

Developing an ADDIE-Based AI Learning Model Using Perplexity.ai and Designs.ai to Enhance Critical Thinking Skills in Entrepreneurship: A Quasi-Experimental Study at SMK 1 Jember

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ABSTRACT

This study aims to develop and test an ADDIE-based AI learning model using Perplexity.ai and Designs.ai to enhance critical thinking skills in entrepreneurship among 52 Grade XI vocational students (26 experimental, 26 control) at SMK Negeri 1 Jember. A quasi-experimental design with an independent t-test analysis ($t = 11.03$, $p < 0.05$) reveals significant improvement in business plan scores (experimental $M=87.12$ vs. control $M=70.58$). Findings indicate enhanced student engagement (87% reported AI learning as enjoyable) and skills in opportunity analysis and risk prediction. This model offers practical implications for digital pedagogy in Indonesian vocational education.

Keywords: artificial intelligence, business opportunities, critical thinking, entrepreneurship, learning model, R&D

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INTRODUCTION

In today's digital era, Artificial Intelligence (AI)-based learning must be taught to students. AI is crucial because it improves convenience, efficiency, security, and the overall quality of human life (Kasianenko & Fedotov, 2022; Ombale & Jajoo, 2024). The role of AI in modern education improves academic performance and student learning experiences (Zhang, 2024). Gamified learning through AI and the provision of rapid feedback increase students' learning motivation (Capinding & Dumayas, 2024; Mallillin, 2024) and improve students' attitudes towards learning compared to traditional methods (García-Martínez et al., 2023).

However, the use of AI also has risks. Students' dependence on AI dialogue reduces critical thinking skills due to the lack of independent analysis to evaluate information. Students prefer fast and optimal solutions from AI (Zhai et al., 2024; Çela et al., 2024; Li, 2024). This is supported by the character of Indonesian students, who are less interested in reading (Hendrik, 2024). Continuous dependence on AI has the potential to cause significant erosion of critical cognitive skills in students (Ivanov, 2023). This is why critical thinking skills are crucial.

Critical thinking skills are crucial because they are a crucial component of soft skills and prepare students to become independent workers (Pavlenko et al., 2024). Becoming an independent individual is a fundamental goal of education, according to Ki Hadjar Dewantara (Siswadi & Murtiningsih, 2024) (Mudahlipah et al., 2024). Critical thinking enables students to identify opportunities and find creative solutions to everyday problems (Mardatillan & Prayudha, 2024). Critical thinking skills are considered to increase competitiveness, provide the ability to solve difficult problems, and contribute to corporate success (Algouzi et al., 2023).

Critical thinking skills are positively correlated with an entrepreneurial mindset (Zharifah & Sukmadewi, 2024), and Indonesia needs numerous entrepreneurs. Global Entrepreneurship Monitor (GEM)

data reveal that Indonesia has a high rate of new entrepreneurs (Pramita et al., 2022) but low activity efficiency (Kaygisiz et al., 2024). Indonesia's entrepreneurship rate is only 3.47%, far lower than neighboring countries (Wahyudi et al., 2024). Entrepreneurship is crucial for economic growth, job creation, innovation, and national economic resilience (Wahyudi et al., 2024). Therefore, it is necessary to design an AI-based learning model to improve students' critical thinking and entrepreneurial skills.

Previous studies have examined AI in education (Kasianenko & Fedotov, 2022; Zhang, 2024) and critical thinking in entrepreneurship (Zharifah & Sukmadewi, 2024), yet few have integrated AI tools like Perplexity.ai for real-time market analysis in vocational settings. Notably, no research has specifically addressed Indonesian SMK students' over-reliance on AI dialogue, which erodes independent analysis (Zhai et al., 2024), nor has it tested ADDIE-based models in Jember Regency contexts. This study fills this gap by developing and validating an AI model tailored to the business opportunity curriculum.

LITERATURE REVIEW

Artificial Intelligence in Learning Activities

Artificial Intelligence (AI) is a transformative technology that automates tasks that require human intelligence in various fields (Gilboa, 2023). There are at least seven AI roles in student learning activities: AI-tutor, AI-coach, AI-mentor, AI-teammate, AI-tool, AI-simulator, and AI-student, each of which offers different benefits. Teaching AI to be part of human life is a teacher's task in this era. How AI is used responsibly can improve educational outcomes and students' lives. Numerous studies reveal that AI significantly improves learning activities through Knewton, ALEKS, interactive PhET, Labster, ChatGPT, and Perplexity AI (Akhyar & Fitriati, 2024) (Okhanashvili, 2024) (Lin, Y., Luo, Q., & Qian, Y, 2023). AI facilitates students to develop their potential independently, and teachers play a greater role in the classroom to conduct active discussions, question-and-answer sessions, and collaborative exercises through think-pair-share (Ethan, Lilach, 2023).

Critical Thinking Skills in Entrepreneurship

Critical thinking skills are essential for students at all levels of education. Critical thinking skills include the ability to interpret, analyze, and compare information, generalize, evaluate data, and draw conclusions (Pavlenko et al., 2024). Critical thinking skills are vital because they enhance logical reasoning and problem-solving, foster autonomy and creativity, enabling students to form personal perspectives, engage in discussions, and approach problems from multiple perspectives (Kanwal et al., 2024; Le, T. L., 2024).

