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Implementation and Development of Digital Technology-Based Entrepreneurial Skills of Vocational Education Teacher Candidate Students

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Abstract: This study aims to analyze the implementation and development of digital technology-based entrepreneurial skills among prospective vocational education teacher students. Using a mixed method approach with a sequential exploratory design, the study involved 180 students from ten prospective teacher education study programs at the Faculty of Engineering and Industrial Education, Universitas Pendidikan Indonesia. Data were collected through surveys, in-depth interviews, learning observations, and analysis of digital products developed by students. The results of the study indicate that the implementation of digital entrepreneurship learning can improve students' abilities in identifying business opportunities, using digital platforms for business development, and creating innovative technology-based solutions. The main determinants include individual factors such as self-efficacy and experience ($\beta = 0.47$, $p < 0.001$), institutional factors ($\beta = 0.56$, $p < 0.001$), especially technological infrastructure and lecturer competence, and environmental factors ($\beta = 0.41$, $p < 0.01$) such as industry partnerships and stakeholder networks that contribute to the level of quality and innovation of entrepreneurial output. Based on the research findings, the Integrated Digital Entrepreneurship Learning (IDEL) Model has proven effective in developing student abilities. Challenges faced are the digital literacy gap, limited internet access, and lack of curriculum integration. The study recommends the development of an integrated learning model, improving lecturers' digital competence, and strengthening the digital entrepreneurship ecosystem in higher education.

Keywords: digital entrepreneurship; prospective teachers; vocational education; digital technology; learning innovation

Abstrak: Penelitian ini bertujuan menganalisis implementasi dan perkembangan kemampuan kewirausahaan berbasis teknologi digital pada mahasiswa calon guru pendidikan kejuruan. Menggunakan pendekatan mixed method dengan desain sequential exploratory, penelitian melibatkan 180 mahasiswa dari sepuluh program studi pendidikan calon guru Fakultas Pendidikan Teknik dan Industri Universitas Pendidikan Indonesia. Data dikumpulkan melalui survei, wawancara mendalam, observasi pembelajaran, dan analisis produk digital yang dikembangkan mahasiswa. Hasil penelitian menunjukkan bahwa implementasi pembelajaran kewirausahaan digital mampu meningkatkan kemampuan mahasiswa dalam mengidentifikasi peluang bisnis, menggunakan platform digital untuk pengembangan usaha, dan menciptakan solusi inovatif berbasis teknologi. Faktor determinan utama meliputi Faktor individual seperti self-efficacy dan pengalaman ($\beta = 0.47$, $p < 0.001$), faktor institusional ($\beta = 0.56$, $p < 0.001$), khususnya infrastruktur teknologi dan kompetensi dosen, environmental factors ($\beta = 0.41$, $p < 0.01$) seperti industry partnership dan jaringan steakholder berkontribusi terhadap level kualitas dan inovasi dari output kewirausahaan. Berdasarkan temuan penelitian, Integrated Digital Entrepreneurship Learning (IDEL) Model terbukti efektif dalam mengembangkan kemampuan mahasiswa. Tantangan yang dihadapi adalah kesenjangan literasi digital, keterbatasan akses internet, dan kurangnya integrasi kurikulum. Penelitian merekomendasikan pengembangan model pembelajaran terintegrasi, peningkatan kompetensi digital dosen, dan penguatan ekosistem kewirausahaan digital di perguruan tinggi.

Kata kunci: kewirausahaan digital; calon guru; pendidikan kejuruan; teknologi digital; inovasi pembelajaran

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INTRODUCTION

The digital era and the Industrial Revolution 4.0 have fundamentally shifted the paradigm of entrepreneurship. Digital technology is no longer just a tool, but has become the primary foundation for creating value and new business opportunities. In the context of vocational education, integrating entrepreneurial skills with digital technology is an urgent need to prepare prospective teachers capable of facing future challenges.

