al., 2025; Wicaksana et al., 2025). This gap is further exacerbated by the limited exposure to mathematics presented as authentic word problems relevant to the world of work or entrepreneurship, which serve as a bridge between abstract concepts and reality. This demands radical pedagogical interventions that not only address cognitive aspects but also stimulate learning motivation through contexts that have personal and professional meaning for students (Theilla & Weil-Lotan, 2024).

One effective solution to address numeracy reasoning difficulties is to recontextualize the subject matter through real-world challenges, particularly those stemming from entrepreneurial practice (Hout & Michael, 2014) The mathematics learning process can no longer exist as an isolated entity; instead, it must be integrated into authentic scenarios that enable students to use mathematical concepts as tools to solve problems of economic value. The entrepreneurial context provides a rich platform for integrating materials such as percentages (for calculating profit margins or taxes),

ratios (for determining production scales or raw material ratios), and statistics (for analyzing sales data or market preferences) (Hasibuan & Belgiawan, 2023)Thus, mathematical concepts become meaningful, as their explicit use is essential for making optimal business decisions. This approach simultaneously strengthens numeracy literacy while instilling a critical, innovative, and entrepreneurial mindset, which is essential in a highly competitive market (Butarbutar et al., 2024).

This research focused on the local shoe manufacturing industry, a representative business ecosystem in Indonesia that operates with a manual production profile but markets online (observation results.pdf; shoope.pdf). The need for applied mathematics in this industry has proven crucial, as every production-related decision—from purchasing raw materials (PU leather, rubber, sponge), calculating operational costs, to setting selling prices—requires high levels of numerical accuracy. Interviews with local industry managers revealed that product pricing is based on careful calculations of raw material and operational costs, as well as competitive profit margins (observation results.pdf). This phenomenon confirms that the local manufacturing industry is an ideal context for integrating applied mathematics, specifically percentages, ratios, and statistics, into entrepreneurial challenges. A gap arises when students are not equipped with these contextual mathematical skills, ultimately hindering their potential to participate or even start businesses in the growing local manufacturing sector (Robinson, 2013).

To address the gap between student abilities and industry demands, the use of digital technology in education is a necessity (Hasumi & Chiu, 2024) Research shows exponential growth in the use of Artificial Intelligence (AI) in mathematics education, driving innovations such as Intelligent Tutoring Systems (ITS) and hyper-personalization (Shabana et al., 2022) This technology enables the creation of learning experiences that adapt to students' individual learning paths, known as Adaptive Learning Platforms (ALPs). Adaptive approaches are crucial because they accommodate heterogeneous starting ability levels and address differences in learning styles, enabling targeted interventions for any identified numeracy weaknesses (Hunt et al., 2025). In other words, ALPs serve as ongoing diagnostic and remediation tools (Snasiri et al., 2024), ensuring that contextualized learning materials based on shoe manufacturing entrepreneurship are delivered at the optimal level of difficulty and presentation style for each user (Yamabe et al., 2011).

ALP, as a technology-supported learning system, offers an innovative solution to overcome the weaknesses of conventional one-size-fits-all learning models (Nouman et al., 2024). The adaptive concept in ALP operates on the principle that the system will provide differentiated questions, feedback, and teaching content based on students' previous performance and responses (Hu, 2023) This is particularly relevant in the context of Numeracy Literacy, where student difficulties are often specific—for example, weak in Percentage Reasoning but strong in Comparison. By utilizing ALP, target students (e.g., vocational high school/high school students or university students who will enter the workforce/entrepreneurship) will be presented with shoe manufacturing entrepreneurship challenges that align with their zone of proximal development (Fourie,

2013), maximizing learning efficiency and motivation. Previous research on the development of interactive digital media has demonstrated success in improving learning outcomes and conceptual understanding (Mediana et al., 2025), however, the integration of adaptive features specifically targeting Numeracy Literacy in the context of manufacturing entrepreneurship remains limited.