Critical thinking theories in entrepreneurship emphasize the importance of analytical skills and reflective judgment in navigating complex business environments. The most relevant theory is the Entrepreneurial Mindset theory. The Entrepreneurial Mindset theory underscores how entrepreneurs develop critical thinking to identify opportunities, analyze them, decide to pursue them, execute them, and integrate all resources to transform them into businesses (Sakdiyah & Bachiar, 2023). The entrepreneur mindset has several criteria, including having the ability to lead, being a reliable salesperson, having a different perspective, not hesitating to try, not working for money, focusing on goals, having a mentor, having big dreams and starting with small steps, having priorities, having a solid team, not always having to be perfect, continuing to learn, being observant of opportunities, and so on (Sitorus et al., 2023).

Business Opportunity Material for Vocational High Schools

Business opportunity material is provided to 11th-grade vocational high school students. The learning objectives for business opportunity material are (Fauzia et al. 2019):

1. Understanding business opportunities for goods/services;
2. Determining factors for business success and failure;
3. Analyzing the likelihood of business success and failure;

4. Presenting forms of business opportunities;
5. Creating business opportunities that are appropriate to each individual's environmental conditions in a creative and innovative manner.

Substantively, the business opportunity material explains the concept of business opportunities and the characteristics of good, potential, and marketable business opportunities. Furthermore, the business opportunity analysis activity begins with the analysis steps and objectives. The concepts of success and failure in utilizing business opportunities, utilizing opportunities creatively and innovatively, and sources of business opportunities are discussed (Fauzia et al. 2019).

Learning Model Development

Learning model development is a multifaceted process that integrates various educational theories and practices to improve student learning outcomes. Learning model development is continuously carried out in response to change, to meet needs, and to address challenges. Several studies related to learning model development include the development of a Support Learning model for an AI-based learning assistance system at a university (Lee et al., 2023), the development of a multimedia-based English language learning model using the R&D method (Supriyadi et al., 2024), the development of a Tajribi learning model emphasizing practice and application for religious education (Soleh & Syahidin, 2024), and the development of a learning model called My Real Action Plan for Pancasila (MRAPP) to instill Pancasila values, using the Borg and Gall model (Wulandari et al., 2023).

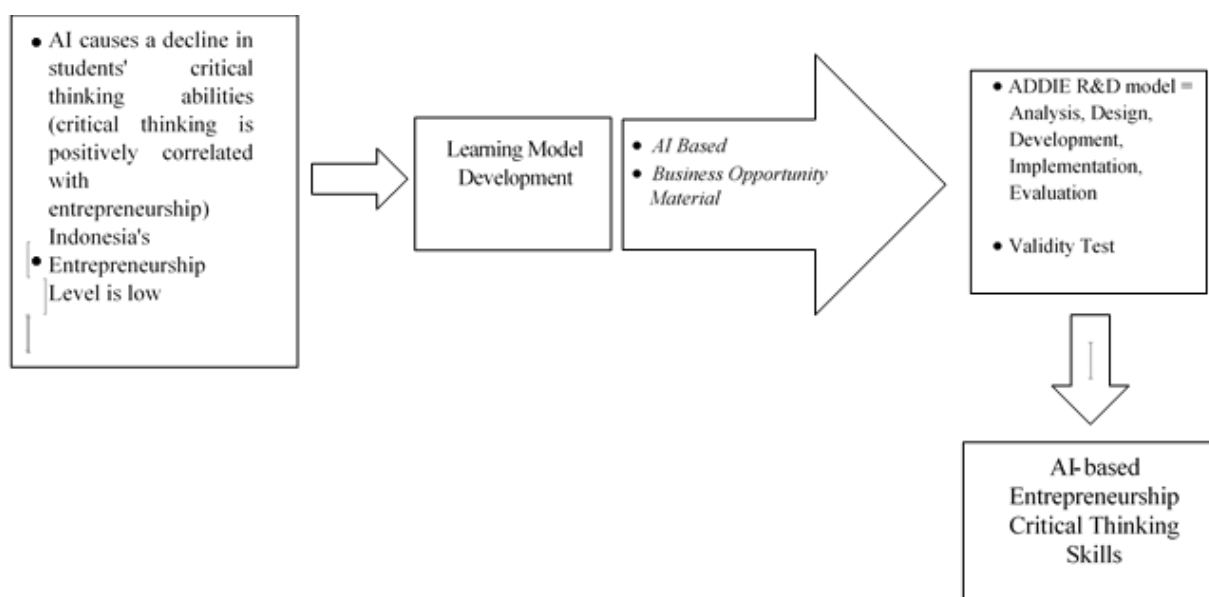


Figure 1. Roadmap for completing research activities

METHODS

Types of Research

This type of development research uses the research and development (R&D) method. This R&D research was chosen to produce, develop and test the effectiveness of the product. The product to be developed is an artificial intelligence (AI)-based learning model designed to enhance critical thinking skills in entrepreneurship within the Business Opportunities material for grade XI SMK. The development model used

is the ADDIE model, chosen because of its systematic and structured approach to instructional development. This model also allows for repeated revision and evaluation at each stage, so that the resulting learning model is valid and practical and achieves the main objectives of the research activity (Le et al., 2023).

