AI and Blockchain Integration in Entrepreneurship-Based Coding Education: Advancing Student Startup Readiness in the Digital Era

Basri[1*], Teuku Isnaini[1], Sayed Achmady[1], Hidayatun Nadhira[1], Muhammad Iqbal[2]

[1]Jabal Ghafur University, Aceh, Indonesia | ORCID: https://orcid.org/0009-0008-3093-5954 (Basri) | https://orcid.org/0009-0005-1283-2650 (Teuku Isnaini) | https://orcid.org/0000-0002-8007-8646 (Sayed Achmady) | https://orcid.org/0009-0006-0636-9249 (Hidayatun Nadhira)

[2]Bina Bangsa Getsempena University, Aceh, Indonesia | ORCID: https://orcid.org/0000-0001-6373-0738

***Corresponding Author:** Basri

Abstract. This study aims to develop and evaluate the effectiveness of an entrepreneurship-based coding education model integrated with Artificial Intelligence (AI) and Blockchain technology to enhance secondary school students' technical and entrepreneurial competencies. Employing a Research and Development (R&D) design guided by the ADDIE framework, the study was conducted at Fatih Bilingual Boarding School in Banda Aceh, Indonesia, involving 120 students, several teachers, and startup mentors. Pre- and post-test results revealed statistically significant improvements in students' coding skills (mean increase from 58.3 to 82.1) and entrepreneurial knowledge (from 54.7 to 80.6). The AI-powered adaptive learning system effectively personalized content based on students' cognitive profiles, while the Blockchain component supported business idea validation and digital security through simulated startup pitch sessions. Approximately 70% of student teams reached Technology Readiness Levels (TRL) 6–7, and 60% independently produced business model canvases and pitch decks. The findings demonstrate that integrating disruptive technologies into coding education fosters innovation, collaboration, and competence in student-led startup development. This model offers strong potential for replication as a curriculum framework for digital entrepreneurship education in secondary schools, particularly within the contexts of Industry 4.0 and 5.0.

Keywords: Entrepreneurship-based learning; coding education; artificial intelligence; blockchain integration; student startup development

1. Introduction

The evolution of the global digital ecosystem has significantly reshaped paradigms in economics, education, and entrepreneurship. Digital transformation presents new opportunities for younger generations to engage in technology-driven economies, particularly through startup development (Battisti et al., 2022). Despite a 22% increase in digital MSMEs in Aceh over the past three years, only 7% are student-initiated (Aceh Communication and Informatics Agency, 2023), indicating substantial untapped potential. Bati et al. (2021) attribute this gap to the lack of integration between technology education and business acumen among school-age learners.

Fatih Bilingual Boarding School, a leading tech-focused institution in Banda Aceh, has implemented introductory coding programs since 2022. However, according to the school's curriculum team, while 50% of students have completed basic programming courses, only 15% have independently developed tech-based

projects. This observation aligns with Karnalim and Simon (2021), who argue that coding education devoid of business application tends to yield fragmented knowledge.

An internal survey in 2023 involving 120 students found that 82% were interested in launching startups. However, 67% lacked understanding of business validation processes or funding access. These concerns echo Hasche and Linton (2021), who identified market validation and business modeling as critical failure points for student-led ventures.

While the school has adequate infrastructure (30 computers and 100 Mbps internet bandwidth), the use of advanced technologies such as AI and Blockchain in entrepreneurship education remains absent. Notably, 95% of students expressed the need for an integrated learning platform combining digital business case studies with interactive technology, as recommended by Kwangmuang et al. (2025).

Another barrier is the minimal collaboration between schools and local startup ecosystems. Data from the Aceh Provincial Education Office (2023) reveals that only 10% of schools in Aceh have partnerships with digital industry players, limiting student access to business incubation or tech-based competitions. Khurniawan et al. (2021) emphasize that such collaborations are essential for enhancing the quality of school-based entrepreneurship education.

Curricular analysis further reveals that despite the implementation of bilingual and project-based learning systems, integration between coding and entrepreneurship at Fatih School remains partial. As of 2023, 80% of coding materials focused on programming syntax, while business elements—such as market analysis, intellectual property (IP) management, or pitch deck development—constituted only 5%. Among alumni who attempted to launch startups (2018–2022 cohort), 90% reported a lack of business literacy as their primary barrier. Lopes and Miguel (2023) highlight the importance of "computational entrepreneurship" in school curricula, blending digital problem-solving with business design thinking.