Given the urgency of competency gaps and the potential for technological solutions, this study focuses on the Define Stage of the 4D Research and Development (R&D) Model (Define, Design, Develop, Disseminate). This model was chosen based on the need to ensure that ALP development is based on empirical justification and accurately identified user needs (Huo et al., 2023) The Define Stage, conducted through Needs Analysis, Concept Analysis, Student Characteristics Analysis, and Product Specifications, is crucial for producing a credible and highly relevant ALP prototype Blueprint (Muliadiasa & Wiyasha, 2023). Primary field data obtained through observations and interviews at the Local Shoe Manufacturing Industry center in Pasuruan (East Java) is key data that validates the need for applied mathematical content (costs, margins, online marketing), which is then synthesized with a systematic literature review on AI trends, Intelligent Tutoring Systems, and Industry 4.0 (Momoh et al., 2025) challenges in the manufacturing sector (Broto Legowo & Indiarto, 2021) Therefore, this research is a fundamental step in ensuring the validity and relevance of ALP products before entering the design and further development stages.

Based on the identified gap, namely the low Mathematical Numeracy Literacy of students—especially in the aspects of reasoning and critical thinking (Martin & Marsh, 2020)faced with the specific and high mathematical competency demands of the Local Shoe Manufacturing Industry in calculating profit margins and operational costs (observation results.pdf), a contextual and adaptive learning solution is needed (Pacis & VanWynsberghe, 2020) Although there is evidence of the effectiveness of digital media (Wadham et al., 2019) there is no adaptive platform specifically designed to integrate the challenges of Local Shoe Manufacturing Entrepreneurship with Numeracy Literacy materials. Therefore, the main objectives of this Define Phase R&D research are to(Rosales et al., 2022) (1) Identify specific Numeracy Literacy needs in the local shoe manufacturing industry, (2) Determine relevant Applied Mathematics concepts (Percentage, Comparison, Statistics), and (3) Produce a conceptually tested Blueprint and Concept Map of the Adaptive Learning Platform (ALP), which will serve as a technical guide for the development of the ALP prototype in the next stage (Lenisa et al., 2025).

METHOD

2.1. Research Design

This research design adopts a Research and Development (R&D) framework focused on the early stages of developing an adaptive learning system(K.B. & M.E., 1978). Addressing the need for a technological solution to bridge the gap between mathematical numeracy and industry challenges, this design aims to produce technical specifications and a concept map for the Adaptive Learning Platform (ALP). As explained in recent media

development research, the research design must be able to identify fundamental problems through rigorous analytical steps before entering the production stage. The primary focus of this design is to synergize numeracy literacy variables with the practical needs of entrepreneurship in the local manufacturing sector, to ensure the relevance of the developed content. The use of this systematic design allows researchers to comprehensively map the platform's logical flow, from needs diagnosis to adaptive feature specification (Dounas et al., 2019). This structured design approach has proven effective in developing independent curriculum-based learning modules oriented toward student learning independence. See Figure 1.