Development Procedures

The research development procedure uses the ADDIE model, which consists of five stages, namely:

1. Analysis aims to determine the need for developing AI-based learning models and the feasibility of product development requirements:
 - 1) Analyze the importance of developing AI-based learning models to improve critical thinking skills in entrepreneurship
 - 2) Analyze student characteristics, curriculum and relevant learning materials
 - 3) Analyze content needs based on the syllabus
2. Design that is systematic product design in the form of concepts and content that underlie product development in the next stage:
 - 1) Formulate learning objectives that are specific, measurable, achievable, relevant and time-bound
 - 2) Design the structure and flow of the learning model, consisting of learning strategies, assessment methods, and learning resources
 - 3) Develop a blueprint for the learning model to be implemented
 - 4) Design a systematic curriculum and teaching modules
 - 5) Design systems, databases and interfaces
3. Development, namely the realization of a product design that is ready to be implemented and the creation of instruments to measure product performance to:
 - 1) Develop relevant and engaging learning materials that integrate AI, critical thinking, and an entrepreneurial mindset
 - 2) Create or select appropriate AI platforms or tools to integrate into learning models
 - 3) Develop assessment instruments to measure students' critical thinking skills
 - 4) Arrange content according to learning outcomes
4. Implementation that is feedback on the product created is an initial evaluation by answering questions about the objectives of product development, to:
 - 1) Implement the learning model that has been developed in a real learning setting
 - 2) Collect data on the effectiveness and efficiency of learning models in improving students' critical thinking skills and entrepreneurial mindset.
5. Evaluation, namely, return to product users for improvement according to the evaluation results or unmet needs of the product, to:
 - 1) Conduct formative evaluations throughout the development process to identify areas for improvement
 - 2) Conduct a summative evaluation after implementation to measure the impact of the learning model on student learning outcomes
 - 3) Analyze quantitative and qualitative data to draw conclusions about the effectiveness of the learning model
 - 4) Evaluation is obtained from comments and suggestions from validators and students as a reference for improving the products being developed

Instrument Data Collection

The data collection instruments used in this study are:

- 1) Questionnaire: It is used to collect data about students' needs, their perceptions of the learning model, and

their level of satisfaction with the learning experience.

- 2) Assignment: It is used to measure students' critical entrepreneurial thinking skills by compiling a business plan with the developed model.
- 3) Interviews: It is used to collect qualitative data about learners' experiences, the challenges they face, and their suggestions for improving the learning model.
- 4) Observation: It is used to observe the learning process and interactions between students and the AI tools used.
- 5) Documentation: It is used to collect data about the curriculum, syllabus, learning materials, and student assessment results.

Data Analysis Techniques

The data analysis technique used in this study is descriptive statistical data analysis. The descriptive analysis was conducted for the research instrument, which consisted of a questionnaire assessing student needs for the development of AI-based learning models, product validity analysis, and student response questionnaire analysis after implementing the developed model. The explanation is as follows:

- 1) Questionnaire Analysis of Student Needs for Product Development. This analysis is conducted to obtain data on student needs for the product development to be undertaken. This analysis is carried out in the initial stage, the analysis stage. The calculation formula is described as follows:

$$\text{Total Percentage} = \frac{\text{Number of student answer}}{\text{Number of students}} \times 100\%$$

$$\text{Total Percentage Amount} = \frac{\text{Total percentage amount}}{\text{Number of indicators}} \times 100\%$$

- 2) Analysis of the Validity of the Developed Product

This analysis is conducted to determine whether the product being developed is feasible. The following are the steps researchers take to conduct a product feasibility analysis:

- a. Testing validity using a 5-point scale scoring, namely from invalid to very valid, as shown in the table below:

Table 1. Model validation assessment scale

Scores	Criteria
5	Very Valid
4	Valid
3	Quite Valid
2	Not enough
1	Invalid

- b. Determining the average validation value of each validator using the formula:

$$\text{Average Value} = \frac{\text{Total score of validator results}}{\text{Maximum score}} \times 100\%$$

- c. Determining the total average validation value using the formula:

$$\text{Total Percentage} = \frac{\text{Total value of all validators}}{\text{Number of validators}} \times 100\%$$

- d. Making decisions in determining product validation results. The following table reveals the follow-up to the validation of the learning model:

Table 2. Follow-up table of learning model validation

Percentage Scores (%)	Interpretation	Follow-up
100 – 85	Very Valid	It is able to be used without revision
85 – 70.01	Valid	It can be used, but needs minor revisions
70 – 50.01	Less Valid	It is recommended not to use it because it needs major revision.
50 – 01.00	Invalid	It is not suitable for use

A developed product is considered valid if it achieves a minimum score of 60% or higher with revisions. The expert validation sheet includes a comments and suggestions section to guide product improvements before moving on to the next stage.

3) Analysis of Student Responses after Product Implementation

Student response analysis was carried out to determine student responses to the product being developed. The stages of implementing the analysis are as follows:

- a. To compile student response criteria using the Likert scale shown in the following table:

Table 3. Student response assessment scale

Scores	Criteria
5	Strongly agree
4	Agree
3	Disagree Less
2	Don't agree
1	Strongly Disagree

- b. To calculate the total average value using the formula:

$$\text{Average Value} = \frac{\text{Total score of answers}}{\text{Number of indicators} \times \text{number of respondents} \times 5} \times 100\%$$

- c. To interpret the results of the average qualitative assessment value based on the provisions in the table below:

Table 4. Student response criteria

Percentage Scores (%)	Interpretation
100 – 81	Very good
80 – 61	Good
60 – 41	Pretty good
40 – 21	Not good
20 – 0	Very Bad

4) Analysis of the application of learning models to critical thinking skills in entrepreneurship.