Given these conditions, Fatih School was selected as the site for developing and testing an integrated coding learning model based on entrepreneurship and supported by AI and Blockchain technologies. With high student interest in entrepreneurship, supportive infrastructure, and regional policy alignment with digital innovation (Qanun Aceh No. 1, 2019), the school provides an ideal testbed. The proposed model leverages AI to personalize learning pathways and Blockchain to simulate funding mechanisms and protect intellectual assets through smart contract frameworks.

This study also aligns with Aceh's strategic vision to increase student-led startups by 50% by 2025. Therefore, a successful model implemented at Fatih School could serve as a blueprint for scalable entrepreneurship education across Western Indonesia and other developing regions, contributing to a more inclusive and technologically adaptive digital education ecosystem. This study seeks to address the following research questions:

a) RQ1: How effective is the proposed coding learning model in building students' entrepreneurial competencies at the secondary school level?
b) RQ2: In what ways does the integration of AI and Blockchain enhance the model's ability to support student startup development?
c) RQ3: What facilitating and hindering factors influence the implementation of the AI- and Blockchain-based entrepreneurship model at Fatih School?
d) RQ4: What impact does the integrated learning model have on students' readiness to launch tech-based startups in a regional digital ecosystem?

2. Literature Review

To design an effective and contextually relevant learning model, it is essential to examine existing literature on the intersection of coding, entrepreneurship education, and the use of disruptive technologies in pedagogy. This section explores foundational concepts and current developments in entrepreneurship-based coding instruction, the educational applications of Artificial Intelligence (AI) and Blockchain, and the role of integrated digital competencies in empowering students. It also identifies critical research gaps that this study seeks to address within secondary school settings.

2.1 Coding and Entrepreneurship Education in the Digital Era

The emergence of digital entrepreneurship has reshaped how educational institutions prepare students for innovation-driven economies. Entrepreneurship education is now recognized as a key enabler of 21st-century skills, including resilience, problem-solving, creativity, and digital literacy (Sarkar & Jena, 2022).

Computational thinking a foundational concept introduced by Lodi and Martini (2021) is increasingly integrated into secondary curricula through coding instruction. However, Mills et al. (2025) argue that coding education often remains overly focused on syntax and logic, with limited real-world relevance. Studies by Sansone et al. (2024) emphasize that coding without entrepreneurial context may result in narrow technical proficiency. In contrast, project-based learning (PBL) merging coding with business applications has proven effective in developing technical and entrepreneurial skills simultaneously (Shekarian & Parast, 2021).

2.2 The Potential of AI and Blockchain in Learning Environments

Artificial Intelligence (AI) transforms education through adaptive learning systems that tailor content to students' cognitive profiles. Dhananjaya et al. (2024) highlight machine learning's ability to support real-time diagnosis of student competencies, facilitating personalized pathways and differentiated instruction.

Blockchain technology offers unprecedented opportunities in educational certification, digital identity, and data security. Ayub Khan et al. (2021) propose that its decentralized structure enhances trust in academic records. In entrepreneurship education, smart contracts can simulate startup funding environments, while digital ledgers enable secure intellectual property validation (Silaghi & Popescu, 2025).

2.3 Entrepreneurship Education as a Path to Student Empowerment

Abdalla Khidir Abdalla and Khudair (2023) emphasize that entrepreneurship education **fosters** not only business creation but also student agency, leadership, and values-driven decision-making. Effective models require real-world challenges, industry engagement, and iterative reflection (Rao et al., 2024).

In Indonesia, Hasan et al. (2024) note persistently low entrepreneurial literacy among students, attributing this to the absence of integrated digital business practices in curricula. Equipping students early with entrepreneurial competencies is thus essential for long-term economic resilience.

2.4 Research Gap

While prior studies address coding education *or* entrepreneurship in isolation, few explore models integrating both with AI and Blockchain—especially in secondary education. Most research focuses on higher education or professional ecosystems. Empirical work is notably limited in:

- Examining AI-driven personalization in entrepreneurship-based coding education;
- Simulating Blockchain-based funding/IP protection in secondary schools;
- Assessing technological impact on student-led startup development.

3. Methodology

This study employed a systematic and iterative approach to develop, implement, and evaluate a technology-enhanced, entrepreneurship-based coding education model. In line with the study's objectives—particularly the integration of Artificial Intelligence (AI) and Blockchain to support student startup development—a

comprehensive methodological framework was essential to address both the technical and pedagogical dimensions of the intervention.

A Research and Development (R&D) design, guided by the ADDIE instructional model (Analysis, Design, Development, Implementation, and Evaluation), was selected to ensure a structured, phased process for designing, testing, and refining the model within an authentic educational environment. This approach allowed for the alignment of instructional innovation with practical classroom dynamics.

The following subsections present the study's research design, participants and setting, data collection instruments, procedures, and validation strategies.