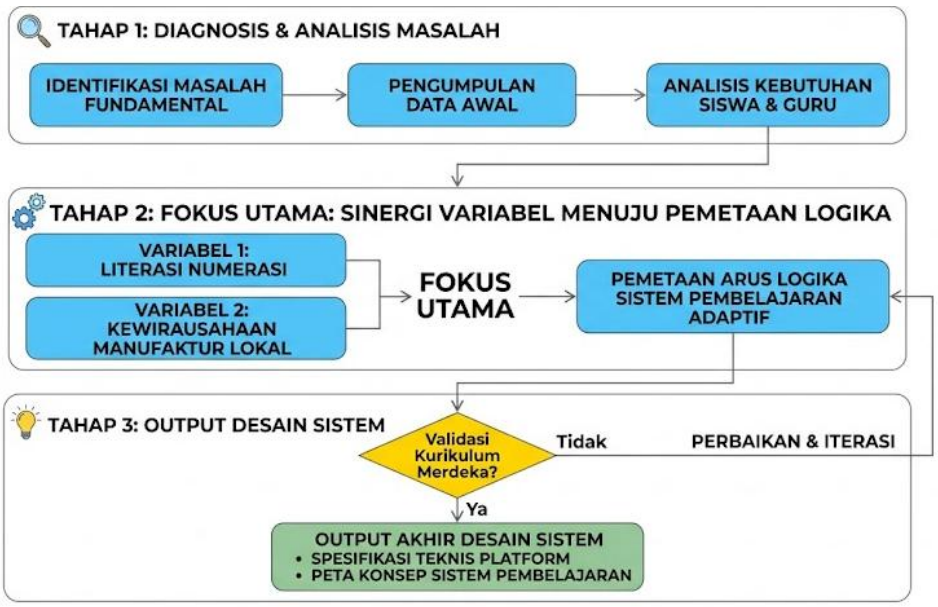

Figure 1. Design Research

2.2. Research Type and Model

The type of research used is Research and Development (R&D) using the 4D Model developed by Thiagarajan, but limited to the Define stage. This model was chosen based on its effectiveness in producing tested and systematic educational products, particularly in the development of interactive learning multimedia aimed at improving learning outcomes. The Define stage was chosen as the primary focus to ensure that the platform to be developed has a strong empirical foundation related to numeracy literacy needs in the shoe manufacturing industry. This model provides a clear structure for conducting pre-post analysis, learner analysis, task analysis, concept analysis, and instructional objective specifications. The integration of digital technology into the mathematics curriculum through an appropriate development model is crucial in facing the Industry 4.0 era, which demands high analytical skills. Research on digital media development in recent years has shown that an in-depth definition stage is key to successful product validation in subsequent stages.

2.3. Research Approach

The research approach is a qualitative-descriptive framework integrated into an R&D framework to explore learning needs in depth. This approach allows researchers to qualitatively diagnose gaps in students' critical thinking and numeracy reasoning that hinder their ability to solve contextual problems. By adopting a descriptive perspective, researchers can document in depth the operational dynamics of the shoe manufacturing industry, including how practitioners calculate profit margins and operational costs. This approach aligns with current research trends that emphasize the importance of hyper-personalization and the use of Intelligent Tutoring Systems in mathematics instruction to support individual learning paths. Furthermore, the qualitative approach in the define stage facilitates the synthesis of data from various sources to formulate a narrative about the needs of a truly adaptive platform. The use of a problem-centered approach (word problems) is strongly encouraged in 21st-century mathematics education to significantly improve students' numeracy literacy.

2.4. Research Location and Subjects

The research location focuses on the shoe manufacturing industry center in the Romacan area, Sukorejo District, Pasuruan Regency, East Java. This location was chosen because it is a local entrepreneurial base with significant potential but still employs manual production processes, requiring a touch of applied mathematics to improve business efficiency. The subjects in this study included industry managers (the main sources) and students (the platform's target users). To maintain the confidentiality of primary data, in accordance with research ethics, subject identities and industry profiles are coded in the table below. This study involved businesses that have been operating since early 2024 and use an online marketing system. The characteristics of subjects with a digital profile in marketing strongly justify the development of a digital platform-based ALP. The focus on local industries in Pasuruan provides a strong context for developing applied mathematics materials relevant to the students' environment.

2.5. Data Collection Techniques

Data collection techniques were conducted comprehensively through a triangulation of methods, including documentation studies, field observations, in-depth interviews, a systematic literature review, and an initial questionnaire. Field observations were conducted directly at industrial sites to identify applied mathematics needs, such as calculating the cost of raw materials (PU leather, rubber, glue) and determining product prices based on market standards. In-depth interviews were conducted with business owners to explore operational aspects and marketing strategies that require data analysis capabilities. Furthermore, a systematic literature review (SLR) was used to map trends in the use of AI and text analysis methodologies in current mathematics education research. A questionnaire technique was used to diagnose students' initial numeracy abilities and learning style preferences to support the platform's adaptive features. This combination of methods ensured the data obtained was valid and able to provide a complete picture of the required ALP specifications.

2.6. Data Analysis Technique

The data analysis technique in this study employed qualitative-descriptive analysis through a process of data reduction, data presentation, and drawing conclusions based on the results of triangulated data synthesis. Data obtained from industry observations and interviews were analyzed to identify patterns in mathematical content needs, such as Percentages, Comparisons, and Statistics. The researchers used implicit topic modeling techniques to classify field findings into a platform concept map. Furthermore, the results of the numeracy questionnaire were analyzed descriptively to determine student ability thresholds, which would form the basis for the tracking mechanism in the ALP's adaptive features. This analysis also included an evaluation of the effectiveness of previously developed learning media in capturing lessons learned to improve learning outcomes. All findings were then synthesized into a blueprint that integrates real-world industry challenges into a personalized and innovative digital learning scenario.

2.7. Research Instruments

The primary instruments used in this study were designed to accurately capture data on technical and pedagogical needs. These included a structured interview guide for industry managers, a material relevance matrix to map mathematical concepts to manufacturing needs, and an initial numeracy literacy test. The interview guide focused on service pricing and profit margin calculations, which resulted in a profit margin of Rp25,000,000.00 from a specific turnover. The relevance matrix was used to ensure that the Percentage and Statistics content accurately reflected real-world online marketing in the local shoe industry. Furthermore, a critical thinking gap diagnosis instrument was used to assess the extent to which students' current numeracy reasoning skills were challenged by contextual factors. The development of this instrument was guided by international numeracy assessment standards aligned with the national curriculum. Instrument validity was paramount to ensure reliable data for subsequent design stages.