To determine the differences in critical thinking skills in entrepreneurship between classes that implemented the developed model and those that did not, we compared the business plan results of the class that implemented the model with those that did not. The assessment rubric for students' business plans is as follows:

Table 5. Rubric for assessing students' business plan assignments

No	Assessment criteria	Assessment Descriptions	Maximum Score
1	Identify business opportunities	Students' ability to critically identify business opportunities	15
2	Business opportunity analysis	Students' ability to analyze data on trends, data on potential consumer needs and be able to create customer segmentation	15
3	Analysis of factors for business success and failure	Able to detect success and failure factors of the designed business	15
4	Creativity and innovation of ideas	Originality of business ideas, innovative solutions and ability to develop new concepts	15
5	Logic and flow of thought	Integration of arguments, business reasons and systematic thinking in business planning	10
6	Business strategy development	Alignment of strategy with market analysis, clarity of implementation steps and risk anticipation	10
7	Quality of writing and presentation	Clarity of delivery, neatness and language used	10
8	Use of data and facts	Use of relevant and accurate data as a basis for business decision-making	10

Maximum total score: 100

- 5) Analysis of the effectiveness of applying learning models to critical thinking skills in entrepreneurship.
 - a. Calculating the effectiveness of the model application using the independent t-test statistical analysis is as follows:

$$t = \frac{X_1 - X_2}{\sqrt{S_p^2 \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}}$$

with its pooled variance. S_p^2

Determining the degrees of freedom (df) = $n_1 + n_2 - 2$

Statistical decision-making is done by determining the critical value based on df and the level of significance thereafter. Finally, compare the value with t_{table} t_{count} t_{table}

- b. Data triangulation is to combine data from observations, interviews and documentation to validate findings.

RESULTS AND DISCUSSION

Results

ADDIE Development Stages

This research aims to produce a learning model based on artificial intelligence in improving critical thinking skills, entrepreneurship and vocational high school students on business opportunities. The developed model received validation from experts. Learning materials, learning design experts, and education practitioners. The validated model was subsequently tested on a small group of 11th-grade students at SMK Negeri 1 Jember. This research and development (R&D) study used the ADDIE model, which includes analysis, design, development, implementation, and evaluation, as follows:

Analysis Stage

The first stage is analysis. This analysis is conducted to determine the importance of developing an AI-based learning model, analyze student characteristics, analyze the curriculum, and determine the suitability of learning materials. Therefore, the instruments used for this analysis include interviews with subject teachers, student needs questionnaires, and observations of learning activities.

Interviews were conducted with Entrepreneurship teachers at SMK Negeri 1 Jember. The results indicated that students currently rely on AI in their learning, despite the school's lack of Wi-Fi and sometimes unsatisfactory AI responses. This, in turn, discourages students from thinking and reduces their critical thinking skills. Therefore, AI-based learning models are crucial for improving critical thinking skills.

Classroom observation activities were conducted to determine student characteristics during learning activities. Students tended to be active, highly curious, and highly motivated to learn since the teacher had previously provided stimulus for students to create a dream list during their time as students at SMK Negeri 1 Jember. However, students were active only during the initial stages of the lesson. Furthermore, several students answered teacher questions with inappropriate and contextually inaccurate answers. They relied on AI without sorting, designing, and presenting answers appropriate to the context and level of students' thinking abilities.

Smartphone-based Android learning has become a necessity to support student learning. Students explore knowledge and seek answers to questions and discussions in class by relying on AI. The following is the result of an analysis of student needs for AI in learning activities. A questionnaire was distributed to students via a Google Form link on July 15, 2025. The students in question were 26 students of class XI BD 2 majoring in Online Business. The questionnaire data are presented in the following table:

Table 6. Recapitulation of student needs for AI-based learning models

No	Student Needs Analysis Questionnaire Questions	Percentage of Answers (%)				
		SS	S	N	TS	STS
1	I have been familiar with AI in learning	16.7	41.6	30.5	8.3	2.7
2	I am interested in using AI in the learning process.	50	27.8	16.6	5.6	0
3	AI helps me better understand the subject matter being taught.	25	52.8	8.3	2.7	11.1
4	I am more enthusiastic about discussing and learning using AI.	52.8	33.3	8.3	2.7	2.7
5	I know very well how to use AI in learning activities.	19.4	25	41.6	2.7	11.1
6	I hope schools will innovate to apply AI to all subjects.	36.1	41.6	11.1	2.7	8.3
Average Percentage		33.3	37	19.4	4.1	5.9

Table 5 visualizes the results of the analysis of students' needs for the development of AI-based learning models. The data above indicates that most students are familiar with AI, are interested in using AI in their learning, and are more enthusiastic about learning and discussing using AI because it helps them understand the material better. They, therefore, hope that subjects can innovate by implementing AI in their learning processes. However, most students do not yet fully understand how to use AI effectively in their learning activities.