3.1 Research Design

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model consisting of Analysis, Design, Development, Implementation, and Evaluation (Spatioti et al, 2022). The ADDIE framework was selected for its systematic and iterative structure, which is well-suited to technology-enhanced learning innovations. The study was grounded in a pragmatic paradigm, allowing for the flexible integration of both quantitative and qualitative methods to evaluate the effectiveness, feasibility, and contextual relevance of the proposed learning model (Creswell & Clark, 2017).

The primary objective was to develop and validate an integrated coding learning model based on entrepreneurship principles, supported by Artificial Intelligence (AI) and Blockchain technologies. The model was designed to enhance students' capacity to conceptualize and develop digital startups within a secondary education setting.

3.2 Participants and Setting

The research was conducted at Fatih Bilingual Boarding School in Banda Aceh, Indonesia, a private institution recognized for its digital infrastructure and technology-focused curriculum. The school was selected due to its existing programming courses and student interest in entrepreneurship.

Participants included 120 students from Grades 10 to 12, selected using stratified purposive sampling based on their prior participation in basic coding classes and interest in digital entrepreneurship. In addition, five ICT teachers and two local startup mentors were involved in co-design and evaluation processes.

The school's infrastructure included a computer lab with 30 workstations and broadband internet (100 Mbps), which supported the technical implementation of AI and Blockchain platforms used in this study.

3.3 Instruments and Data Collection

Data were collected in alignment with the five stages of the ADDIE model:

3.3.1 Analysis Stage

In-depth interviews were conducted with five ICT teachers and the curriculum development team to identify gaps between existing coding instruction and entrepreneurship needs. Document analysis was performed on syllabi, lesson plans, and student portfolios (2021–2024). A needs assessment survey was distributed to 120 students to measure entrepreneurial interest, digital literacy, and understanding of AI and Blockchain. Additional insights were obtained through field visits to two local startups in Banda Aceh to map industry expectations regarding student competencies.

3.3.2 Design Stage

A co-design workshop was held with 10 students, 3 teachers, and 2 startup practitioners to create learning modules based on real-world cases, such as developing AI-powered applications for mapping local SMEs. The technology components included:

- An adaptive learning algorithm (built using TensorFlow) for personalized content delivery;
- A Blockchain-based prototype using Hyperledger Fabric to simulate startup funding and intellectual property protection via smart contracts.

Design validation was conducted using a two-round Delphi technique involving two edtech experts and one blockchain developer.

3.3.3 Development Stage

A hybrid learning module was developed, combining 30% theory and 70% hands-on projects. A key module titled "Building a Minimum Viable Product (MVP) with Python and the Business Model Canvas" was designed to integrate technical and business skills. A web-based learning platform was created, incorporating:

- An AI-powered recommendation engine for content adaptation;
- A Blockchain-based project certification system and virtual pitching space.

Pilot testing involved 30 Grade 11 students, focusing on functionality, user interface, and student engagement. Feedback was used to refine content complexity, navigation, and system responsiveness.

3.3.4 Implementation Stage

The full model was implemented over three months in real classroom settings. Teachers received intensive training on project-based digital pedagogy and platform usage. Students formed 10 startup teams (3–4 members each) tasked with developing tech-based solutions to local issues. Mentoring was supported via global platforms such as Coursera Mentor, enabling access to international business mentors. The final project included a Blockchain Pitch Day, where students presented their startups and used a token-based system for simulated investment validation.

3.3.5 Evaluation Stage

Effectiveness was assessed through pre- and post-tests measuring coding skills (algorithm design, debugging) and business skills (SWOT analysis, business model canvas). Paired sample t-tests and linear regression were conducted using SPSS v25. Qualitative data from focus group discussions (FGDs) with students, teachers, and industry partners were used to explore perceptions, challenges, and perceived benefits. Observational data were collected during pitching sessions to assess technology usage and team collaboration. Product quality was reviewed by a panel of experts—including IT lecturers, government education representatives, and local investors—based on innovation, feasibility, and scalability. Blockchain audits ensured data integrity and digital certification authenticity.

3.4 Data Validation and Reliability

Instruments were validated using expert judgment and exploratory factor analysis to ensure content and construct validity. Reliability testing using Cronbach's Alpha produced scores above 0.80, indicating strong internal consistency. Methodological triangulation via surveys, interviews, and observation was applied to enhance credibility. Member checking with participants confirmed the accuracy of interpretations, while peer debriefing helped reduce researcher bias.

4. Results

The results are presented according to the study's objectives and research questions. Both quantitative and qualitative data were analyzed to assess the effectiveness of the entrepreneurship-based coding learning model integrated with Artificial Intelligence (AI) and Blockchain. Four main findings emerged from the data.