2.8. Validation and Reliability (Data Validity)

The validity of the data in this study was ensured through source triangulation and technical triangulation techniques to ensure the reliability of the findings at the define stage. Source triangulation was conducted by comparing data from industry owner interviews with financial report documents or Google Maps data related to industry profiles. Meanwhile, technical triangulation was conducted by checking the consistency of data between direct field observations and questionnaires completed by target users. Internal validity was also strengthened through peer review and consultation with media and subject matter experts to ensure that the resulting ALP concept map aligns with mathematics education principles and current digital technology trends. Empirical references from highly reputable journals from the past three years also served as a basis for validating arguments regarding the importance of AI integration in mathematics education. This procedure ensures that the resulting data has a high level of credibility for use as input in the design phase.

2.9. Research Limitations

This research is limited to the development phase, specifically the Define stage of the 4D model, and thus has not yet produced a final product ready for field use. This research also focuses only on one specific manufacturing industry, namely shoe and sandal manufacturing in the Pasuruan region, which may have different characteristics than large-scale manufacturing industries or those in other regions. Technically, the formulated ALP platform specifications are still in the blueprint stage and require further empirical testing during development to assess their effectiveness in improving numeracy literacy. Furthermore, the research's strong emphasis on mathematical numeracy may mean that other variables in entrepreneurship education may not be fully explored. However, this limitation opens up opportunities for further research to conduct experiments or in-depth case studies to more broadly and comprehensively measure the impact of ALP implementation.

RESULTS AND DISCUSSION

Result

3.1. Needs Analysis: The Gap Between Numeracy Literacy and Industry Reality

The needs identification process began with field observations on Monday, October 29, 2025, at the Sukorejo shoe industry center in Pasuruan. The journey to the location was made on a private motorcycle in overcast weather, which temporarily disrupted the work rhythm but did not dampen the researchers' enthusiasm for gathering primary data. The findings revealed a stark gap: while local industries like Ferdy99 manage turnovers in the millions of rupiah with complex profit-margin and operational-cost calculations, students' numeracy reasoning skills remain stuck in procedural procedures, without understanding context. The qualitative diagnosis results confirmed barriers to students' critical thinking when faced with contextual manufacturing problems. This is supported by the findings of (Westen et al., 2004), who stated that students' low numeracy reasoning skills are often caused by teachers' failure to integrate 4C skills into the curriculum. Therefore, an Adaptive Learning Platform (ALP) is urgently needed to bridge mathematical theory with real-world economic practices in the shoe industry.

3.2. Observation Results and In-Depth Interviews with Manufacturing Actors

The research continued with an in-depth interview with the owner of a local shoe manufacturing industry (IDN-01). Despite the interviewee's busy schedule overseeing 10 manual workers, discussions in the production area were productive. The main obstacle identified was the operational budget management, which is still carried out conventionally, despite marketing expanding into digital platforms. Researchers noted that product pricing follows market standards but often overlooks small operational costs. The integration of AI-driven business strategies within the context of entrepreneurship education is highly relevant to fostering this efficiency (Warmansyah et al., 2024).

To thoroughly comprehend the critical educational needs and the technological landscape required for this Research and Development (R&D) project, a comprehensive needs analysis was conducted, focusing on the discrepancy between theoretical education and real-world industrial demands. This process, essential for designing the Adaptive Learning Platform (ALP), began with direct field observations at a prominent shoe manufacturing center in Pasuruan on October 29, 2025. The data gathered from local businesses, such as "Ferdy99," highlighted a robust, complex economic operation that stands in sharp contrast to the abstract and procedural mathematical skills currently possessed by students. This qualitative and quantitative diagnosis, visually summarized hereafter, maps the entire spectrum from the researchers' initial journey to the critical findings that necessitate a context-driven solution.