The growth of the entrepreneurial sector depends heavily on synergy between educational institutions and the business and industrial world. These partnerships should be built on a collaborative entrepreneurship learning framework, enabling relevant entrepreneurship projects to be conducted in knowledge-intensive companies (Secundo et al., 2017). Partnerships should also be based on innovative learning methods, integrating entrepreneurship with the creative economy (Van Horne et al., 2021). Entrepreneurship and innovation education, along with vocational education guidance in China, are two crucial components that must be prioritized simultaneously. This can be achieved by optimizing course content tailored to the unique characteristics of each major, establishing school-based courses on innovation and entrepreneurship guidance, and enhancing integrated education practices (Hou, 2024).

Previous research in vocational education and entrepreneurship requires continued attention to uncover new discoveries. The need for continuous research stems from the rapid pace of change, the diversity of fields within the vocational world, and the rapid development of digital technology. To address these challenges, vocational education needs to adapt quickly to the digital era, particularly in the area of entrepreneurship. Furthermore, graduate efficacy needs to be supported by an integrated system of entrepreneurial and digital technology ecosystems. In African countries, graduates' interest in entrepreneurship is also still low. For example, in Nigeria, most agricultural vocational graduates tend not to establish agricultural businesses but rather seek skills certification to secure paid employment (M. Francis et al., 2019).

The rapid and rapid development of digital technology has significantly impacted the business and education worlds. This influence requires businesses and education to adapt. The

rapid development of digital technology can be a solution or a problem, depending on the readiness of educational institutions and businesses. Numerous studies have been conducted in the fields of education and entrepreneurship, based on metadata information, but when linked to entrepreneurship specifically for vocational education and digital technology, published data remains limited. Therefore, more comprehensive and in-depth research on vocational education and entrepreneurship is needed. Therefore, this study will examine vocational education and entrepreneurship in relation to the development of digital technology for prospective vocational education teachers.

This research will continue the findings of related research such as; topic trends, research developments on entrepreneurship education as seen from institutions, countries, the most productive authors, and an overview of the implementation and development of digital technology-based vocational and entrepreneurship education among prospective vocational teacher students. The importance of digital technology in many sectors of life is increasingly felt, Indonesia's readiness to adopt and explore digital technologies capable of driving transformation in government, educational institutions, business models and community lifestyles is also lacking. This is indicated by data from the 2023 World Digital Competitiveness Ranking, which places Indonesia at 45th out of 63 countries. How to adapt, education and training, the technology ecosystem and information technology integration are issues that need to be addressed so that Indonesia can utilize digital technology advances for economic growth and improving the quality of life.

The latest trending topics related to entrepreneurship education include innovation and entrepreneurship education, innovation and entrepreneurship, and evaluation models. Innovation in education and entrepreneurship, supported by digital technology, has become a necessary culture for any region or country seeking sustainable progress. For example, the Chinese government has made every effort to encourage technological innovation, even elevating it to a national strategic level, and technological innovation has achieved leading international excellence in several fields (M. Zhang & Huang, 2023). In addition to innovation and evaluation models being the latest trend in 2024, there have also been trending topics in previous years such as e-learning, quality control, big data, entrepreneurship education, students, educational computing, adolescents, training, empirical analysis, engineering entrepreneurship, professional aspects, personnel training, ecology, entrepreneurship programs, societies and institutions, social participation, and institutional frameworks (Sultono et al., 2025).

Vocational education plays a strategic role in preparing a competent and ready-to-use workforce. However, the increasingly digitally-driven world of work demands that vocational educators not only master technical competencies but also possess an entrepreneurial spirit that adapts to technological developments. Prospective vocational education teachers need to be equipped with the skills to identify business opportunities, develop innovative solutions, and utilize digital technology in the learning process and business development.

According to data from the Central Statistics Agency (2024), Indonesia's digital economy sector accounts for 8.2% of the national GDP and is predicted to grow to 12% by 2030. This growth creates significant opportunities for the development of digital entrepreneurship, particularly in vocational education and training. However, an initial survey of 500 prospective vocational education students showed that only 32% had a good understanding of digital entrepreneurship, and only 18% had ever developed a digital technology-based product or service.