4.1 Improvement in Coding and Entrepreneurial Competencies

A pre-test and post-test were conducted with 30 Grade 11 students as the experimental group. The tests assessed coding and entrepreneurial skills using standardized instruments. As shown in **Table 1**, the average score for coding increased from 58.3 (SD = 10.4) to 82.1 (SD = 8.6), while the average business score increased from 54.7 to 80.6.

Table 1. Pre-Test and Post-Test Scores in Coding and Entrepreneurship (n = 30)

omain	:e-Test Mean	ɔst-Test Mean	[ean Difference	ʌalue	·value
ɔding	3.3	1	23.8	87	0.001
ıtrepreneurship	4.7	0.6	25.9	0.24	0.001

Statistical analysis using paired sample t-tests revealed significant improvements in both domains ($p < 0.001$), indicating that the integrated learning model effectively enhanced students' technical and business competencies.

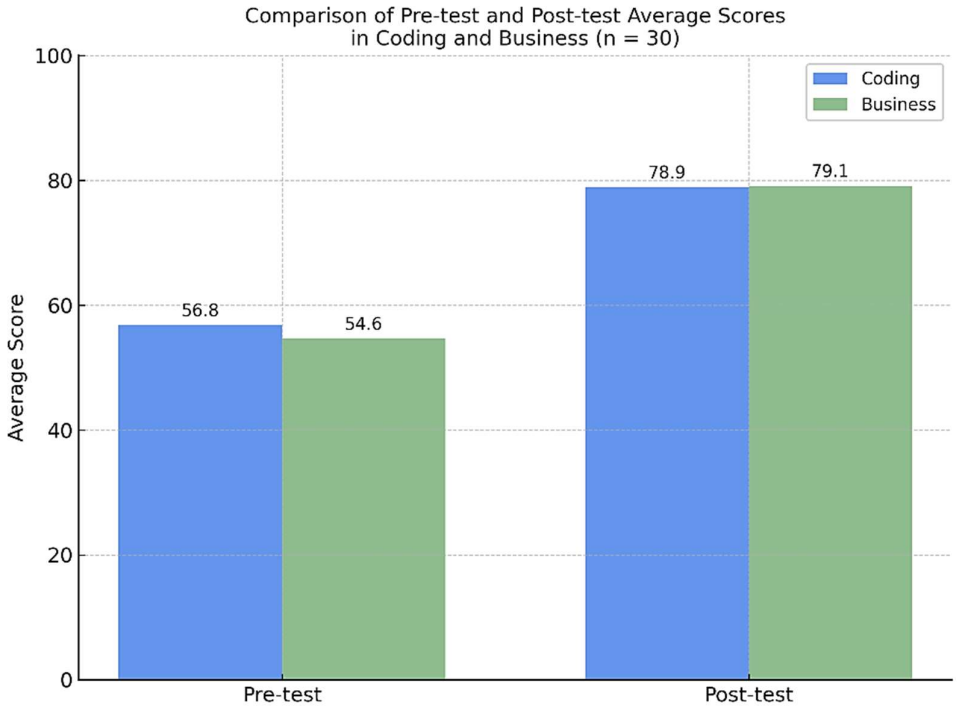

Figure 1 Comparison of Pre-Test and Post-Test Average Scores in Coding and Entrepreneurship (n = 30)

Qualitative data from focus group discussions (FGDs) supported the quantitative findings. Students reported a clearer understanding of how coding can be applied to solve real-world problems and develop viable business models. Teachers observed increased student initiative, teamwork, and cross-disciplinary collaboration.

4.2 Impact of AI and Blockchain Integration on Learning

The AI-based adaptive learning system successfully personalized students' learning pathways. Based on system logs and student feedback, 26 out of 30 students (86.7%) accessed custom-recommended content aligned with their learning pace and preferences. A majority (73%) rated the AI feature as "very helpful," while 20% considered it "moderately helpful."

Simultaneously, the Blockchain module facilitated experiential learning regarding digital verification, data integrity, and smart contracts. All 10 student teams participated in the Blockchain Pitch Day, during which they presented startup ideas and received token-based investment simulations via Hyperledger Fabric.

Table 2. Student Perception of AI and Blockchain Features

ːature	ıategory	ːrcentage (%)
I Recommendation	ːry Helpful	3.3

	oderately Helpful	.0
	ess Helpful	7
ockchain Simulation	ained New Understanding	.3
	terested to Explore	7

The Blockchain audit revealed 100% consistency between pitch submissions and their tokenized records, validating the system's technical functionality and pedagogical value.

