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Design and implementation of a generative AI-supported entrepreneurship education system based on project-based learning

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Abstract: This study designs and evaluates ABL-Startup, a generative AI-supported entrepreneurship education system grounded in Project-Based Learning (PBL). The study mapped five PBL stages onto entrepreneurship tasks: idea formulation, market and persona analysis, AI-guided business modeling, feasibility and revenue analysis, and Demo Day, and implemented them in a four-layer architecture integrating a prompt engine, PSST-based document generation, presentation generation, and mock investment evaluation. Functional alignment, task-efficiency data, and exploratory pilot satisfaction results for the system were analyzed. ABL-Startup connected stage-based learning activities with cumulative outputs and iterative feedback. In the pilot context, business plan drafting decreased from approximately four weeks and 12 working hours to one week and three hours, while overall satisfaction reached 4.88/5; writing efficiency, process appropriateness, and AI usefulness scored 4.95, 4.90, and 4.89, respectively. Generative AI can operate as process-embedded instructional scaffolding rather than merely as a writing tool, although controlled studies are required to establish learning effects. The system can lower novice learners' documentation burden, support consistent instructor feedback, and be adapted for university courses, startup camps, and public entrepreneurship programs.

Keywords: *Educational support system, Entrepreneurship education, Generative AI, Project-based learning, PSST.*

1. Introduction

1.1. Research Background

The Fourth Industrial Revolution has rapidly transformed industrial structures and competency requirements through advances in artificial intelligence, big data, cloud computing, and hyperconnectivity. These changes have also required a fundamental shift in the goals and methods of education. In particular, generative artificial intelligence (Generative AI) has recently emerged as a general-purpose technology that supports higher-order cognitive activities such as text generation, question answering, summarization, idea expansion, and feedback provision. As a result, Generative AI has become a key technological driver of teaching and learning innovation in higher education. UNESCO has acknowledged that generative AI offers new possibilities for education and research while emphasizing the need for human-centered use and pedagogically grounded implementation [1].

Against this backdrop, Project-Based Learning (PBL) has continued to attract attention as a pedagogical approach in which learners engage in inquiry, collaboration, decision-making, and product creation around authentic problems. Guo et al. [2] reported that PBL in higher education has positive effects on students' affective and cognitive outcomes, as well as product performance, identifying authenticity and product-oriented learning as key elements of PBL [2]. These characteristics are closely aligned with the competencies increasingly required in future societies, including critical thinking, collaboration, and creative problem-solving, and are therefore particularly suitable for practical learning domains such as entrepreneurship education.

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Entrepreneurship education, in turn, involves complex problem-solving processes such as idea generation, market exploration, customer problem identification, business model design, strategy formulation, and investment pitching. In this sense, entrepreneurship education is highly compatible with PBL. Rather than merely delivering theoretical knowledge, entrepreneurship education should enable learners to identify real opportunities, validate them, and transform them into executable business structures. Motta and Galina emphasized that experiential learning in entrepreneurship education helps bridge the gap between theory and practice and provides learners with experiences similar to actual entrepreneurial behavior [3]. Therefore, entrepreneurship education is likely to achieve stronger educational outcomes when combined with the problem-solving structure of PBL.

More recently, generative AI has been recognized as a new educational infrastructure capable of supporting each stage of entrepreneurship education. By assisting learners with idea expansion, information structuring, draft writing, iterative revision, and immediate feedback, generative AI may function as a cognitive scaffolding tool throughout complex task performance. Recent review studies on the use of generative AI in higher education have pointed out that, although generative AI is being utilized in various ways, including course design, learning support, and feedback provision, its effectiveness depends less on the technology itself than on the quality of pedagogical design and contextualization [4]. Accordingly, the effective application of generative AI to entrepreneurship education requires more than simple tool adoption; it calls for an educational engineering approach that integrates the technology into a PBL-based learning structure.

1.2. Necessity of the Study

Despite its importance, conventional university-level entrepreneurship education faces several structural limitations. First, entrepreneurship education requires learners to perform multiple complex tasks, including idea generation, problem definition, customer analysis, market research, business model design, revenue structure analysis, and investment pitch preparation. Such processes impose a substantial cognitive burden on novice learners. In particular, writing structured documents such as business plans and presentation materials requires simultaneous decision-making regarding information selection, logical organization, and expression, thereby further increasing the difficulty of learning. This explains why entrepreneurship education, although highly valuable as a form of practical learning, often becomes a barrier for beginners [3].

Second, entrepreneurship education relies heavily on continuous and individualized feedback from instructors, yet such support is often difficult to provide adequately in real classroom settings because of time and personnel constraints. Since each team differs in idea quality, market context, and document completeness, instructors are expected to provide repetitive yet customized feedback. However, in large classes or short-term intensive programs, such support is difficult to sustain. Although generative AI has the potential to address this feedback scalability problem, its use as a generic tool detached from the educational context may instead lead to superficial output production [1, 4].

Third, the actual use of generative AI in educational settings often remains unstructured. In many cases, students simply input ad hoc questions into general-purpose conversational tools and use the outputs they receive. As a result, the quality of outcomes varies widely depending on learners' prompt-writing skills. Such usage does not adequately reflect curricular goals or assessment structures and thus cannot systematically support learners' thinking processes. UNESCO has also stressed that the educational use of generative AI should be designed together with policy, pedagogy, competency frameworks, and ethical review rather than being treated as a standalone technology [1]. Therefore, merely introducing generative AI into entrepreneurship education is insufficient; a system-level approach is needed to integrate learning flow, feedback structure, and output generation in alignment with PBL stages.

In this respect, entrepreneurship education is a field in which the advantages of generative AI can be highly practical, while the risks of unstructured adoption are also considerable. Entrepreneurship involves discovering real-world problems, designing solutions, and translating them into the language of marketability and business feasibility. Accordingly, learners require continuous guidance and feedback throughout the process. In particular, Kim [5] reported the implementation of ABL-Startup, a generative AI-based educational support system grounded in a stage-based business plan education process derived from PBL theory, and showed that it could reduce learners' documentation burden while increasing their concentration on implementing entrepreneurial ideas. This suggests that, in entrepreneurship education, generative AI should be designed not as a simple writing aid but as a stage-based cognitive support system.

1.3. Purpose of the Study

The purpose of this study is to propose the design and implementation of a generative AI-based system, ABL-Startup, that supports the entire process of university entrepreneurship education based on Project-Based Learning theory. More specifically, this study aims to: first, reconstruct the traditional stages of PBL in accordance with the actual flow of entrepreneurship education and thereby establish an educational process model; second, design generative AI functions that can support learners' thinking and output generation at each stage; and third, propose the system architecture and core modules required to implement such a model. In this sense, the study seeks to reposition generative AI not as a simple question-and-answer tool but as a core component of an educational system that promotes learners' problem-solving and product development.

The proposed ABL-Startup system is not merely an AI-based conversational tool. Rather, it is an integrated educational support system that sequentially assists learners with key entrepreneurship tasks, including idea refinement, market analysis, customer persona development, business model formulation, feasibility review, and presentation preparation. In other words, instead of using generative AI as an automation tool that replaces learners' thinking, this study positions it as a pedagogical scaffolding tool that reduces cognitive burden and promotes inquiry and expression throughout complex project performance.

1.4. Research Questions and Scope

This study addresses the following research questions.

First, how can the core stages of PBL be reconstructed appropriately for the context of entrepreneurship education, and how can the resulting educational process be designed as a generative AI-based support system?

Second, what architecture and functional modules are required to implement a generative AI-based system capable of supporting the full process of entrepreneurship education?

Third, to what extent can the proposed generative AI-supported entrepreneurship education system effectively satisfy the core principles of PBL and the practical requirements of entrepreneurship education?

To answer these questions, this study proceeds as follows. First, it reviews prior studies on PBL, the educational use of generative AI, and methodologies in entrepreneurship education to establish a theoretical foundation. Second, it designs a PBL-based system process model that reflects the full process of entrepreneurship education. Third, it proposes the system architecture and core functional modules necessary to implement the designed process. Fourth, it examines the extent to which the proposed system satisfies the core principles of PBL through an analysis of functional validity and the results of a pilot application. Overall, this research design aims to integrate the educational logic of PBL, the practical structure of entrepreneurship education, and the scaffolding potential of generative AI into a coherent framework.