Furthermore, as prospective vocational education teachers, students are not only required to master digital entrepreneurship skills for themselves, but also to play a strategic role as agents in shaping the entrepreneurial ecosystem within their educational institutions. This dual role makes strengthening digital entrepreneurship competencies even more crucial, as its impact not only on individual readiness but also on their ability to sustainably cultivate a culture of innovation and economic independence within the school environment.

This gap indicates the need for in-depth research on how to implement and develop digital technology-based entrepreneurial skills in prospective vocational education teacher students. This research is crucial for providing a comprehensive overview of existing conditions, identifying influencing factors, and formulating effective development strategies. The general objective of this study is to analyze the implementation and development of digital technology-based entrepreneurial skills in prospective vocational education teacher students.

METHOD

This research employed a mixed methods approach with a sequential exploratory design. This approach was chosen to gain a comprehensive understanding of the complex phenomenon of digital technology-based entrepreneurial implementation and development. The first phase used qualitative methods for in-depth exploration, followed by a quantitative phase for validation and generalization of the findings.

Population, Sample and Informants

Population: All students of vocational education study program at the Faculty of Engineering and Industrial Education, Universitas Pendidikan Indonesia who have taken entrepreneurship courses or courses related to digital technology. The following is an explanation of the number of students in each educational study program, including; Culinary Arts Education 324 people, Automotive Engineering Education 406 people, Industrial Automation and Robotics Engineering Education 217 people, Building Engineering Education 321 people, Agro-industrial Technology Education 257 people, Architectural Engineering Education 267 people, Mechanical Engineering Education 423 people, Fashion Design Education 266 people.

Quantitative sample: 180 students from 8 study programs selected using stratified random sampling.

Table 1. Number of Research Samples Per Education Study Program

No.	Name of Study Program	Sample
1	Culinary Arts Education	22
2	Automotive Engineering Education	23
3	Industrial Automation and Robotics Engineering Education	22
4	Building Engineering Education	23
5	Agro-industrial Technology Education	22
6	Architectural Engineering Education	22
7	Mechanical Engineering Education	23
8	Fashion Design Education	23
Total Sample		**180**

Qualitative: 14 informants selected using purposive sampling, consisting of:

a. 8 prospective vocational education student teachers (semesters 5-8).
b. 4 lecturers teaching entrepreneurship and digital technology courses.
c. 2 digital entrepreneurship practitioners in education.

Data collection technique

Qualitative Data

In-depth interviews: Semi-structured interviews with standardized interview guides, lasting 30-60 minutes per informant, recorded with the informant's consent and transcribed verbatim. Participatory Observation: Observation of digital entrepreneurship learning in class, observation of student activities in using digital technology, notes and photo/video documentation. Document Analysis: Curriculum and syllabus of related courses, digital

products developed by students and reports of student entrepreneurship activities.

Quantitative Data

Survey Instrument: A structured questionnaire with a 5-point Likert scale that measures, a list of measurement scales used in quantitative research to measure various constructs related to digital entrepreneurship, with Cronbach's Alpha (α) reliability values for each scale.

a. Digital Entrepreneurship Intention Scale (α = 0.89).
b. Digital Literacy Competency Scale (α = 0.91).
c. Entrepreneurial Self-Efficacy Scale (α = 0.87).
d. Technology Acceptance Scale (α = 0.85).

Validity and Reliability::

a. Construct validity through Confirmatory Factor Analysis

   Construct validity refers to the extent to which a measurement instrument actually measures its intended theoretical construct. It ensures that observable indicators (questionnaire items) accurately reflect latent constructs that cannot be directly observed.

b. Reliability testing using Cronbach's Alpha

   Reliability testing using Cronbach's Alpha is a statistical method for measuring the internal consistency of a measurement scale or research instrument. Cronbach's Alpha evaluates the extent to which items within a scale consistently measure the same construct.

Data Analysis Techniques

Qualitative Data Analysis

Thematic Analysis:

a. Manual coding using deductive and inductive approaches.
b. Inter-rater reliability with two independent coders (κ = 0.83).
c. Analysis using NVivo 12.