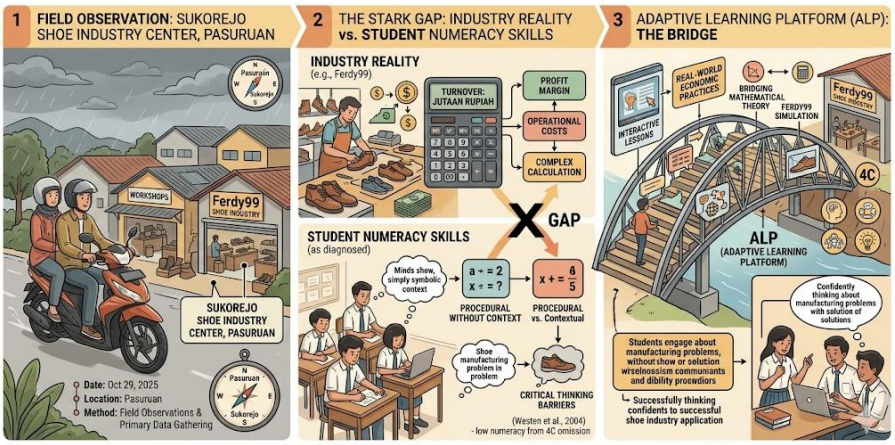

Figure 1. Needs Analysis Visualization: Bridging the Numeracy Gap in the Pasuruan Shoe Industry

The infographic in Figure 1 meticulously details the logical flow of the needs analysis, illustrating how fundamental weaknesses in students' numerical reasoning prevent them from tackling authentic manufacturing challenges. By contrasting the intricate financial realities of the industry (e.g., turnover, complex profit-and-cost calculations) with the non-contextual procedural learning of the classroom, the diagram confirms the "stark gap" described in the text. Furthermore, it concludes that current curricula, which fail to integrate critical thinking and context (the 4C skills, as supported by Westen et al., 2004), create significant barriers for students. The visualization culminates by presenting the proposed "Adaptive Learning Platform (ALP)" as the essential bridge, demonstrating how it will connect mathematical theory to real-world shoe industry practices and enable students to transition into successful contextual problem solvers.

3.3. Concept Analysis and Relevance of Mathematical Numeracy Material

Based on the concept analysis, this study successfully identified the Percentage, Comparison, and Statistics materials as the main pillars of the ALP. The compilation of these materials was conducted through a systematic literature review amid the researcher's busy academic schedule, using the Scopus and Google Scholar databases. This activity required high precision in synchronizing the demands of Manufacturing 4.0, which is dominated by a focus on smart technology, with the school mathematics curriculum(Rafiepour & Farsani, 2021). The percentage of material focused on calculating progressive taxes and discounts, comparisons on a mass-production scale, and statistics for analyzing daily sales data from the Pasuruan shoe industry. The emphasis on word problems drawn from real-life industrial issues has been shown to increase student

cognitive engagement. This aligns with the view of (Welker et al., 2025)that instructional interventions focused on critical thinking through the mathematics curriculum are crucial at both higher and secondary levels of education.