2. Theoretical Background

2.1. Project-Based Learning

Project-Based Learning (PBL) is a constructivist instructional approach in which learners engage in inquiry around authentic and ill-structured problems, produce tangible outputs, and complete their learning through presentation and reflection. Thomas described PBL as a learning model characterized by centrality, driving questions, constructive investigation, autonomy, and realism [6]. Likewise, Guo et al. [2] defined PBL in higher education as a learning process centered on authentic projects and product development [2]. These definitions suggest that PBL is not simply a method of assigning tasks, but a pedagogical structure that organizes learning around authentic problem-solving.

The essence of PBL lies, first, in placing authentic problems at the starting point of learning. Instead of reproducing instructor-provided answers, learners are required to explore and interpret problems whose solution paths are not predetermined and to construct their own strategies for solving them [6]. Second, the learning process itself includes repeated cycles of inquiry, collaboration, decision-making, and revision. Third, learning outcomes are externalized through concrete products such as reports, prototypes, presentations, and demonstrations [2, 6]. Fourth, these products are assessed through performance-based evaluation, thereby revealing learners' ability to apply knowledge and solve problems in practical contexts. In a systematic literature review on authentic assessment in higher education, Vlachopoulos and Makri [7] reported that assessments based on authentic tasks contribute to the development of 21st-century skills and employability [7].

Because of these characteristics, PBL is particularly suitable for learning domains characterized by uncertainty and complexity. Entrepreneurship education includes tasks such as problem discovery, market exploration, customer understanding, value proposition refinement, business model construction, and strategy formulation, all of which lack predefined answers. Accordingly, it shows strong structural compatibility with PBL. Motta and Galina [3] noted that experiential learning in entrepreneurship education helps bridge the gap between theory and practice and positively influences entrepreneurial intention and competency development [3]. This implies that entrepreneurship education is more closely related to actual task performance and product-centered learning than to conventional lecture-based knowledge transmission.

However, PBL does not automatically guarantee strong educational outcomes. Guo et al. [2] pointed out that the effectiveness of PBL in higher education varies depending on the quality of project design, the level of authenticity, the assessment method, and the support structure provided by instructors [2]. In particular, the more complex and open-ended the task, the more likely novice learners are to experience a high cognitive burden. Without appropriate scaffolding, the problem-solving process may remain superficial [2, 6]. Therefore, when implementing PBL in entrepreneurship education, where tasks are highly complex, it is necessary to provide structured outputs, stage-based guidance, and repeated feedback.

2.2. Educational Use of Generative AI

Generative AI refers to technologies based on large language models that can generate text, images, code, summaries, and feedback, and it has rapidly spread across educational settings in recent years. UNESCO has pointed out that generative AI creates new possibilities for education and research while simultaneously raising issues related to data privacy, ethics, age appropriateness, and human-centered control [1]. In other words, the educational value of generative AI lies not merely in its technical performance, but in how it is integrated into sound pedagogical design.

From an educational perspective, the significance of generative AI lies in its potential to function not as a substitute for learners' thinking, but as a tool that stimulates and extends thinking. In a systematic literature review on generative AI literacy in schools, Park [8] identified understanding, usage, evaluation and integration, ethics, and attitudes as key competencies required for the educational use of generative AI, while also noting that learners often struggle with prompt writing and the critical evaluation of AI-generated outputs [8]. Similarly, Wang et al. [4] argued that the effectiveness of generative AI in higher education depends less on the technology itself than on the level of instructional design and contextual integration [4]. This suggests that generative AI should not merely provide answers, but should be designed in a way that supports learners in reviewing, evaluating, and reconstructing its outputs.

In particular, generative AI deserves attention as a scaffolding tool. Scaffolding refers to instructional support that helps learners perform tasks they cannot yet complete independently while gradually fostering autonomy. Generative AI can support complex tasks step by step by providing questions, structuring outlines, generating initial drafts, suggesting revisions, and offering feedback. Dai et al. [9] reported that, in an online PBL environment enhanced by generative AI, students' learning approaches, cognitive engagement, and learning outcomes were significantly affected [9]. This finding suggests that generative AI can provide substantial support in project-based learning environments by assisting with idea organization, information structuring, and task progression.

Generative AI may also play a meaningful role in regulating learners' cognitive load in project-oriented classes. In entrepreneurship education, learners are expected to conduct information searches, structure documents, revise repeatedly, and prepare presentations simultaneously. Under such conditions, generative AI can reduce non-essential burdens and enable learners to focus more on core problem-solving activities [4, 9]. However, such support should not be designed as automation that bypasses thinking; rather, it should be structured in ways that organize and deepen thinking. UNESCO similarly emphasizes that generative AI must not replace educational goals and that human judgment and accountability should remain central [1].

At the same time, the educational use of generative AI requires careful consideration. Park [8] stressed that ethical awareness, academic integrity, privacy protection, and critical evaluation of AI outputs are essential components of generative AI literacy [8]. Therefore, to use generative AI educationally, at least three conditions should be satisfied. First, learning goals and assessment criteria must be explicit. Second, learners should be required to review, revise, and reconstruct AI-generated outputs. Third, instructors should function not simply as judges of final products, but as facilitators who monitor learners' reasoning and decision-making processes [1, 8].

Recent scholarship on AI in education also reinforces this position. Holmes and Tuomi [10] argued that the educational use of AI should be understood as part of a broader sociotechnical transformation of teaching and learning rather than as a stand-alone automation trend [10]. Likewise, Kasneci et al. [11] emphasized that large language models such as ChatGPT create both opportunities and challenges for learning support, feedback, and knowledge construction in educational settings Kasneci et al. [11]. Crompton and Burke [12] similarly concluded that AI in higher education should be examined in terms of field-wide adoption patterns, pedagogical integration, and ethical governance rather than only technological efficiency [12].

2.3. Entrepreneurship Education Methodology and the PSST Framework

Entrepreneurship education should go beyond simply delivering concepts of entrepreneurship or entrepreneurial spirit; it should support learners in discovering real opportunities, validating them, and transforming them into executable business structures. Motta and Galina [3] concluded that experiential learning in entrepreneurship education provides learners with experiences similar to actual entrepreneurial behavior and contributes positively to the formation of entrepreneurial intentions and competencies [3]. This suggests that entrepreneurship education is inherently action-oriented and that actual task performance and product development are central components of this field.

In this context, various frameworks have been used in entrepreneurship education to help structure learners' thinking. While the Business Model Canvas, Lean Startup, and Customer Development are widely recognized globally, in the Korean context of early-stage entrepreneurship education and government-supported startup proposal preparation, the PSST (Problem-Solution-Scale-up-Team) format has been widely used in practice. The Korean Ministry of SMEs and Startups [13] press release on the reform of the venture confirmation system stated that the previous business plan format had been replaced with the PSST format, which is widely used to attract venture investment and apply for government support. The ministry described PSST as a storytelling-based format that organizes plans from product and service development to commercialization according to the sequence of problem definition, solution, scale-up strategy, and team composition [13]. This indicates that PSST is not merely an informal business practice but also a structure institutionalized within the Korean entrepreneurship and venture ecosystem.

PSST is educationally useful because it structures entrepreneurial ideas around four key questions. First, Problem refers to clearly defining the customer problem and market pain points to be addressed. Second, Solution concerns how the problem will be addressed through a product or service and why the solution is effective and differentiated. Third, Scale-up includes the revenue structure, market entry strategy, growth potential, and expansion strategy, thereby requiring learners to translate ideas into the language of business viability. Fourth, Team refers to the competencies, role distribution, and feasibility of the entrepreneurial team, concretizing the agents responsible for execution [13]. Such a structure provides novice learners with a useful framework for transforming vague ideas into coherent business narratives.

The educational strength of PSST lies in its ability to reduce the ambiguity that entrepreneurship beginners often face when writing business plans. Rather than leaving ideas in an unstructured form, PSST places them within the logic of problem-solution-growth-team, thereby enabling learners to organize their thinking step by step. From a PBL perspective, this can be understood as a cognitive template or performance framework for constructing project outputs. Accordingly, PSST may function as a structuring device that supports learners' output development in entrepreneurship education [3, 13].

However, PSST also has limitations. Although the framework itself is relatively concise, filling each element with actual data and persuasive logic is far from simple. For example, in the Problem stage, learners must present customer problems with supporting evidence; in the Solution stage, they must explain differentiation and feasibility; and in the Scale-up stage, they must provide numerical or strategic explanations of revenue generation and market entry. For novice learners, this process can quickly turn into a substantial documentation burden, and without repeated instructor feedback, there is a risk that the framework will be filled out only superficially. Kim [5] also pointed out that although the PSST structure is useful for organizing learners' ideas, stage-based guidance and AI-based support are still necessary during the actual writing process [5]. This suggests that, while PSST is a valuable framework, it needs to be combined with systematic support to function effectively in educational settings.