Cohen's Kappa (κ = 0.83)

Formula Cohen's Kappa: $\kappa = (Po - Pe) / (1 - Pe)$

a. Po = observed agreement.
b. Pe = expected agreement by chance.

Interpretation of Kappa Value:

a. κ = 0.83: Almost perfect agreement.

Standard of Interpretation:

a. $\kappa < 0.00$: Poor.
b. $\kappa = 0.00$-0.20: Slight.
c. $\kappa = 0.21$-0.40: Fair.
d. $\kappa = 0.41$-0.60: Moderate.
e. $\kappa = 0.61$-0.80: Substantial.
f. $\kappa = 0.81$-1.00: Almost perfect.

Analysis Steps:

Data analysis was carried out sequentially, including: (1) data transcription and cleaning, (2) initial coding and pattern identification, (3) theme development and refinement, and (4) validation through member checking to ensure the validity of the findings.

Quantitative Data Analysis

The quantitative data analysis in this study involved two main approaches. First, descriptive analysis was conducted by calculating measures of central tendency and variability, as well as frequency distributions for categorical variables. Second, inferential analysis was applied using multiple regression analysis to identify predictive factors, ANOVA to test differences between groups, and Structural Equation Modeling (SEM) for path analysis. All quantitative data analyses were processed using SPSS 26.0 and AMOS 24.0 software.

RESULTS AND DISCUSSION

Result

The State of Students' Digital Entrepreneurship Skills

Student Digital Literacy Profile

The results of a survey of 180 university students revealed significant variation in digital literacy levels. Based on the Digital Literacy Competency Scale, 31% of students had a high level of digital literacy (score 4.0-5.0), 48% had a moderate level (score 3.0-3.9), and 21% had a low level (score <3.0). The findings revealed that although respondents mastered basic digital literacy skills, such as using office applications, internet browsing, and social media ($M = 4.12$, $SD = 0.67$), their understanding of advanced digital skills—such as programming, data analysis, and digital content creation remained relatively low ($M = 2.84$, $SD = 0.91$).

In-depth interviews revealed that students tend to use digital technology for consumption rather than creation. Informant MS-15 stated: "I can use various applications, but if I'm asked to create my own application or website, I'm still confused about where to

start."

Digital Ability to Identify Digital Business Opportunities

Data analysis shows that 84% of students were able to identify digital business opportunities in vocational education after participating in a structured learning program. The most frequently identified opportunities include:

1. Online learning platforms (67% of students),
2. Skill assessment apps (54% of students),
3. Vocational product marketplaces (43% of students),
4. Virtual training simulators (38% of students).

Learning observation results show that students with high exposure to digital technology tend to be more creative in identifying opportunities. They are able to see the gap between industry needs and available technological solutions.

Implementation of Technology in Business Development

Data shows that 78% of students successfully implemented digital technology in the business prototypes they developed. The most commonly used platforms were:

1. Social media marketing (89% of students),
2. E-commerce platforms (67% of students),
3. Digital payment systems (56% of students),
4. Cloud-based collaboration tools (45% of students),
5. Website development (34% of students).

Analysis of the digital products developed by students showed varying levels of innovation. Seventy-one percent of students successfully created innovative solutions that addressed real-world problems in vocational education, albeit with varying levels of technological complexity.

Factors Influencing Ability Development

Individual Factors

Self-Efficacy and Motivation: SEM analysis results show that entrepreneurial self-efficacy has a significant influence on digital entrepreneurship intention ($\beta = 0.47$, $p < 0.001$). Students with high levels of confidence in their entrepreneurial abilities tend to be more active in exploring digital opportunities.

Prior Experience with Technology: Students with prior experience with programming or digital content creation performed better in developing technological solutions ($r = 0.62$, $p < 0.001$). Informant MS-23 explained: "Because I learned coding in high school, it was easier

when asked to create a simple application."

Risk Tolerance: Regression analysis showed that risk tolerance significantly contributed to innovation behavior ($\beta = 0.34$, $p < 0.01$). Students who were willing to take calculated risks were more likely to explore new technologies and develop disruptive business ideas.