4.3 Enablers and Barriers to Implementation

The implementation of the integrated entrepreneurship-based coding model supported by AI and Blockchain was influenced by a combination of enabling factors and encountered challenges. These findings are derived from focus group discussions (FGDs), observational data, and triangulated qualitative evidence involving students, teachers, and startup mentors.

4.3.1 Enablers

Several key enablers contributed significantly to the successful implementation of the AI- and Blockchain-integrated entrepreneurship-based coding model at Fatih Bilingual Boarding School. First, students exhibited a high level of interest in both technology and entrepreneurship. A preliminary survey of 120 students indicated that 82% were highly motivated to develop technology-based startups, and over 92.3% actively participated in voluntary mentoring sessions during the program.

This strong student engagement provided a solid foundation for the program's success. Second, the school possessed sufficient digital infrastructure, including 30 modern computer units and 100 Mbps internet bandwidth, which enabled smooth execution of coding projects and access to AI-driven personalized learning platforms. A post-intervention survey confirmed that 86% of students found the infrastructure highly supportive for their startup development efforts. Third, the program benefited from strong teacher commitment and leadership support. All five ICT teachers participated in intensive training workshops, with three of them successfully redesigning their lesson plans to integrate entrepreneurship, AI, and Blockchain components. Moreover, school administrators provided extended learning hours and space for consultations, demonstrating institutional readiness for pedagogical innovation.

4.3.2 Barriers

Despite these favorable conditions, several challenges emerged during implementation. One of the most prominent barriers was the initial lack of teacher familiarity with the core technologies involved. All five ICT teachers reported no prior experience using AI-based adaptive learning systems or Blockchain platforms in educational settings, which necessitated foundational training before full model implementation. Another major challenge was the limited availability of time for intensive mentoring. Due to tight school schedules and the limited number of startup mentors, only six out of ten student teams were able to receive consistent weekly mentoring throughout the 12-week program. Furthermore, students faced conceptual difficulties in the early stages, particularly in understanding smart contracts and tokenization processes. Approximately 40% of students struggled to distinguish between conventional programming logic and decentralized Blockchain operations during the initial simulation exercises.

Only four teams were able to complete tokenized pitch submissions independently. To address these issues, the research team implemented several mitigation strategies, including structured teacher training workshops, simplification of technical content through AI-assisted visual modules and adaptive quizzes, and scaffolded mentoring support involving both peer mentoring and access to global mentors through platforms such as Coursera and Discord. These targeted interventions helped narrow the knowledge gap, enhanced student confidence, and improved overall engagement with the integrated learning model.

4.4 Student Readiness to Launch Tech-Based Startups

Over the three-month implementation, students worked in 10 startup teams. Their projects addressed local needs such as health tracking, Islamic finance tools, and cooperative school services.

Technology Readiness Level (TRL) assessments indicated that 7 out of 10 teams reached TRL 6–7, meaning their prototypes were functional and ready for further development. Furthermore, 60% of teams independently produced comprehensive business model canvases (BMC) and pitch decks, while 30% required facilitation and only one team was unable to complete their documentation.

Table 3. Startup Project Outcomes by Student Teams

eam	oject Theme	RL	MC & Pitch Deck	oft Skills
	I-Based Learning App		dependent	igh
	ocal SME Mapping Tool		dependent	igh
	hool Waste Management System		ith Assistance	edium
	aria Digital Payment System		dependent	igh
	nline Tutoring Platform		complete	edium
	alal Product Marketplace		dependent	igh
	igital Zakat Calculator		ith Assistance	igh
	ealth Monitoring App		dependent	igh
	ecentralized Donation Platform		ith Assistance	edium
	ockchain-Based School Co-op		dependent	igh

Overall, 70% of student teams achieved functional prototypes, and 60% demonstrated strong communication, collaboration, and problem-solving skills during pitch presentations.

5. Discussion

This study demonstrated the effectiveness of an integrated learning model that combines entrepreneurship education, Artificial Intelligence (AI), and Blockchain technology to enhance both technical and entrepreneurial competencies among secondary school students. Implemented at Fatih Bilingual Boarding School, the model successfully addressed a critical educational gap by linking coding education with startup development in a real-world context. Through rigorous application of the ADDIE instructional design framework, the study not only validated the model's pedagogical impact but also identified practical enablers and barriers to its broader implementation. Four key discussion points emerged from the findings.

5.1 Strengthening Dual Competencies through an Integrated Model

The statistically significant increase in students' coding scores (from 58.3 to 82.1) and entrepreneurial scores (from 54.7 to 80.6) underscores the potency of the integrated model in fostering dual competencies. These results reflect the benefits of bridging technical education with business-oriented project-based learning (PBL). Prior studies by Borghi (2025) have emphasized that contextualizing academic content in real-life entrepreneurial scenarios strengthens student engagement and knowledge retention. Our findings reaffirm this, demonstrating that embedding business cases within coding instruction promotes holistic skill development.