The broader entrepreneurship education literature further supports the rationale of the present design. Systematic and longitudinal studies have shown that entrepreneurship education can influence entrepreneurial intention, attitudes, competence development, and perceived feasibility, although its effects depend on pedagogical design and learning context [14, 15]. In particular, entrepreneurship education has been described as an evolving domain that must move beyond content transmission toward action-oriented and experience-based pedagogies [16], while the evaluation of entrepreneurship education programs requires methods capable of capturing both short-term attitudinal change and longer-term learning outcomes [17].

This interpretation is also consistent with prior work showing that entrepreneurship programs can increase learners' entrepreneurial intentions by combining learning, inspiration, and resource access [18]. In addition, entrepreneurship in education has been framed as a means of developing opportunity recognition, initiative, and value creation across different educational levels and contexts [19], and prior doctoral-level assessment research has highlighted the need for more robust approaches to measuring the impact of entrepreneurship education beyond self-reported perceptions [20].

2.4. Interim Summary

The literature review above yields three major implications. First, PBL is a learning model centered on authentic problem-solving and product-oriented assessment, and it shows strong compatibility with entrepreneurship education [2, 6, 7]. Second, generative AI can be used as a scaffolding tool that expands learners' thinking and supports complex tasks, but its effectiveness depends heavily on instructional design and critical-use structures [1, 4, 8, 9]. Third, PSST is a practical structuring framework widely used in Korean entrepreneurship education and business plan writing. While it is useful for helping novice learners develop entrepreneurial ideas, it may lead to superficial completion unless stage-based guidance and repeated feedback are provided [5, 13].

Accordingly, this study integrates PBL's learning structure, generative AI's educational scaffolding function, and PSST's entrepreneurial output framework to design an AI-based system that supports the full process of entrepreneurship education. The following chapter presents a system process model that connects PBL stages with entrepreneurship education processes on the basis of these theoretical discussions.

3. System Process Modeling

3.1. Overview of the System Process Model

This chapter presents the system process model of ABL-Startup based on the theoretical foundations discussed in Chapter 2, namely Project-Based Learning (PBL), the educational use of generative AI, and the PSST framework. The purpose of system process modeling in this study is not merely to enumerate functional steps, but to design a coherent learning flow in which learners' entrepreneurial project performance is structured into pedagogically meaningful stages, generative AI is embedded in each stage as instructional support, and concrete outputs are progressively generated and reused.

PBL is characterized by authentic problem-solving, inquiry, collaboration, product development, presentation, and reflection [2, 6]. Entrepreneurship education similarly involves complex practical processes such as idea generation, market exploration, business model formulation, feasibility analysis, and pitching. Because of this structural alignment, the present study reconstructs the general stages of PBL in a manner appropriate for entrepreneurship education and translates them into a generative AI-supported educational system.

More specifically, the system process model proposed in this study is designed according to three core principles. First, there should be alignment between the educational stages and the system functions. In other words, the tasks performed by learners at each stage should correspond directly to the support functions provided by the system. Second, the model should be output-centered, meaning that each stage should generate a clearly identifiable intermediate output that serves as the basis for subsequent stages. Third, the model should be iterative rather than strictly linear, allowing learners to revise and revisit previous stages when necessary. As shown in Figure 1, the overall process follows a stage-based progression while also incorporating feedback loops from the final presentation stage back into earlier analytical and modeling stages.

3.2. Mapping PBL Stages to the Entrepreneurship Education Process

To connect the general stages of PBL with the actual flow of entrepreneurship education, this study reconstructs the five conventional stages of PBL into five entrepreneurship project stages. While PBL is commonly organized around the sequence of problem posing, inquiry, product development, critique and revision, and presentation [6], the present study maps these stages onto the entrepreneurship education context as follows: idea formulation, market analysis and customer persona development, AI-guided business modeling, feasibility analysis and revenue estimation, and demo day and mock investment simulation.

This reconstruction is meaningful because it preserves the pedagogical logic of PBL while reflecting the actual sequence of activities typically required in entrepreneurship education. Entrepreneurship learning does not end with ideation; rather, it requires learners to develop their ideas into documents, business structures, and persuasive presentations with market and executional validity. Accordingly, the educational process must support both cognitive development and documentation processes simultaneously. In response to this need, this study incorporates generative AI as a stage-based scaffolding tool throughout the entrepreneurship learning process [1, 4, 8, 9].

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The first PBL stage, problem posing, is translated into the entrepreneurship stage of idea formulation, where learners define the problem they want to solve and summarize the core value of their idea. The second stage, inquiry, is translated into market analysis and customer persona development, where learners investigate external conditions and target users. The third stage, product development, becomes AI-guided business modeling, where learners structure their business idea using the PSST framework. The fourth stage, critique and revision, becomes feasibility analysis and revenue estimation, where the business logic is critically evaluated and revised. Finally, the fifth PBL stage, presentation, is reconstructed as demo day and mock investment simulation, where learners communicate their business idea persuasively and receive evaluative feedback.

This mapping is visually summarized in Figure 1, which shows not only the pedagogical correspondence between PBL and entrepreneurship education stages but also the stage-linked outputs accumulated throughout the learning process. The figure also highlights that the process is recursive rather than unidirectional, reflecting the iterative nature of entrepreneurial validation.

The first stage is the initial phase of entrepreneurial project development, in which learners identify a meaningful problem and formulate an entrepreneurial idea. From a PBL perspective, this corresponds to identifying an authentic problem worth solving and constructing the project's driving question [6]. In entrepreneurship education, learners are expected to derive startup ideas from their interests, social issues, technological trends, or industrial changes; however, these ideas must be articulated not merely as abstract inspirations but in terms of whose problem is being solved and how.

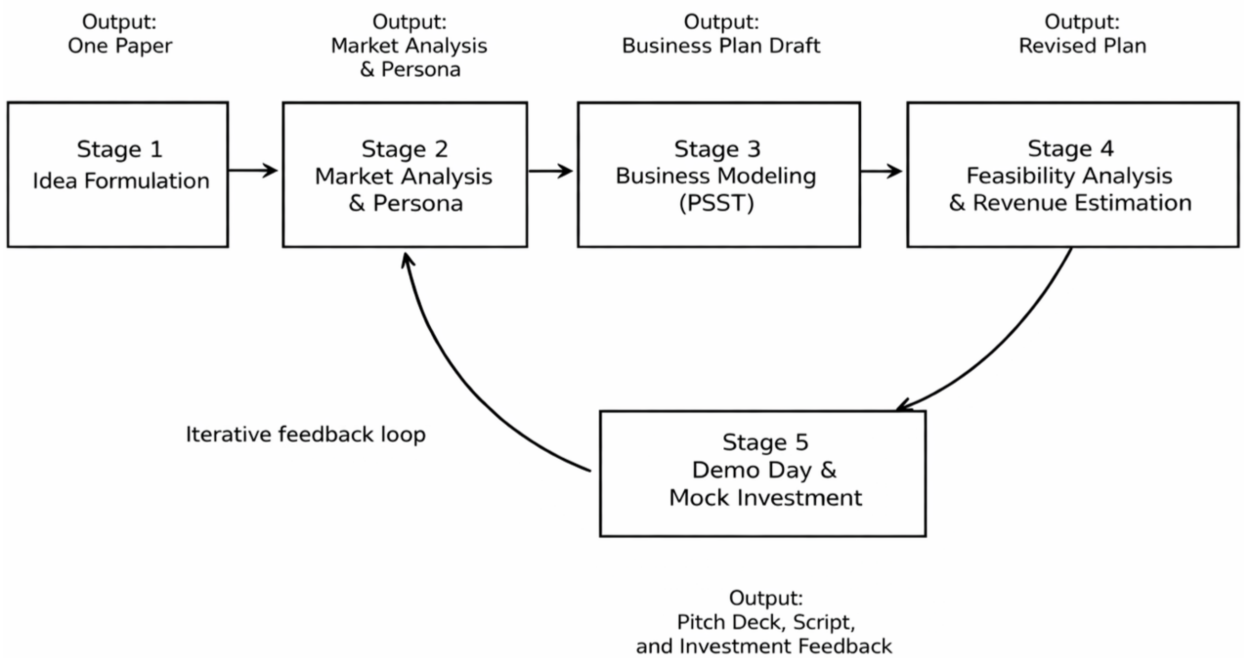

Figure 1.
PBL-based process model of ABL-Startup with stage-linked outputs and iterative feedback.