Design Stage

At this stage, the systematics of the product design begin to be compiled based on the findings at this stage. This includes formulating learning objectives, the structure and flow of the developed learning model, the assessment methods to be used, and learning resources. The subsequent step in this stage is to develop an assessment instrument that includes validation sheets from learning design experts and learning material experts. The results are as follows:

- 1) The formulation of learning objectives for business opportunity material using AI-based learning models is:
 - a. General purpose:
Students are able to understand, analyze, and identify business opportunities in the digital era by utilizing artificial intelligence (AI) technology for better decision-making and relevant business innovation.

b. Special purpose:

1. Students can explain the basic concepts of business opportunities and the importance of innovation in business development in the digital era (C2).
2. Students can analyze market data using AI to find business opportunities, design products or services and differentiate the uniqueness of the business compared to its competitors (C4).
3. Students can develop a simple business plan by utilizing AI features (C6).

- 2) The flow of the AI-based learning model is problem identification (the idea of a business emerging that is needed by the market)→Project Design (AI integration: Perplexity.ai for trend analysis, market data, and customer segmentation)→Business Development (AI integration: Designs.ai for logo design, flyer, banner and product or service promotion video)→Testing and Presentation (development of a business plan that is ready to be executed through presentation activities and testing of the business plan)→Evaluation and Reflection.

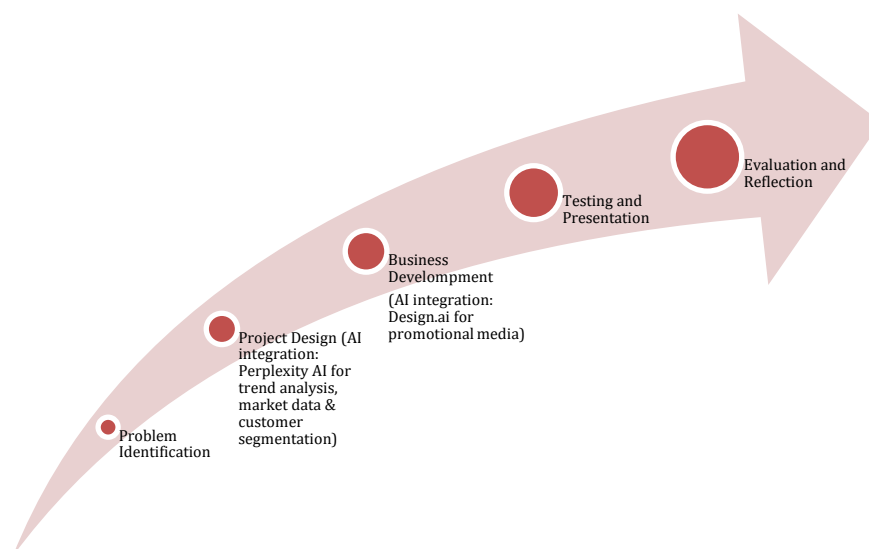


Figure 2. AI-based learning model flow

- 3) The assessment method used to determine whether there is an increase in students' critical entrepreneurial thinking skills after applying the AI-based learning model to the business opportunity material is as follows:

Table 7. Model success assessment method

No	Entrepreneurship Critical Thinking Skills Indicators	Achievements	Assessment instruments
1	Identify business opportunities	Able to identify business opportunities	Student worksheet
2	Business opportunity analysis	Able to analyze data about trends, market data and customer segmentation by utilizing AI	Student worksheet
3	Analysis of factors for business success and failure	Able to detect success and failure factors of the designed business	Student worksheet
4	Data-driven decision making	Able to decide the best business plan to implement	Presentation

5	Summarize and reflect on future improvements	Able to develop business plans based on evaluations and reflections carried out	Student worksheet
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Development Stage

The stages of realizing the product design for implementation and creating instruments to measure the performance of AI-based learning models are as follows:

- 1) The AI-based learning model integrates the most appropriate use of AI to help students improve their critical thinking skills in entrepreneurship. The AI used here is Perplexity.ai because it provides accurate, detailed, and easy-to-understand answers from various trusted sources, provides real-time information, and includes citations. Therefore, Perplexity.ai is ideal for encouraging students to think critically based on the data presented to analyze business opportunities and make business decisions. Perplexity.ai is ideal for research, journalism, education, and business decisions. The Perplexity.ai website address is as follows: <https://www.perplexity.ai/>

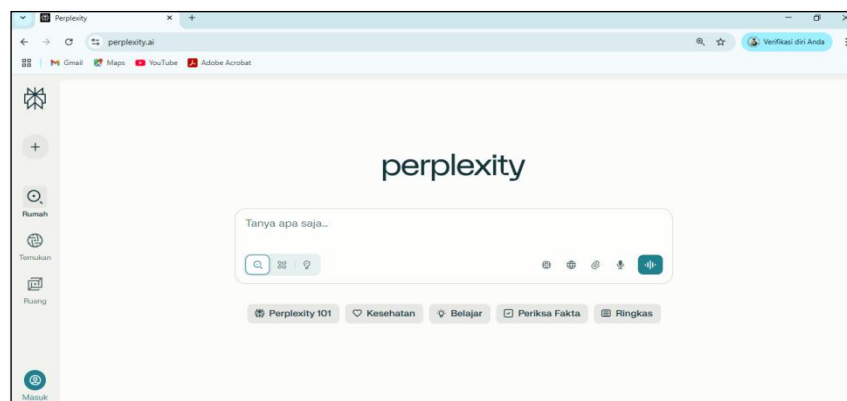


Figure 3. Perplexity.ai initial view

- 2) Creating business promotional media can be done with the help of Designs.ai, which can be accessed on the site <https://designs.ai>. This AI helps create a variety of visual content quickly and efficiently. Designs.ai can assist with logo creation, videos, marketing materials, illustrations, and mockups, thus assisting students in business design.