Students in this study engaged in complex problem-solving through projects such as AI-powered local SME mapping tools and Blockchain-based digital cooperatives. These hands-on experiences provided authentic applications of their coding knowledge while also cultivating business acumen. This aligns with Kolb's experiential learning theory, which advocates for learning through concrete experiences, reflective observation, and active experimentation (Morris & Thomas, 2020). By navigating the intersection of programming and entrepreneurship, students were not merely learning isolated skills but developing a systems-thinking approach essential for 21st-century innovation.

Moreover, this integration helped students overcome the traditional dichotomy between "STEM" and "business" tracks in education. Rather than choosing between technical or entrepreneurial pathways, learners were empowered to become digital creators capable of solving problems, designing products, and launching ventures. This interdisciplinary capability is particularly crucial in the era of Industry 4.0 and Society 5.0, where innovation stems from the convergence of diverse domains.

5.2 The Role of AI and Blockchain in Transforming Pedagogy

One of the study's major contributions is the empirical validation of AI and Blockchain as transformative educational technologies. The AI component functioned as a dynamic learning companion, offering differentiated content based on students' real-time performance and cognitive profiles. This feature aligns with Essa et al. (2023), who argue that adaptive learning technologies can personalize education, improve learner outcomes, and reduce dropout rates.

Students responded positively to AI-based recommendations, with 86.7% accessing personalized learning pathways and 73.3% rating them as "very helpful." These results indicate not only system usability but also pedagogical value. The AI system helped close competency gaps, accelerate learning for advanced students, and increase engagement by offering relevant content tailored to individual needs.

Simultaneously, the Blockchain element served as both a technological and pedagogical innovation. By simulating startup ecosystems through smart contract frameworks and token-based investment scenarios, students experienced firsthand how digital assets are verified, protected, and transacted in contemporary digital economies. The Blockchain Pitch Day, where students presented startup ideas to simulated investors using token transactions, was a unique highlight that elevated both technical rigor and experiential authenticity.

The educational benefits of Blockchain observed in this study support Lam and Dongol (2022) proposition that Blockchain can introduce transparency, traceability, and ownership into learning ecosystems. Students were able to grasp abstract concepts such as decentralization and intellectual property through practical exercises, thereby increasing conceptual clarity and real-world relevance.

Taken together, the integration of AI and Blockchain transformed conventional coding instruction into a responsive, immersive, and future-oriented learning environment. It provided students not just with tools but with technological mindsets, preparing them for active participation in rapidly evolving digital landscapes.

5.3 Readiness to Launch Startups as a Success Indicator

An important metric of success in this study was students' demonstrated readiness to conceptualize and develop viable tech-based startups. The achievement of Technology Readiness Levels (TRL) 6–7 by 70% of student teams, coupled with 60% independently completing business model canvases and pitch decks, reflects a high level of startup literacy and innovation potential. This goes beyond knowledge acquisition to measurable entrepreneurial action.

The transition from "learning about technology" to "creating with technology" is a critical pedagogical shift emphasized by the European Commission (2016). In this study, students moved from passive recipients of information to active innovators addressing real problems—such as health access, halal product tracking, and Islamic finance tools. Their engagement in prototyping, pitching, and iterative development mirrors the stages of actual startup incubation processes.

Additionally, students developed crucial soft skills such as collaboration, critical thinking, communication, and adaptability, which are essential for long-term entrepreneurial success. Through interdisciplinary team-based projects, they learned to navigate uncertainty, utilize feedback, and make decisions based on data. The

process of creating and presenting their startups boosted their confidence, autonomy, and strategic thinking skills, all of which are applicable in both academic and professional settings.

In many cases, student ideas were rooted in local contexts, addressing region-specific needs and leveraging cultural relevance. This suggests that entrepreneurship education, when localized and technology-infused, can act as a bridge between education and community development.

5.4 Implementation Factors and Scalability Potential

The implementation of this integrated model revealed both facilitating and inhibiting factors. On the enabling side, high student motivation, access to robust digital infrastructure, and strong leadership support at the institutional level contributed significantly to the program's success. The school's commitment to innovation was evident in the allocation of time, resources, and training for both teachers and students.

However, the study also encountered notable barriers. Chief among these was the initial lack of teacher familiarity with AI and Blockchain technologies. None of the five ICT teachers had prior experience integrating these tools into instruction, which necessitated significant upskilling. The model's success, therefore, depended on intensive professional development and ongoing mentoring—a finding consistent with the Technological Pedagogical Content Knowledge (TPACK) framework (Abedi & Emmanuel, 2024), which emphasizes that technology integration requires not only content knowledge but also pedagogical alignment.