3.3. Stage-by-Stage System Process Design

3.3.1. Stage 1: Idea Formulation (One Paper)

In the ABL-Startup system, the primary inputs at this stage include free-form idea descriptions, keywords, problem statements, and relevant industrial domains. Based on these inputs, generative AI structures the idea into a One Paper format that includes a problem definition, target customer, core value proposition, and expected impact. Importantly, the AI does not simply summarize the learner's input; rather, it identifies missing elements and presents them in the form of guiding questions. In this way, the system helps learners improve the clarity of the problem and the specificity of the customer definition.

The main output of this stage is a preliminary One Paper draft. As indicated in Figure 1, this output becomes the foundational document for subsequent stages, particularly market analysis and customer persona development. Therefore, Stage 1 functions as the point at which a loosely defined idea is transformed into a structured project starting point.

The second stage focuses on exploring the external environment and customer context of the entrepreneurial idea. In PBL, the inquiry stage involves not merely collecting data but meaningfully exploring information to solve the target problem [2, 6]. In entrepreneurship education, this includes activities such as analyzing market size, competition, customer needs, user context, purchasing motivations, and the limitations of existing alternatives.

3.3.2. Stage 2: Market Analysis and Customer Persona Development

At this stage, the system uses the One Paper document generated in Stage 1 as the basis for suggesting relevant market research categories and providing templates for customer segmentation and persona development. Based on learner responses, generative AI produces descriptive customer persona profiles and structures key elements such as pain points, needs, and usage scenarios. In doing so, the system helps learners examine whether their idea has value in an actual market environment.

The outputs of this stage include a market analysis summary and a customer persona document. As shown in Figure 1, these outputs serve as critical inputs for the following stage, where learners begin to construct a business model. Thus, Stage 2 plays an important role in moving learners from internally defined ideas to externally grounded opportunity validation.

The third stage is the core output-formation stage of the entrepreneurial project and corresponds to the product-development stage of PBL [2]. At this point, learners are expected to transform the problem and market insights identified in earlier stages into an actual business structure. To accomplish this, the present study adopts the PSST (Problem-Solution-Scale-up-Team) framework as the organizing logic for business modeling [5, 13].

3.3.3. Stage 3: AI-Guided Business Modeling

The system provides AI prompt sequences corresponding to each PSST element. In the Problem component, the system checks whether the customer's problem has been stated clearly and persuasively and whether the limitations of existing alternatives have been identified. In the Solution component, it supports learners in articulating the main functions, differentiation, implementation logic, and expected benefits of the proposed product or service. In the Scale-up component, the AI encourages learners to explain the revenue structure, pricing strategy, market-entry strategy, and growth potential. In the Team component, it helps structure team roles, competencies, potential collaborators, and implementation capacity.

This stage is especially important because it converts exploratory thinking into structured entrepreneurial documentation. The output is a PSST-based business plan draft, and the system additionally provides completeness checks and recommendations for revision. In Figure 1, this stage is positioned at the center of the process, emphasizing its role as the main bridge between early-stage idea exploration and later-stage validation and presentation. Accordingly, Stage 3 is where a learner's entrepreneurial idea is transformed into persuasive business logic.

The fourth stage involves critiquing and refining the generated business plan draft. In PBL, the critique and revision stage is not limited to correcting superficial errors; rather, it includes re-examining the internal logic and validity of the output and improving it by incorporating new evidence and perspectives [2, 6]. In entrepreneurship education, this stage is especially important because even an interesting idea cannot develop into a viable business model unless it demonstrates marketability, feasibility, and profitability.

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At this stage, the system takes the PSST-based draft as input and evaluates it from multiple perspectives, including market feasibility, profitability, execution feasibility, and persuasive strength. Generative AI supports this process by simulating multiple evaluative roles, such as a market analyst, financial reviewer, investor, and instructor. It provides revision suggestions, highlights logical gaps, and asks follow-up questions to encourage deeper reflection.

3.3.4. Stage 4: Feasibility Analysis and Revenue Estimation

The main outputs of this stage are a revised business plan and a basic revenue estimation sheet. As shown in Figure 1, these revised outputs serve as the immediate basis for the final stage, involving demo day and a mock investment simulation. The system also stores revision history, allowing learners' improvement trajectories to be traced over time. This feature is educationally meaningful because it supports process-oriented evaluation rather than focusing only on the final result.

The fifth stage corresponds to the presentation and sharing stage of PBL and is implemented in entrepreneurship education as Demo Day and mock investment evaluation [2]. At this stage, learners reconstruct the entire project process into a persuasive narrative and externalize their ideas through presentation and evaluation.

The system automatically generates a draft pitch deck based on the revised business plan and key project data. Learners then review and revise the generated deck to finalize their presentation materials. In addition, the system provides a mock investment evaluation mechanism that combines AI-based investor evaluations with peer evaluation. In this way, learners do not merely submit a final assignment; instead, they participate in an experience that resembles actual entrepreneurial pitching and investment review.

3.3.5. Stage 5: Demo Day and Mock Investment Simulation

The outputs of this stage include the pitch deck, presentation script, and mock investment evaluation results. As visualized in Figure 1, this stage is not the endpoint of the process but the main source of iterative feedback. The evaluation outcomes produced here can trigger revisions to market analysis, business modeling, and feasibility reviews, thereby reinforcing the recursive nature of entrepreneurial learning.

Although the proposed system process is presented in five stages, its actual operational structure is iterative rather than strictly linear. Entrepreneurial projects do not typically move from an initial idea to a complete business model in a one-way sequence. For example, market analysis may reveal that the original problem definition needs to be revised, and investor feedback may require the business model or revenue logic to be restructured. Therefore, the system is designed to include feedback loops that allow learners to return to earlier stages when necessary [2, 5].

This iterative structure is clearly illustrated in Figure 1, where the mock investment stage feeds back into earlier stages, especially market analysis, business modeling, and feasibility refinement. This design reflects the reality that entrepreneurial project development is based on repeated validation and revision rather than fixed, sequential completion.

3.4. Iterative Structure and Data Flow of the System Process

From a data-flow perspective, the output of each stage functions as the input for the next stage. The One Paper generated in Stage 1 becomes the basis for market analysis in Stage 2. The market and customer data developed in Stage 2 support business modeling in Stage 3. The business plan draft produced in Stage 3 is reviewed and revised in Stage 4. The revised business plan in Stage 4 becomes the source material for generating a pitch deck and conducting a mock investment simulation in Stage 5. Finally, the evaluation and feedback obtained in Stage 5 may prompt learners to revisit earlier stages.

This structure means that ABL-Startup is not merely a set of isolated AI functions. Rather, it is a cumulative, process-oriented educational system in which learning data and outputs are interconnected across stages.

The educational significance of the system process model proposed in this study can be summarized in four ways. First, it concretizes the problem-solving structure of PBL in the context of entrepreneurship education, thereby reconstructing entrepreneurship classes as integrated project experiences rather than fragmented assignments [2, 6]. Second, by embedding generative AI across the stages of learning, it implements a scaffolding structure that reduces learners' cognitive burden while supporting the development and refinement of outputs [1, 4, 8, 9]. Third, by integrating PSST as a practical entrepreneurial framework into the learning process, the system helps learners convert ideas into persuasive business plans and presentation materials [5, 13]. Fourth, by storing stage-based outputs and revision histories, the system enables process-oriented assessment rather than relying solely on final results.

Most importantly, the proposed process model positions generative AI not as a simple automation tool, but as an educational facilitator that provides questions, structures drafts, and supports critique and revision depending on the learning stage. As reflected in Figure 1, the model is organized around linked outputs and recursive feedback rather than around one-way task completion. This means that generative AI is reinterpreted not as an external convenience technology, but as a core support element embedded within the instructional process itself.

3.5. Educational Significance of the System Process Model

This chapter reconstructed the general stages of PBL in accordance with the context of entrepreneurship education and embodied them in the process model of the ABL-Startup system. The study proposed a five-stage entrepreneurial project structure consisting of idea formulation, market analysis and customer persona development, AI-guided business modeling, feasibility analysis and revenue estimation, and Demo Day and mock investment simulation. It also presented the stage-wise flow of inputs, processes, outputs, AI support functions, and deliverables systematically, thereby showing that the proposed system constitutes a process-based model reflecting both educational theory and entrepreneurship practice.

The significance of this chapter lies in showing that the proposed system is not simply a functional AI tool but a pedagogically grounded process model that supports the full entrepreneurial learning journey. Figure 1 further clarifies that the model operates as a recursive, output-linked instructional structure rather than as a one-way sequence of activities. The following chapter presents the system architecture and implementation design required to operationalize this process model in practice.