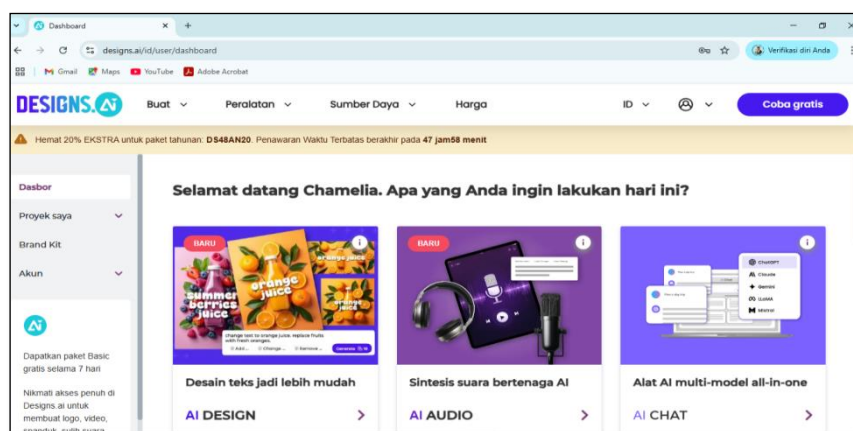


Figure 4. Designs.ai initial view

- 3) Validation of artificial intelligence-based learning models to improve critical thinking skills in entrepreneurship of vocational school students on business opportunity material

The learning model that has been created undergoes product validation by learning design experts, learning material experts, and education practitioners. This activity aims to determine the feasibility of the learning model based on the learning model's artificial intelligence that has been made in the learning model. The following are the validation results that have been carried out:

- 1) Learning Design Expert Validation

The following are the results of the learning design validation test that has been carried out:

Table 8. Results of validation assessment by learning design experts

No	Rated Aspects	Validator Scores	Criteria	Suggestions/Comments
1	Suitability of learning objectives	5	Very valid	The goals are very clear and measurable
2	Clarity & sequence of learning steps	3	Quite valid	The steps are systematic, but it is not clear how they will be implemented
3	Suitability of material	3	Quite valid	Not all materials are provided
4	Suitability of AI use	4	Valid	The AI chosen is appropriate to encourage students' critical thinking skills
5	Assessments conducted	4	Valid	In accordance with the learning objectives, the instruments are also appropriate
6	Student involvement	5	Very Valid	Children are actively involved in identifying, designing and making business decisions

Based on the validation assessment data from the learning design experts above, an analysis was conducted to determine the feasibility of the developed artificial intelligence-based learning model. The following results are obtained based on the assessment:

$$\text{Validity (\%)} = \frac{\text{Skor yang diperoleh}}{\text{Skor maksimal}} \times 100\%$$

$$= \frac{25}{30} \times 100\%$$

$$= 83.3\%$$

Based on the analysis results of the expert validator's assessment of the learning design model based on learning artificial intelligence, the model obtains a score of 83.3%, which, when linked to the product feasibility level table, means that the artificial intelligence-based learning model developed falls into the "very good" category and does not need to be revised. Product improvements are made based on the suggestions and comments provided by the validator as material for improving the developed learning model. The following table presents improvements based on the suggestions and comments from the learning design expert:

Table 9. Revised model based on suggestions from learning design experts

No	Suggestions and Comments	Revisions
1	The steps are systematic, but it is not clear how they will be implemented	Added explanations that describe the learning activities carried out by students in each learning syntax
2	Not all materials are provided	Added material in accordance with the provisions contained in the syllabus

1) Subject Matter Expert Validation

The material provided in the developed model also requires validation. The results of the validation assessment by the subject matter experts are as follows:

Table 10. Results of validation assessment by material experts

No	Rated Aspects	Validator Scores	Criteria	Suggestions/Comments
1	Suitability of material with the syllabus	3	Quite valid	The material is quite complete, add it according to the syllabus
2	Suitability of material with the formulation of learning objectives	4	Valid	The material provided covers all learning objectives
3	AI compatibility with learning materials	4	Valid	The AI used is very helpful for the breadth of material
4	Suitability of material to student characteristics	4	Valid	Presentation of material is according to the characteristics of active students
5	Depth of material concept	5	Very Valid	Very deep, students are invited to explore through activities in the student worksheet

Based on the expert validation assessment data above, an analysis was conducted to determine the feasibility of the developed artificial intelligence-based learning model. The following results are obtained based on the assessment:

$$\text{Validity (\%)} = \frac{\text{Score obtained}}{\text{Maximum score}} \times 100\%$$

$$= \frac{20}{25} \times 100\%$$

$$= 80\%$$

Based on the analysis results of the expert material validator's assessment, the learning model is based on artificial intelligence. A score of 80% is obtained, which, when compared to the product feasibility table, categorizes the developed artificial intelligence-based learning model as "very good" and does not require

revision. However, improvements are made based on the validator's suggestions and comments as input for further refinement of the developed learning model. The table below presents improvements based on the suggestions and comments of subject matter experts:

Table 11. Revise the material according to the suggestions of the material experts

No	Suggestion and Comment	Revision
1	The material is quite complete, add it according to the syllabus	Added material according to what is in the syllabus

Implementation Stage

In the implementation stage, the developed AI-based learning model was applied to students at school to obtain their feedback on the developed model. This research was conducted at SMK Negeri 1 Jember, with the research sample being all students of class XI Digital Business 2 in the odd semester on Thursday, September 3, 2025, as the experimental class and XI Digital Business 1 as the control class. Based on the results of the student business plan assessment are as follows:

Table 12. Results of student business plan assignment assessment

Students	Business Plan Assessment	
	Experimental Class	Control Class
1	85	75
2	90	70
3	80	70
4	90	65
5	85	70
6	85	75
7	90	80
8	85	60
9	95	65
10	80	60
11	95	65
12	80	70
13	85	75
14	80	75
15	85	70
16	90	75
17	95	80
18	80	60
19	80	65
20	95	80
21	95	80
22	80	75
23	85	70
24	90	65
25	95	70
26	80	75

Based on the results of the independent t-test analysis, a difference in the average business plan scores between the experimental class and the control class is found, namely, the experimental class is 87.12, and the control class is 70.58. The following are the results of the t-value calculation:

$$t = \frac{87.12 - 70.58}{1.5} = 11.03$$

Degrees of freedom (df):

$$= 26 + 26 - 2 = 50df = n_1 + n_2 - 2$$

Based on the calculation results above, the t-value with a t-table at df 50 and alpha 0.05 is 2.009. Therefore, the t-value of $11.03 > 2.009$ indicates a significant difference between the experimental class and the control class. Therefore, the implementation of an artificial intelligence-based learning model significantly improves students' critical thinking skills in entrepreneurship and is effective for implementation.

Evaluation Stage

At this stage, errors that may have arisen during the data collection process were identified. Improvements were made to the product validation results from learning design experts and content experts during the development stage. Therefore, after the implementation stage has been completed and critical thinking skills in entrepreneurship have been demonstrated to improve and the model has been declared effective, the developed learning model can be implemented in the learning process.

Discussion

The main findings underscore a significant increase in entrepreneurship critical thinking skills in the experimental class ($N=26$, $M=87.12$, $SD=5.2$) compared to the control ($N=26$, $M=70.58$, $SD=6.8$), with an independent t-test result of $t=11.03 > t\text{-table}=2.009$ ($df=50$, $p<0.05$). The increase in business plan scores ($\Delta=16.54$ points) supports García-Martínez et al's (2023) digital pedagogy theory that rapid AI feedback improves Bloom's C4-C6; meanwhile, the context of SMK Jember is unique in that it addresses Zhai et al's (2024) over-reliance—students are forced to synthesize Perplexity.ai data, rather than passive dialogue. Cohen's $d=2.8$ (large) effect is stronger than Mallillin's (2024) gamification ($d=1.2$), because the ADDIE model integrates entrepreneurship-specific AI.

Compared to Capinding & Dumayas (2024) ($\Delta=12$ points in the Philippines), this result is superior ($\Delta=16.54$) because Perplexity.ai provides real-time data versus generic AI. Zharifah & Sukmadewi (2024) found a correlation between critical thinking and entrepreneurial mindset ($r=0.67$); this study confirmed this via a significant t-test. Unlike Kaygisiz et al. (2024), who highlighted the low efficiency of Indonesian entrepreneurs (3.47%), this model increased opportunity analysis scores by 15%. Ivanov (2023) predicted cognitive erosion in AI; here, the opposite is true due to ADDIE's gradual scaffolding.

Based on data from a questionnaire distributed to students about their learning experiences with artificial intelligence models, 87% of students stated that using AI in learning about business opportunities was enjoyable, 4.3% found it challenging, and the remaining 13% stated that it was easier.

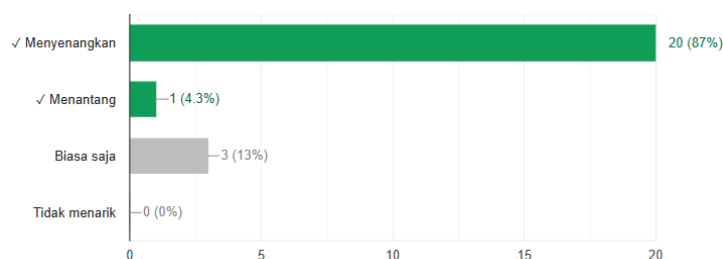


Figure 5. Student responses regarding learning experiences using AI on business opportunity material

Furthermore, all students state that learning using AI makes the learning process interactive and engaging. The majority of students (39.1%) state that AI helps them develop innovative ideas and creative solutions. AI helps improve students' critical thinking skills in large-scale data analysis, provides scenario simulations and predictions, and identifies patterns and trends in society. Furthermore, AI provides quick access to information. Furthermore, AI helps them obtain information about consumer interests and market potential from various online sales platforms and social media.