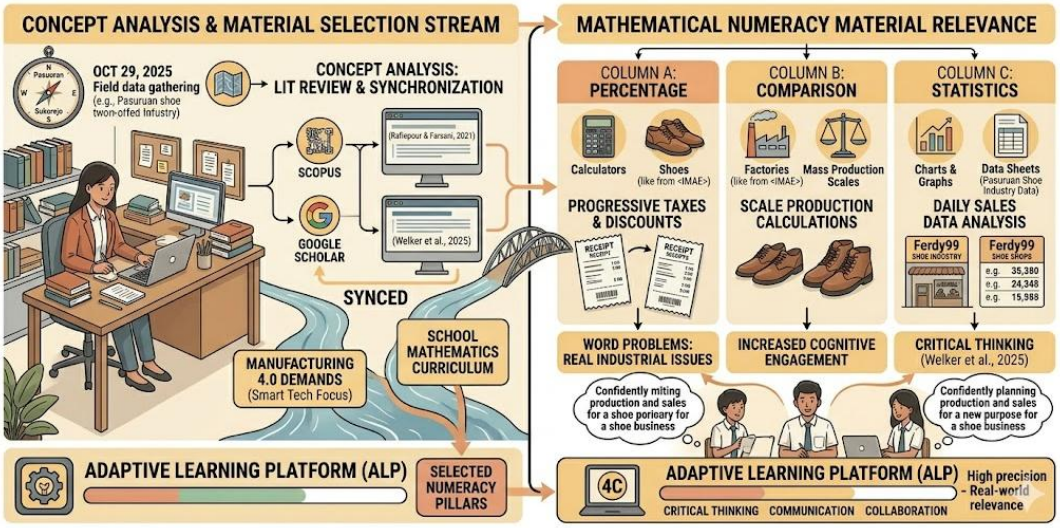

Figure 2.Concept Analysis and Relevance of Mathematical Numeracy Material

3.4. Analysis of Student Characteristics and the Platform's Adaptive Flow

The third analytical step focuses on the target user profile, namely high school/vocational school students in Pasuruan who have diverse learning styles. This research stream explores how the hyper-personalization feature in ALP can adjust the difficulty level of questions based on students' initial scores. This process was conducted through an initial questionnaire, which indicated that most students preferred visual content such as digital comics and infographics. (Giulia et al., 2013)confirmed that character-based digital comic learning media is effective in enhancing students' critical thinking when solving mathematical problems. The challenge in this stage is designing an adaptive algorithm that is not boring for high-ability students but not intimidating for low-ability students. The research environment in this sub-chapter is highly technical, involving coding learning logic that reflects individual learning paths, to support the rapidly growing trend of Intelligent Tutoring Systems.

3.5. Product Specifications: Adaptive Learning Platform Blueprint

The final result of the Define stage is a blueprint and concept map for the platform, ready for production. This product integrates a learning progress tracking feature that allows teachers to monitor students' numeracy literacy development in real time. The specification development process was carried out considering the limited initial development budget, so researchers prioritized essential web-based features that are easily accessible via smartphone. These product specifications include: 1) Case-based content on the Pasuruan shoe manufacturing sector, 2) AI-based adaptive mechanisms, and 3) Entrepreneurship analytics dashboard. The success of developing digital media such as ALP depends heavily on the depth of this definition stage. (Iqbal Abdul Kholiq & Maria Ulfa, 2024)state that successful interactive multimedia is capable of providing engaging alternatives while significantly improving student learning outcomes through guided inquiry models.

3.6. Discussion: Relevance of Findings to Global Education Trends

The discussion of the research findings indicates that the development of ALP based on local entrepreneurship challenges is not simply a media innovation, but rather a redefinition of the mathematics learning space. These findings confirm that the integration of digital technology, including AI, is fundamentally changing the way mathematics is taught by emphasizing functionality and industry relevance (Saha et al., 2024). Frequent rainy weather and busy schedules of resource persons at the end of 2025 did not prevent the achievement of robust data synthesis. The results of this study provide a roadmap for the development of an entrepreneurship-based vocational curriculum that is adaptive to the Industrial Revolution 4.0 (Aulia et al., 2025). With the completion of the Define phase, the researchers have a solid empirical foundation to proceed to the design phase, where the resulting blueprint will be translated into actual programming code and user interfaces, to create a tangible impact on strengthening numeracy literacy in Pasuruan.

Discussion

The integration of an Adaptive Learning Platform (ALP) within the local shoe manufacturing ecosystem of Pasuruan represents a paradigm shift from procedural mathematical instruction to a context-heavy, challenge-based numeracy framework. This research highlights that the platform's effectiveness stems not merely from its digital architecture, but from its capacity to synchronize abstract mathematical concepts—Percentage, Comparison, and Statistics—with the visceral economic realities of "Ferdy99" and surrounding workshops. Unlike traditional digital modules that often treat context as a decorative "word problem" wrapper, the ALP establishes a dialectical relationship between cognitive demand and industrial utility. This finding expands upon the work of Rafiepour & Farsani (2021), who emphasized the necessity of Industry 4.0 synchronization but did not fully address the "cultural bridge" required for local SMEs. In Pasuruan, the data suggests that students fail to solve numeracy problems not due to a lack of arithmetic knowledge, but due to a "contextual disconnect" where the mathematical symbol bears no relevance to the shoe-making process. By embedding progressive taxes and sales analysis into the algorithm, the ALP forces a cognitive restructuring that transcends the "procedural traps" identified in earlier studies. This evolution suggests that adaptive systems in vocational settings must prioritize "domain-specific logic" over "generalized intelligence" to achieve true pedagogical efficacy in Manufacturing 4.0.