4. System Architecture and Implementation

4.1. Overview of the System Architecture

To implement the PBL-based entrepreneurship education process model proposed in Chapter 3 as an actual learning support system, a structured design is required in which learner interaction, generative AI processing, document generation, data storage, and evaluation functions are integrated into a unified framework. The ABL-Startup system proposed in this study is designed as an integrated digital platform that supports the entire entrepreneurship education process, from idea refinement to business plan generation, automated presentation material creation, and mock investment evaluation [5].

Entrepreneurship education begins with exploratory thinking at the ideation stage and extends through market analysis, business model construction, feasibility review, presentation, and evaluation. Because of this complexity, such an educational process cannot be sufficiently supported by a simple chatbot-based AI tool alone. Rather, an entrepreneurship education support system must preserve stage-based task flows, accumulate user interaction data, structure generative AI outputs into documentable formats, and enable these outputs to be reused as inputs for subsequent stages. Wang et al. [4] argued that the effective use of generative AI in higher education requires contextual integration with instructional design rather than isolated response generation [4]. This implies that entrepreneurship education support systems also require a layered architecture reflecting the pedagogical flow of learning.

Accordingly, this study adopts a four-layer role-based architecture composed of the User Layer, Interface Layer, Business Logic Layer, and Data Layer. Such a layered structure reduces functional coupling, improves maintainability and scalability, and enables the clear separation of the technical implementation of different educational stages. As shown in Figure 2, the proposed architecture integrates user participation, hybrid interaction interfaces, stage-based AI-supported processing modules, and cumulative learning data management into a single educational system. In particular, because generative AI-based systems involve complex interactions among user input processing, prompt control, response post-processing, document generation, and record storage, it is essential to define the role of each layer explicitly [1, 4].

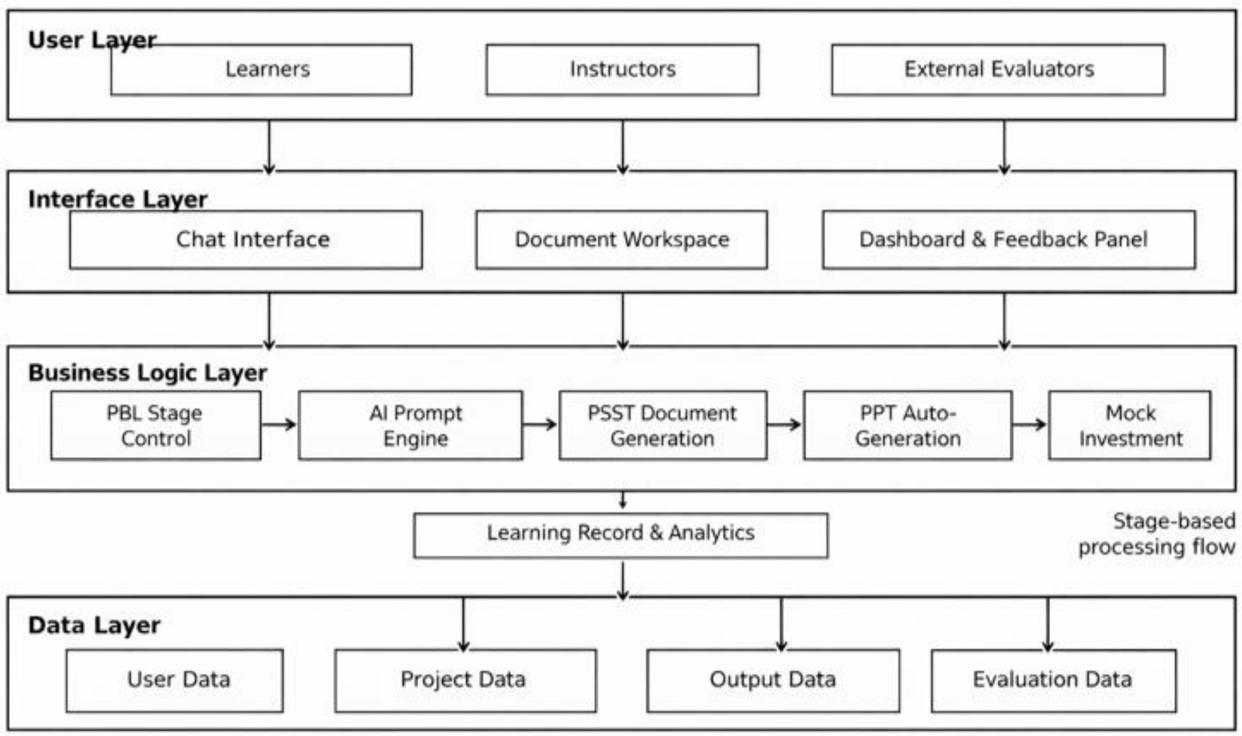

Figure 2.
Four-layer architecture of ABL-Startup integrating user interaction, interface functions, stage-based business logic, and data management.

4.2. Design of the Four-Layer Role-Based Architecture

4.2.1. User Layer

The User Layer includes the system's direct users, namely learners, instructors, and, optionally, external evaluators. Learners are the principal actors in entrepreneurial project performance and use the system to input ideas, review analytical results, revise business plans, generate presentation materials, and participate in mock investment evaluations. Instructors review learners' stage-by-stage progress and outputs, provide feedback, and conduct assessments. External evaluators may participate in the demo day stage as mock investors or mentors.

The core design principle of this layer is role-based access. In other words, although all users access the same system, the available functions and interface views differ depending on the user type. Learners are primarily provided with functions related to their own projects and AI interaction screens, whereas instructors are given access to functions for monitoring overall class progress, reviewing team-based outputs, and checking evaluation data. This role differentiation improves both system security and usability.

Figure 2 provides an architectural overview of how the four layers interact with one another. It shows that learners, instructors, and evaluators access the system through dedicated interfaces, while stage-based business logic modules process entrepreneurial learning tasks and store cumulative outputs in the data layer.

4.2.2. Interface Layer

The Interface Layer refers to the visual and interactive environment that supports user input and output review. In this study, the system interface is divided into three major subcomponents: the chat interface, the document-editing interface, and the dashboard interface.

First, the chat interface supports natural language interaction with generative AI. Through this interface, learners enter questions or respond to system-generated guiding questions, thereby refining their entrepreneurial ideas. The generative AI does not simply provide answers; rather, it offers stage-specific guiding questions and connects users' responses to structured document components. Park [8] emphasized that learners' ability to critically interpret AI outputs and compose appropriate prompts is an important dimension of generative AI literacy [8]. From this perspective, the chat interface can serve as a pedagogical tool that lowers the entry barrier to interaction while gradually improving learners' problem-definition capabilities.

Second, the document-editing interface provides a workspace in which learners can directly view and revise business plan drafts, PSST-based documents, presentation scripts, and pitch deck contents. Outputs proposed by generative AI are not finalized automatically; instead, learners must review, revise, and confirm them. This design helps prevent superficial dependence on AI-generated outputs and preserves learner agency throughout the writing process [1, 8].

Third, the dashboard interface visualizes project progress, completion status by stage, output history, feedback status, and evaluation results. For learners, it provides an overview of individual progress; for instructors, it enables class-wide monitoring of team performance and bottlenecks. In this sense, the dashboard supports process-oriented learning management and enhances the efficiency of educational operations.

4.2.3. Business Logic Layer

The Business Logic Layer is the core processing domain of the system. In this study, it is divided into six major modules: the PBL Stage Control Module, the AI Prompt Engine, the PSST Document Generation Module, the PPT Auto-Generation Module, the Mock Investment Evaluation Module, and the Learning Record and Analytics Module. As illustrated in Figure 2, these modules are not isolated functions; rather, they operate as a stage-based processing chain that transforms learner input into structured business outputs, presentation materials, and evaluative feedback.

The PBL Stage Control Module determines the learner's current stage in the entrepreneurial learning process and automatically invokes the relevant input forms, AI prompts, and output formats required at that stage. For example, in Stage 1, it provides a workflow for drafting the One Paper document; in Stage 3, it generates the PSST-based business document structure; and in Stage 5, it connects pitch deck templates and mock investment evaluation logic. This module operationalizes the process model introduced in Chapter 3 [5].