Another challenge was the limited time available for consistent mentoring, particularly in guiding students through complex concepts such as smart contracts and tokenization. While some teams thrived with minimal guidance, others needed continuous scaffolding. To address this, the program incorporated peer mentoring and global mentorship via online platforms. These strategies partially mitigated the mentorship gap and demonstrate scalable approaches for similar future implementations.

Importantly, the success of this model in a resource-limited but digitally equipped school in Aceh suggests its potential scalability to other under-resourced or rural educational settings. By combining low-cost digital infrastructure with cloud-based AI/Blockchain tools and modular instructional design, the model is both adaptable and replicable. It offers a flexible framework for governments, NGOs, and schools aiming to transform digital entrepreneurship education at the secondary level.

Moreover, the model is well-aligned with Indonesia's broader education and innovation policy agendas, including the Independent Learning curriculum and the national digital literacy strategy. Its focus on student agency, real-world application, and emerging technologies places it at the frontier of educational reform in the Global South.

In summary, this discussion highlights how the integrated entrepreneurship-based coding model with AI and Blockchain components can cultivate future-ready learners. By nurturing dual competencies, leveraging adaptive technologies, and fostering real-world startup experiences, the model offers a blueprint for 21st-century education that is inclusive, contextualized, and innovation-driven.

6. Conclusion

This study demonstrated that integrating Artificial Intelligence (AI) and Blockchain technology into an entrepreneurship-based coding education model can significantly enhance students' technical and business competencies within a secondary school context. Using a systematic R&D approach guided by the ADDIE framework, the model was effectively implemented at Fatih Bilingual Boarding School, resulting in statistically significant improvements in both coding proficiency and entrepreneurial understanding. Students not only developed functional prototypes—70% reaching TRL 6–7—but also showed substantial autonomy in designing business models and pitch decks.

AI-enabled adaptive learning supported personalized content delivery tailored to individual student profiles, thereby boosting engagement and learning outcomes. Simultaneously, Blockchain simulations provided real-world relevance, enabling students to experience digital verification, IP protection, and investment mechanisms within a controlled learning environment. These features bridged the gap between theoretical instruction and practical application, fostering experiential learning and innovation.

Despite initial barriers such as limited teacher familiarity and time constraints for mentoring, structured interventions—like professional training and scaffolded learning—helped mitigate these challenges. The presence of enabling factors, including motivated students, adequate infrastructure, and leadership support, further reinforced the model's effectiveness.

Given its successful outcomes and adaptability, this integrated model offers a scalable and replicable framework for transforming digital entrepreneurship education across similar secondary school settings in emerging economies. It not only cultivates future-ready entrepreneurial competencies but also aligns with global educational imperatives to prepare youth for active participation in innovation-driven digital ecosystems.

7. References

Abdalla Khidir Abdalla, I. H., & Khudair, S. B. (2023). Value-driven Thinking Framework for Developing Responsible Management Learning and Education Programs in Business Schools. *Asric Journal on Social Sciences and Humanities*, 328. https://asric.africa/sites/default/files/2025-06/SC_V4%20Issue%201_27.pdf

Abedi, E. A. (2024). Tensions between technology integration practices of teachers and ICT in education policy expectations: implications for change in teacher knowledge, beliefs and teaching practices. *Journal of computers in education*, *11*(4), 1215-1234. https://doi.org/10.1007/s40692-023-00296-6

Ayub Khan, A., Laghari, A. A., Shaikh, A. A., Bourouis, S., Mamlouk, A. M., & Alshazly, H. (2021). Educational blockchain: A secure degree attestation and verification traceability architecture for higher education commission. *Applied Sciences*, *11*(22), 10917. https://doi.org/10.3390/app112210917

Bati, T. B., & Workneh, A. W. (2021). Evaluating integrated use of information technologies in secondary schools of Ethiopia using design-reality gap analysis: A school-level study. *The electronic journal of information systems in developing countries*, *87*(1), e12148. https://doi.org/10.1002/isd2.12148

Battisti, S., Agarwal, N., & Brem, A. (2022). Creating new tech entrepreneurs with digital platforms: Meta-organizations for shared value in data-driven retail ecosystems. *Technological Forecasting and Social Change*, *175*, 121392. https://doi.org/10.1016/j.techfore.2021.121392

Borghi, M. (2025). Embedding entrepreneurship and technology literacy in the student curriculum: A case study of a module for real estate students. *Innovations in Education and Teaching International*, *62*(3), 959-970. https://doi.org/10.1080/14703297.2024.2382413