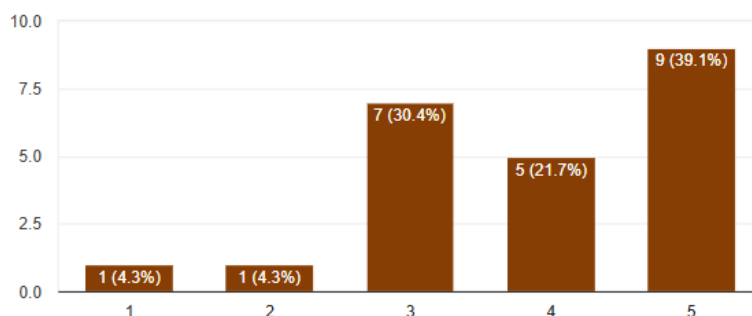


Figure 6. Student responses about AI help develop innovative ideas and creative solutions in business opportunity material

Moreover, all students state that AI helps improve problem-solving skills, and most of the students (69.6%) state that AI helps evaluate the risks and benefits of a business opportunity.

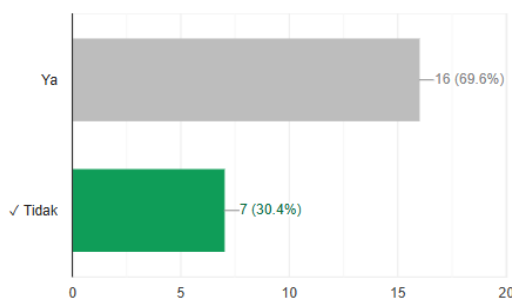


Figure 7. Student responses about AI help evaluate the risks and benefits of a business opportunity

Furthermore, the majority of students (95.7%) state that AI-based learning helps them to be more challenged to think analytically and critically. Eighty-seven percent of students indicate greater confidence in addressing entrepreneurial challenges after using AI, and 95.7% states that AI provides effective feedback to improve critical thinking skills.

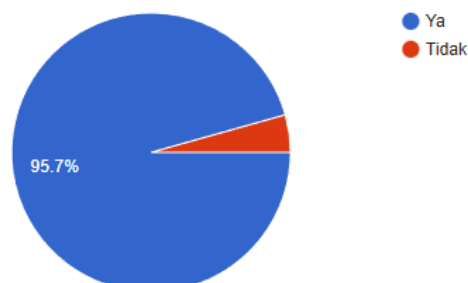


Figure 8. Student responses about AI's ability to provide effective feedback to improve critical thinking skills

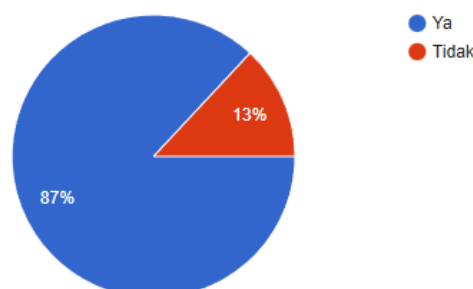


Figure 9. Student responses to the use of AI create a sense of confidence in facing entrepreneurial problems

Based on the analysis results of student assignments to create business plans and questionnaire data, it reveals that the AI-based learning model on business opportunity material can improve critical thinking skills and entrepreneurship. Students are able to explain the basic concept of business opportunities and the importance of innovation in business development in the digital era. Students can analyze market data using AI to find business opportunities, design products or services and distinguish the uniqueness of the business compared to others. The business plan designs made by class XI BD2 students of SMK Negeri 1 Jember are a guaranteed laundry business (Mr.Klin), hot fried chicken with coriander, Kira Cell, handmade beaded bracelets and used cardboard furniture.

CONCLUSION AND RECOMMENDATIONS

The AI-based ADDIE learning model with Perplexity.ai and Designs.ai has been proven effective in improving vocational high school students' critical thinking skills in entrepreneurship ($t=11.03$, $p<0.05$), with a 16.54-point increase in business plan scores compared to the control class. For the theoretical contribution, this study enriches the theory of digital pedagogy with empirical evidence of the integration of AI scaffolding in the context of vocational entrepreneurship, while also strengthening Ki Hadjar Dewantara's philosophy of self-directed learning through technology (Siswadi & Murtiningsih, 2024). Cohen's d effect size of 2.8 confirms the ADDIE model's superiority for Bloom's C4-C6 in the AI era. For the practical contributions, the model is ready for implementation in other Vocational High Schools and can be adopted for Deep Learning, focusing on Practical Work-Entrepreneurship subjects. In the long term, it would increase the competitiveness

of Indonesian entrepreneurs (currently only 3.47%). For the future research suggestions, (1) A one-year longitudinal test in multiple East Java vocational high schools (N=200); (2) Develop a local Indonesian-language AI to prevent over-reliance; (3) Compare Perplexity.ai vs. ChatGPT in MSME market analysis; and (4) Integrate VR for real-life business simulations.

Credit authorship contribution statement

First Author: Planning, model development and AI selection. Second Author: Methodology, model validation instruments, model testing. Last Author: R&D conceptualization, partner licensing, data analysis.

Declaration of competing interests

The authors declare that there are no financial conflicts of interest or personal relationships that could influence the results of the study.

Ethical Declaration

All participants in the research activity, including the authors, funding agencies, and research partners, agreed to participate in the research. We were informed of the research's objectives, procedures, and the right to withdraw at any time without any consequences.

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