The AI Prompt Engine is the key module that directly interacts with the generative AI model. Rather than sending user input to the large language model without processing, the engine preprocesses the input according to educational objectives, combines it with stage-specific prompt templates, and constructs appropriate requests. The AI's responses are then post-processed into document-compatible structures. As Wang et al. [4] argued, the educational value of generative AI depends not only on the model itself but also on the degree of pedagogical contextualization [4]. In this system, the Prompt Engine serves as the technical realization of such contextualization.

The PSST Document Generation Module transforms free-form learner input into structured business plan content based on the Problem-Solution-Scale-up-Team framework. It automatically classifies learner-provided content into PSST categories and generates follow-up questions for missing information.

The PPT Auto-Generation Module reorganizes the main contents of the business plan into a slide structure suitable for presentations. Rather than transferring the text directly, it transforms the content into a concise visual summary optimized for entrepreneurial pitching.

The Mock Investment Evaluation Module integrates AI-based investor evaluation with peer evaluation to generate quantitative and qualitative assessment results. Evaluation criteria may include problem relevance, marketability, innovativeness, feasibility, and presentation quality.

Finally, the Learning Record and Analytics Module stores and analyzes users' input histories, revision counts, time spent at each stage, AI interaction logs, and changes in final outputs. These records may later be used to evaluate the educational effectiveness of the system or to support instructors' process-oriented assessment of learners.

The Data Layer functions as the foundational storage and management layer for all system-wide inputs, generated outputs, evaluation results, and template resources. In this study, the Data Layer is categorized into user data, project data, output data, evaluation data, and template and system resource data.

4.2.4. Data Layer

User data includes basic information about learners and instructors, such as account information, roles, affiliations, and project assignments. Project data includes stage-specific inputs, progress statuses, and timestamps. Output data consist of stage-based deliverables, such as the One Paper, market analysis table, PSST document, business plan, pitch deck, and presentation script. Evaluation data include AI-generated scores, peer evaluation results, instructor feedback, and revision histories. Template and system resource data include prompt templates, document forms, slide design templates, and evaluation rubrics.

The key principles guiding the Data Layer design are reusability across stages and traceability. Outputs generated at one stage should automatically serve as inputs for subsequent stages, while the system must also record when and how revisions were made. UNESCO emphasized that educational uses of generative AI should preserve the visibility of human judgment and learning processes [1]. In this sense, the Data Layer is not simply a storage repository but an infrastructure for evidencing process-oriented learning. As shown in Figure 2, the Data Layer supports all upper layers by storing user, project, output, and evaluation data generated during stage-based entrepreneurial learning.

The AI Prompt Engine serves as the central intelligence of the ABL-Startup system. In this study, the generative AI model is designed not as a simple question-answering tool but as an entrepreneurship education consultant persona. To this end, the system prompt includes role definitions such as entrepreneurship instructor, market analyst, investor, and feedback coach, along with stage-specific response formats and feedback principles [4, 5].

4.3. Design of Core Functional Modules

4.3.1. AI Prompt Engine Design

For instance, in Stage 1, the AI is instructed not to criticize ideas immediately but instead to ask questions that help clarify the problem definition. In Stage 3, it is instructed to examine the logic and specificity of each PSST category and to identify missing evidence by posing questions. In Stage 4, the AI is instructed to provide multidimensional feedback from the perspectives of marketability, profitability, feasibility, and persuasiveness. Such a multipersona prompt design makes it possible to use the same language model for different pedagogical functions, depending on the stage.

The processing flow of the Prompt Engine is as follows. First, learner input is collected. Next, the system identifies the current learning stage and selects the corresponding prompt template. The learner input is then summarized and structured into template variables, and relevant prior outputs are included as contextual information when necessary. The system subsequently sends the request to the generative AI API and receives a response, which is then parsed into appropriate output forms. Finally, the results are transformed into one or more formats, including chat responses, auto-filled document fields, feedback lists, and evaluation data.

The Business Plan Generation Module is responsible for transforming entrepreneurial ideas into structured business documents based on the Problem-Solution-Scale-up-Team framework. The central purpose of this module is to convert learners' free-form ideas into a logical and persuasive business plan draft [5, 13].

4.3.2. PSST-Based Business Plan Generation Module

The implementation process is as follows. First, the module receives data accumulated from Stages 1 and 2, including idea descriptions, problem definitions, market data, and customer persona information. These data are then automatically mapped into PSST slots. For example, customer problems and pain points are assigned to the Problem category, service or product descriptions to Solution, market scale and revenue logic to Scale-up, and team roles and competencies to Team. The AI Prompt Engine then generates draft content for each section and requests additional learner input for missing information.

A key design principle of this process is the maintenance of a semi-automatic co-writing structure rather than full automation. Although the AI generates initial drafts, learners are required to review and revise them, and the system records the revision history. In this way, the writing process itself becomes part of the learning process rather than being reduced to automated text production [1, 8].

In entrepreneurship education, presentation is a critical component of final performance, and in actual startup contexts, the pitch deck is one of the most important persuasive tools. However, learners often experience an additional burden when they must transform their business plan into a visual presentation format after completing the written documentation. To address this issue, this study designs a PPT Auto-Generation Module that converts text-based business plan content into presentation-oriented slide structures [5].

4.3.3. PPT Auto-Generation Module

This module first receives the PSST-based document and key numerical data as input and extracts the central messages to be included on each slide. It then automatically maps titles, bullet points, tables, or simple visual elements into predefined pitch deck templates. For example, slides may be structured around problem definition, customer persona, solution, market opportunity, competitive advantage, business model, financial projections, and team composition.

From a technical perspective, the system may generate slide data in a structured format, such as JSON, and then render it through a presentation template engine into a PPT file. When combined with automatic presentation script generation, the module enables learners to obtain both the presentation deck and a corresponding speaking script simultaneously.

The Mock Investment Evaluation Algorithm is designed to quantitatively assess learners' presentation results during the Demo Day stage and present those results in the form of an investment simulation. This algorithm is intended not only to increase learner engagement but also to transform assessment into a realistic entrepreneurial experience [5].

4.3.4. Mock Investment Evaluation Algorithm

The evaluation criteria reflect common startup review perspectives and may include clarity of problem definition, marketability, innovativeness of the solution, feasibility, profitability, team competence, and presentation persuasiveness. Each criterion may be assigned a weight, and the final score can be calculated by combining AI evaluator scores with peer evaluation scores. If necessary, instructor scores may also be added.

The final score S is defined as follows:

$S = \alpha A + \beta P$

where A denotes the AI evaluator's score, P denotes the average peer evaluation score, and $\alpha + \beta = 1$. If instructor evaluation is added, the equation can be extended as follows:

4.4. User Interface Design

$S = \alpha A + \beta P + \gamma I$

where I denotes the instructor score and $\alpha + \beta + \gamma = 1$.

This structure enables the evaluation process to function not merely as a ranking system, but as a learning mechanism providing realistic feedback and opportunities for reflection.

4.5. Implementation Scenario

The user interface of the proposed system is designed with two simultaneous goals in mind: usability for learners and preservation of pedagogical flow. Although generative AI systems are strong in conversational interaction, entrepreneurship education also requires document review and iterative revision. Therefore, a simple chat interface alone is not sufficient. In response, this study proposes a hybrid interface that integrates conversational and document-oriented UI components.

The screen may be structured into three areas: a chat panel on the left, a document workspace in the center, and a stage progress and feedback panel on the right. In the chat panel, learners interact with the AI by describing ideas and responding to guiding questions. In the central panel, learners can immediately view and revise AI-generated outputs, such as One Paper drafts, PSST-based documents, and presentation slides. In the right panel, they can check the current stage, completion rate, mandatory inputs, feedback summaries, and conditions for moving to the next stage.

This structure is important because it enables learners not merely to consume AI-generated responses but also to integrate them into working documents in real time. Beginners in entrepreneurship often feel overwhelmed during the documentation process, and the combination of guided questioning and automatic document structuring may significantly reduce the psychological barrier to entry [5, 8].

4.6. Interim Summary

The implementation flow of the system can be described as follows. After logging in and creating a new project, the learner is directed to the Stage 1 idea formulation interface. Once the learner enters an entrepreneurial idea, the AI Prompt Engine generates a One Paper draft, which the learner then reviews and finalizes. The system subsequently moves the learner to the Stage 2 market analysis screen, where customer exploration questions and persona templates are suggested based on the outputs of the previous stage.

After the learner responds, the system proceeds to Stage 3, where a PSST-based business plan draft is automatically generated. The learner reviews each section, responds to AI-generated supplementary questions, and revises the document iteratively. In Stage 4, the system provides feedback from the perspectives of marketability, profitability, and execution feasibility, and the learner refines the financial estimates and execution strategies. Finally, in Stage 5, the system automatically generates a pitch deck and presentation script and produces mock investment results based on AI and peer evaluations.