Creswell, J. W., & Clark, V. L. P. (2017). Designing and conducting mixed methods research. Sage publications. https://www.cambridgeenglish.org/Images/735110-studies-in-language-testing-volume-43.pdf#page=53

GM, D., Goudar, R. H., Kulkarni, A. A., Rathod, V. N., & Hukkeri, G. S. (2024). A digital recommendation system for personalized learning to enhance online education: A review. *IEEE Access*, *12*, 34019-34041. https://ieeexplore.ieee.org/document/10445145

Hasan, M., Tiara Hutamy, E., Supatminingsih, T., Ahmad, M. I. S., Aeni, N., & Dzhelilov, A. A. (2024). The role of entrepreneurship education in the entrepreneurial readiness of generation Z students: why do digital business literacy and financial literacy matter?. *Cogent Education*, *11*(1), 2371178. https://doi.org/10.1080/2331186X.2024.2371178

Hasche, N., & Linton, G. (2021). University–industry collaboration: Constructing a business model lab for student venture creation. *International Journal of Entrepreneurial Behavior & Research*, *27*(5), 1241-1263. https://doi.org/10.1108/IJEBR-09-2020-0660

Karnalim, O. (2021). Explanation in code similarity investigation. *IEEE Access*, *9*, 59935-59948. 10.1109/ACCESS.2021.3073703

Khurniawan, A. W., Sailah, I., Muljono, P., Indriyanto, B., & Maarif, M. S. (2021). The collaborative strategy of total quality management and school governance to improving effectiveness of vocational school-based enterprise. *Journal of Educational and Social Research*, *11*(2), 10-21. https://doi.org/10.36941/jesr-2021-0026

Kwangmuang, P., Somabut, A., Duangngern, P., Changpetch, S., Dhithjaroen, C., Techapornpong, O., ... & Samat, C. (2025). Designing an AI-enhanced blockchain and FinTech curriculum for youth: a case study of educational and industrial collaboration. *Education and Information Technologies*, 1-37. https://doi.org/10.1007/s10639-025-13384-0

Lam, T. Y., & Dongol, B. (2022). A blockchain-enabled e-learning platform. *Interactive learning environments*, *30*(7), 1229-1251. https://doi.org/10.1080/10494820.2020.1716022

Lodi, M., & Martini, S. (2021). Computational thinking, between Papert and Wing. *Science & education*, *30*(4), 883-908. https://doi.org/10.1007/s11191-021-00202-5

Lopes, Y. M. (2023). Teaching-learning practice and value creation in edtechs: the inteli case study. *Mackenzie*. https://dspace.mackenzie.br/handle/10899/31892

Mills, K. A., Cope, J., Scholes, L., & Rowe, L. (2025). Coding and computational thinking across the curriculum: A review of educational outcomes. *Review of Educational Research*, *95*(3), 581-618. https://doi.org/10.3102/00346543241241327

Morris, T. H. (2020). Experiential learning–a systematic review and revision of Kolb's model. *Interactive learning environments*, *28*(8), 1064-1077. https://doi.org/10.1080/10494820.2019.1570279

Rao, S. P., Sekhar, S. C., Yadav, T. C., Kumar, V. P., & Haran, B. H. (2024). Implementing Experiential Learning Strategies for Enhanced Business Education in India: Challenges and Opportunities. *Journal of Informatics Education and Research*, *4*(3), 20-33. https://jier.org/index.php/journal/article/view/1301

Sansone, G., Ghezzi, A., Landoni, P., & Rangone, A. (2024). Students' Entrepreneurial Engagement and Student Entrepreneurship: Do Coding and Digital Skills Matter?. *IEEE Transactions on Engineering Management*, *71*, 5733-5743. 10.1109/TEM.2024.3367893

Sarkar, D., & Jena, S. K. (2022). Unleashing potential: A thorough exploration of entrepreneurial competency among educated youth in the 21st century. *European Chemical Bulletin*, *11*(7), 231-241. 10.53555/ecb/2022.11.10.53555/ecb/2022.11.7.28

Shekarian, M., & Parast, M. (2021). Do entrepreneurship skills improve project performance? A project-based learning perspective. *The Journal of Entrepreneurship*, *30*(2), 267-305. https://doi.org/10.1177/09713557211025

Silaghi, D. L., & Popescu, D. E. (2025). A Systematic Review of Blockchain-Based Initiatives in Comparison to Best Practices Used in Higher Education Institutions. *Computers*, *14*(4), 141. https://doi.org/10.3390/computers14040141

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A comparative study of the ADDIE instructional design model in distance education. *Information*, *13*(9), 402. https://doi.org/10.3390/info13090402