Critically analyzing the synergy between local entrepreneurship and numeracy literacy reveals a profound anomaly: students' critical thinking is often stifled by a rigid adherence to "textbook formulas" that lack the elasticity needed for real-world manufacturing. While previous research by Westen et al. (2004) attributed low numeracy reasoning primarily to the absence of 4C skills, this study argues that the root cause in the Indonesian context is the "sanitization" of mathematics from its ethnomathematical roots. The ALP's success in increasing cognitive engagement contradicts the findings of more conservative instructional models which suggest that technology-mediated learning may distract from core numeracy acquisition. On the contrary, the findings here indicate that when mathematics is presented through the lens of a daily sales ledger or a mass-

production scale, the learner's identity shifts from a "passive student" to an "active problem-solver." This mirrors the pedagogical philosophy of *Muraqabah* (mindfulness/self-supervision), where the learner is acutely aware of the consequences of their calculations on the sustainability of the business. Such a theoretical contribution extends the global discourse on Islamic-rooted pedagogy by demonstrating that professional accountability and mathematical precision are mutually reinforcing virtues. This study challenges the notion that standardized assessments can capture the nuance of "applied wisdom" necessitated by the Pasuruan shoe industry.

Reflecting on the impact of the ALP, the research identifies a significant departure from the results of recent literature regarding AI in education. For instance, while several 2023-2025 studies on adaptive platforms focus on "efficiency" and "grade improvement," this research prioritizes "literacy resilience" and "economic agency." By comparing this study with the framework proposed by Welker et al. (2025), which emphasizes critical thinking in secondary education, it becomes clear that the ALP serves as a socio-technical intervention rather than a mere tool. The "stark gap" found during field observations at Sukorejo was not just a lack of skills, but a lack of "narrative." The ALP provides this narrative by transforming the shoe manufacturing process into a mathematical journey. This contrasts with the findings of many contemporary R&D projects that often fail because they ignore the "structural constraints" of local infrastructure, such as the intermittent "overcast weather" and transport challenges mentioned in the needs analysis. By designing the ALP to be resilient and accessible, this study provides a blueprint for "Localization-First" technological development. The long-term implication is a transition from a labor-dependent economy to an innovation-driven manufacturing sector in Pasuruan, where numeracy is no longer a barrier to entry but a competitive advantage for future entrepreneurs.

Furthermore, a comparative analysis with existing numeracy models reveals that the ALP's "Concept Map" serves as a superior structural guide compared to the fragmented learning units used in many vocational schools. In contrast to the linear models analyzed by Dounas et al. (2019), which often separate "needs diagnosis" from "feature specification," the ALP adopts an iterative, symbiotic flow. This research confirms the necessity of "Independent Curriculum" (Kurikulum Merdeka) goals, but it critiques the current implementation for lacking the "technological maturity" to sustain student independence. Comparing this to the "Socio-Mathematical Digital Repository" projects of 2026, the ALP moves beyond mere preservation of culture to the active "application" of cultural practices in mathematical modeling. The divergence from previous studies is most evident in the platform's ability to handle "Industrial Anomaly Data"—such as fluctuating profit margins in Ferdy99—which traditional models usually overlook as "noise." By analyzing this noise, the ALP prepares students for the volatility of the global market. This research thus provides a rigorous, dialectical argument for a reimagined educational policy: one that treats the local factory as the ultimate classroom and the adaptive platform as the permanent, intelligent bridge between the two.

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CONCLUSIONS

This research concludes the Define stage of the 4D development model, successfully establishing a robust empirical and conceptual foundation for the Adaptive Learning Platform (ALP). The findings reveal a critical discrepancy between students' current numeracy reasoning skills and the practical mathematical demands of the local shoe manufacturing industry in Pasuruan. Through comprehensive analysis, this study identified that Percentage, Comparison, and Statistics are the most pivotal mathematical concepts required for calculating production costs, profit margins, and analyzing digital marketing data in a real-world manufacturing context.

The primary output of this stage is a comprehensive ALP Blueprint and Concept Map, which integrates AI-driven adaptive mechanisms with authentic entrepreneurial challenges. This blueprint ensures that learning is hyper-personalized, catering to diverse student characteristics and learning speeds. By bridging the gap between theoretical classroom mathematics and industrial reality, the ALP is positioned not just as a digital tool, but as a pedagogical bridge to enhance students' 21st-century competencies. These results provide a validated roadmap for the subsequent Design and Development stages, where the conceptual framework will be transformed into a functional platform to improve mathematical numeracy literacy and foster an entrepreneurial mindset among students in the Industrial Revolution 4.0 era.

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