This implementation scenario demonstrates how the PBL-based entrepreneurship education process proposed in Chapter 3 can be operationalized as a sequence of interconnected system functions. In other words, the proposed system is not merely a collection of tools, but a process-centered entrepreneurship education support system that follows the flow of project performance.

This chapter presented the architecture and core functional modules of the ABL-Startup system for implementing the PBL-based entrepreneurship education process. The proposed system adopts a four-layer structure composed of the User Layer, Interface Layer, Business Logic Layer, and Data Layer, and integrates an AI Prompt Engine, a PSST-based Business Plan Generation Module, a PPT Auto-Generation Module, a Mock Investment Evaluation Algorithm, and a hybrid user interface. Figure 2 clarifies that the system is organized not as a simple chatbot environment, but as a multilayer educational architecture in which user interaction, instructional processing, and cumulative data management are systematically interconnected.

This design prevents generative AI from remaining merely a writing aid and instead enables it to function as core infrastructure that supports the entire entrepreneurship education process in a staged manner. In particular, the architecture has educational and technical significance in terms of reducing learners' cognitive burden, extending instructors' feedback capacity, automating output transformation, and accumulating process-oriented learning data. The next chapter examines the extent to which this system satisfies the core principles of PBL and the practical requirements of entrepreneurship education through functional validation and pilot application analysis.

5. Performance Validation and Pilot Application Results

5.1. Overview of Performance Validation

The performance validation of the proposed ABL-Startup system should be approached from a perspective different from that of conventional software performance evaluation. This is because the system is not merely an information-processing tool but an educational support system designed to assist the entire entrepreneurship education process based on the principles of Project-Based Learning (PBL). Accordingly, rather than focusing only on narrowly defined technical indicators, such as processing speed or response time, this chapter examines the extent to which the system faithfully implements the core principles of PBL in the context of entrepreneurship education and effectively supports learners' task performance.

The performance validation framework adopted in this study consists of three dimensions. The first is functional validity, which concerns whether the system consistently implements the educational processes and system functions proposed in Chapters 3 and 4. The second is efficiency, which addresses whether the time and effort required for business plan drafting and presentation preparation can be reduced. The third is pilot application results, which evaluate learner satisfaction and practical usability through actual educational implementation. This three-part framework is appropriate for a design-oriented study because it addresses both system logic and field applicability.

5.2. Functional Validity

Functional validity refers to whether the proposed system consistently implements the core structure of PBL, problem posing, inquiry, product development, critique and revision, and presentation, within the context of entrepreneurship education. The ABL-Startup system was designed to define a five-stage process for business plan development, guide business plan writing through AI support, automatically generate presentation materials, and provide objective feedback through mock investment participation. This structure directly corresponds to the process model introduced in Chapter 3 and is also functionally linked to the stage control module, prompt engine, document generation module, and investment evaluation module described in Chapter 4 [5].

First, in terms of educational process alignment, the proposed system adopts a structure that reconstructs the stage-based learning flow of PBL into entrepreneurship education tasks. Rather than functioning as a fragmented set of tools, the system follows the entrepreneurial learning process from idea formulation through presentation and evaluation. This indicates that the system's design logic is consistent with the pedagogical flow of entrepreneurship education.

Second, in terms of learning support alignment, the system uses generative AI not as a simple response generator but as a guiding tool that supports learners in documenting and refining their entrepreneurial ideas. Conventional entrepreneurship education often places a substantial cognitive burden on learners as they attempt to transform abstract ideas into business models, and excessive time is often spent on documentation rather than conceptual development itself. The proposed system addresses this problem by offering stage-based AI guidance, structured document generation, and presentation support, thereby functioning as a pedagogical scaffolding mechanism [5].

Third, in terms of output generation alignment, the proposed system supports a continuous output structure that begins with initial ideas and extends to business plans, presentation materials, and investment evaluation results. Because business plan writing and pitch deck generation are integrated within the same system, the transition cost between outputs is reduced, and the continuity of the learning flow is strengthened. This is particularly meaningful in entrepreneurship education, where learners frequently struggle to convert written documents into persuasive presentation formats.

Taken together, the proposed system may be considered functionally valid because it supports educational process flow, stage-based learning assistance, and cumulative output generation in a coherent manner. However, this functional validity should be interpreted as an exploratory judgment grounded in design logic and pilot application outcomes, rather than as a causal conclusion derived from controlled experimentation.

5.3. Efficiency Analysis

Another important dimension of system validation concerns whether the proposed system can reduce the time and effort required for documentation tasks and presentation preparation in entrepreneurship education. According to the source study on ABL-Startup, learners using the system completed the first draft of a business plan within approximately one week and about three hours of actual work time. In contrast, under conventional manual writing conditions within a similar educational context, preparing the first draft reportedly required approximately four weeks and around twelve hours of actual work time [5].

This difference suggests that the proposed system may substantially reduce both the time and effort associated with entrepreneurial documentation. This improvement in efficiency can be explained by three main system characteristics. First, the AI Prompt Engine transforms free-form idea input into a structured business plan draft, thereby reducing the burden of starting with a blank document. Second, the business plan writing process is organized into clearly defined stages, reducing the cognitive cost associated with deciding what to write first and how to structure the content. Third, the automatic generation of presentation materials reduces the additional workload required to convert a written business plan into a slide-based pitching format.

From an educational perspective, these findings imply that a generative AI-based entrepreneurship education system can reduce learners' non-essential documentation burden and allow them to devote more time to meaningful activities such as market exploration, validation, and idea refinement. Nevertheless, because these figures were obtained from a specific pilot context, they should be interpreted carefully rather than generalized without reservation.

5.4. Pilot Application Results and Satisfaction Analysis

ABL-Startup was pilot-tested in an actual entrepreneurship education setting for prospective entrepreneurs, and the source study reported that the system reduced learners' documentation burden and increased their concentration on implementing business ideas. In that study, learner satisfaction was measured using a five-point Likert scale. The overall average satisfaction score was 4.88, while writing efficiency received the highest score, at 4.95, followed by process appropriateness at 4.90 and AI usefulness at 4.89 [5].

These findings suggest that learners perceived the proposed system not merely as a convenient technological tool but as a practically useful educational support mechanism throughout the business plan development process. The high score for writing efficiency indicates that learners experienced the system as making the process of organizing entrepreneurial ideas into written and presentation-ready forms substantially easier. Likewise, the high scores for process appropriateness and AI usefulness indicate that the system was positively evaluated not only for technological convenience but also for its alignment with the instructional logic of entrepreneurship learning tasks.

These results imply that the proposed system has a meaningful level of acceptance and practical usability in actual entrepreneurship education settings. At the same time, the current evidence is centered primarily on learner satisfaction and field application. Therefore, the pilot application results should be interpreted as initial validation evidence and as a foundation for future empirical studies, rather than as definitive proof of educational effectiveness.

5.5. General Discussion

Taken together, the results of this chapter indicate that the proposed ABL-Startup system has functional validity in that it supports a PBL-based entrepreneurship education process through a coherent stage structure, improves efficiency by reducing the time required for business plan drafting and presentation preparation, and demonstrates strong practical usability and learner acceptance in pilot applications. In particular, the combination of a five-stage business plan development process, AI-based writing guidance, automated presentation generation, and mock investment evaluation reflects the practical requirements of entrepreneurship education to a substantial extent [5].

At the same time, several limitations should be noted. First, the currently available findings are based on pilot implementation and satisfaction surveys rather than controlled experimental research. Second, reductions in writing time and increases in satisfaction do not necessarily imply improved output quality or stronger long-term entrepreneurial competencies. Third, although AI-based structuring and feedback are useful, instructor review and learners' critical judgment remain essential. Therefore, the performance of the proposed system should be interpreted not as the full automation of entrepreneurial learning, but as a support mechanism that reduces the burden and provides process structure.

5.6. Interim Summary

This chapter examined the performance of the ABL-Startup system in terms of functional validity, efficiency, and pilot application outcomes. The analysis indicates that the proposed system technically implements a PBL-based entrepreneurship education process, reduces learners' burden in business plan writing and presentation preparation, and demonstrates high learner satisfaction in practical educational contexts. These findings suggest that the system has meaningful potential as a support tool for entrepreneurship education.

However, because the results presented in this chapter are based on an exploratory pilot application, more rigorous follow-up studies are required, including controlled comparisons, expert rubric-based evaluations, and longitudinal tracking of learning outcomes. Even so, the findings provide foundational evidence that generative AI can function not merely as an auxiliary tool, but as an educational support system embedded within the instructional process of entrepreneurship education.

6. Conclusion and Implications

6.1. Summary of the Study

This study aimed to propose the design and implementation of ABL-Startup, a generative AI-supported system for entrepreneurship education grounded in the principles of Project-Based Learning (PBL). As generative AI has rapidly emerged as a transformative technology in higher education, its educational value depends not merely on its technical capabilities but also on how it is pedagogically designed and embedded within the learning process [1]. Against this backdrop, the present study reinterpreted generative AI not as a simple question-answering or writing-assistance tool, but as a core educational component capable of structuring problem-solving processes and supporting learners' thinking throughout entrepreneurship education.

To achieve this objective, the study first reconstructed the general stages of PBL into a five-stage entrepreneurship education process consisting of idea formulation, market analysis and customer persona development, AI-guided business modeling, feasibility analysis and revenue estimation, and a demo day with a mock investment simulation. Based on this process model, a four-layer system architecture was proposed, including the User Layer, Interface Layer, Business Logic Layer, and Data Layer. In addition, core modules such as the AI Prompt Engine, the PSST-based Business Plan Generation Module, the PPT Auto-Generation Module, the Mock Investment Evaluation Module, and the hybrid user interface were designed to operationalize the proposed process.

The study also examined the educational and functional validity of the system through pilot application results reported in the source study on ABL-Startup. According to that study, the system was pilot-tested in entrepreneurship education settings for prospective entrepreneurs, and the results suggested that learners' documentation burden was reduced while their concentration on implementing business ideas was enhanced. The same study reported an overall average satisfaction score of 4.88 out of 5, with writing efficiency receiving 4.95, process appropriateness 4.90, and AI usefulness 4.89 [5]. These findings indicate that the proposed system has practical potential as a structured support tool for entrepreneurship education.

Taken together, this study is meaningful because it moved beyond the idea of introducing generative AI as an auxiliary tool and instead designed and implemented it as an integrated support system embedded in a PBL-based instructional process. In other words, the study did not merely automate certain educational tasks; rather, it systematically structured the entire entrepreneurship education process and positioned AI to function as a provider of questions, structuring support, draft generation, feedback, and presentation assistance throughout that process.

6.2. Academic and Practical Implications

The first academic implication of this study lies in its proposal of an integrated design model that connects PBL theory, generative AI technology, and entrepreneurship education within a single instructional framework. While prior research has separately discussed the effectiveness of PBL, the experiential nature of entrepreneurship education, and the educational potential of generative AI, relatively few studies have integrated these three domains into a coherent educational system design. By reconstructing PBL stages into entrepreneurship education processes and embedding generative AI as a stage-specific scaffolding tool, this study provides a concrete framework that bridges educational technology research and entrepreneurship education research.

The second academic implication lies in the reinterpretation of the PSST-based business planning framework from the perspective of educational process design. In many practical settings, PSST is primarily used as a business proposal or planning format. However, this study reconceptualized PSST as a project output structure through which learners define problems, construct solutions, formulate growth strategies, and clarify execution roles. In doing so, the study emphasizes that business plan writing should not be understood merely as document production, but as a structured learning process through which learners investigate real problems and refine entrepreneurial logic.

The third academic implication is that this study elevated generative AI from a peripheral support technology to a core element of the educational process. In many educational contexts, generative AI is still used in fragmented ways, such as sentence generation, translation, summarization, or ad hoc question answering. By contrast, this study designed generative AI to operate across the full learning flow, including idea refinement, market analysis, business plan drafting, feedback generation, pitch deck preparation, and mock investment evaluation. This demonstrates that generative AI can be conceptualized not as an external convenience tool, but as a structured instructional support mechanism embedded within educational design [1].

From a practical perspective, the first implication of this study is that it offers a model capable of improving the efficiency and consistency of entrepreneurship education delivery. In entrepreneurship classes, instructors are often required to provide repeated feedback to teams with widely differing ideas, levels of progress, and document quality. The proposed system can reduce this burden to some extent by offering stage-based guidance, automatic structuring, draft generation, and presentation transformation, thereby allowing instructors to provide more consistent support [5].

The second practical implication is that the system can lower the entry barrier for novice learners and increase engagement in entrepreneurial projects. The high satisfaction scores related to writing efficiency suggest that learners perceived the system as effectively reducing one of the major difficulties in entrepreneurship education: the burden of documentation. For beginners who are unfamiliar with market logic and business structures, AI-supported structuring may reduce the uncertainty that often characterizes the early stages of entrepreneurial project development and help them transform ideas into viable business concepts more quickly.

The third practical implication is that the proposed structure has the potential to be extended beyond university entrepreneurship courses to startup camps, extracurricular programs, and public entrepreneurship training initiatives. Because the system is based on a process-centered architecture and modular functional design, it is not restricted to a single course format. Rather, it can potentially be adapted to various educational settings in which entrepreneurial project development is required.

6.3. Limitations and Future Research Directions

Despite its contributions, this study has several limitations. First, performance validation was based on exploratory pilot application results rather than a rigorous experimental design involving a control group. Therefore, although the reported satisfaction and efficiency results provide meaningful evidence of practical utility, it cannot be concluded that the proposed system significantly improves learning outcomes compared with conventional methods. Future research should include controlled comparisons, pre- and post-test designs, and more rigorous empirical validation.

Second, this study focused mainly on writing efficiency and learner satisfaction, but it did not independently and quantitatively evaluate the quality of the generated business plans and presentation materials. Faster draft generation does not necessarily imply stronger entrepreneurial competence or higher-quality business plans. Accordingly, future studies should assess output quality from multiple perspectives, such as logical coherence, innovativeness, feasibility, and persuasiveness, using rubric-based expert evaluations involving entrepreneurship educators, investors, and practitioners.

Third, the educational use of generative AI inevitably raises the issue of hallucinations, including inaccurate market information, overgeneralized claims, and plausible but unverified statements. UNESCO has warned that generative AI in education creates important issues related to bias, misinformation, lack of explainability, and the weakening of human-centered judgment [1]. In entrepreneurship education, where market analysis, profitability estimation, and competitive positioning are essential, the uncritical acceptance of AI-generated content may undermine the quality of learning. Therefore, future systems should incorporate safeguards such as source-verification functions, validation checklists, instructor-approval mechanisms, and confidence indicators to reduce such risks.

Fourth, even if generative AI functions as a powerful support tool, the role of the instructor cannot be fully replaced. Entrepreneurship education involves not only document production but also value judgment, contextual interpretation, ethical reflection, and team-dynamics management. These dimensions require human facilitation and professional educational judgment. Accordingly, generative AI-supported systems should be understood as tools that support instructors by allowing them to focus more on essential pedagogical interventions, rather than as replacements for instructors themselves [1].

Based on these limitations, several directions for future research may be proposed. First, controlled experimental studies are needed to examine the effects of the proposed system on entrepreneurial competence, problem-solving ability, output quality, and learning engagement. Second, longitudinal studies should investigate whether the effects of the system are sustained after course completion, particularly in relation to entrepreneurial intention, business continuation, and subsequent project performance. Third, the functionality of the system could be extended beyond text-based support to include market data integration, more advanced financial simulation, multimodal pitch-deck generation, and collaborative, team-based features. Fourth, comparative studies across disciplines and learner profiles could contribute to the development of more refined and adaptive models of AI-supported entrepreneurship education.

6.4. Final Conclusion

This study proposed the design and implementation of ABL-Startup, a generative AI-supported entrepreneurship education system based on PBL theory, and explored its practical potential through findings from a pilot application. The results suggest that the proposed system can function as an integrated educational support system by structuring the entire entrepreneurship education process into stages, reducing learners' burden in formalizing ideas and preparing documentation, and supporting feedback and presentation preparation. In particular, the pilot findings imply that when generative AI is combined with appropriate instructional design, it can alleviate some of the core practical difficulties of entrepreneurship education [5].

Ultimately, the central message of this study is that generative AI should not be understood merely as an automation tool but rather as a learning support system embedded within the instructional process. Entrepreneurship education is a representative form of practice-based learning in which problem definition, inquiry, design, validation, and presentation are tightly connected. These processes can potentially be organized in a more systematic and scalable manner through the combination of generative AI and PBL. The significance of this study lies in demonstrating this possibility at both the design and pilot application levels, thereby providing a practical foundation for future research on generative AI-supported innovation in higher education.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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