Institutional Factors

Technology Infrastructure: The availability of adequate technology infrastructure is a strong predictor of successful implementation ($\beta = 0.56$, $p < 0.001$). Universities with well-equipped computer labs, sufficient internet bandwidth, and adequate software licenses demonstrated higher success rates.

Lecturer Competence: Interviews with lecturers revealed that 67% of lecturers still need to improve their competency in integrating digital technology with entrepreneurship learning. Lecturer DS-04 stated: "I understand the concept of entrepreneurship and also understand technology, but integrating the two in effective learning is still challenging."

Support System: Study programs that have incubators, mentorship programs, and funding support show a higher success rate in producing digital entrepreneurs (73% vs. 45% in study programs without adequate support systems).

Environmental Factors

Industry Partnerships: Collaboration with industry significantly contributes to practical learning experiences ($\beta = 0.41$, $p < 0.01$). Students who have the opportunity to interact with practitioners demonstrate a better understanding of real-world applications.

Peer Networks: Social network analysis revealed that students with diverse peer networks tend to develop more innovative business ideas. Collaboration and knowledge sharing among students accelerate the learning process and enhance creativity.

Model Pengembangan yang Efektif

Integrated Learning Framework

Based on data analysis and identified best practices, this research produced the Integrated Digital Entrepreneurship Learning (IDEL) Model, which consists of five main components:

1. Foundation Building Phase

   The first phase, the Foundation Building Phase, is designed to build a solid competency foundation. This phase includes digital literacy assessments and remediation programs to address skill gaps, an introduction to basic entrepreneurial concepts, an understanding of the current technological landscape, and participation in workshops to

develop an entrepreneurial mindset.

2. Exploration Phase

   In the Exploration Phase, students enter the exploratory phase to identify digital business opportunities. This phase focuses on mastering opportunity identification techniques, technology trend analysis, and market research methods. These techniques are then applied in intensive ideation and brainstorming sessions to generate and validate potential business ideas.

3. Development Phase

   The Development Phase focuses on transforming ideas into tangible products through a continuous process. This phase begins with the development of a prototype using various digital tools, which is then crystallized into a Minimum Viable Product (MVP). This product is then tested with users to gather feedback that forms the basis for an iterative refinement process.

4. Implementation Phase

   The Implementation Phase is the business realization phase, which includes business model validation, digital marketing strategy implementation, technology deployment, and continuous performance measurement to evaluate business sustainability.

5. Scaling Phase

   The Scaling Phase is the final phase, focusing on business escalation through the implementation of growth strategies, integration of more advanced technologies, development of strategic partnerships, and ongoing planning to ensure long-term business sustainability.

Pedagogical Approach

Based on research findings, three learning models have proven effective in improving digital entrepreneurial literacy. First, the implementation of Project-Based Learning with digital integration through authentic projects that simulate a complete entrepreneurial journey with increasing complexity. Second, the Flipped Classroom model optimizes class time by utilizing online resources for theoretical learning, freeing up the focus of face-to-face sessions for practical activities, collaboration, and mentoring. Third, the Peer Learning approach and collaboration within diverse teams with complementary skills have been proven to not only improve learning outcomes but also encourage the creation of innovative solutions.

Assessment Strategy

The assessment in this study was designed based on a competency-based assessment approach to measure students' actual competencies, not just theoretical knowledge. To achieve this goal, a specific assessment rubric was developed to assess key aspects such as creativity, innovation, technical implementation, and business feasibility.

As the primary evaluation instrument, the digital portfolio developed by students serves as a key artifact. This portfolio curates a comprehensive entrepreneurial journey and serves as tangible evidence that records learning outcomes and professional skill development.

The involvement of industry practitioners in the Authentic Assessment system aims to provide external validation and bridge real-world perspectives in assessing student work, thereby enhancing the relevance and credibility of the evaluation process.

Challenges and Barriers

The Digital Divide

Despite being a digital native generation, there is still a significant gap in advanced digital skills. As many as 43% of students experience difficulties using sophisticated digital tools for business development. The rural-urban divide also contributes to disparities in technological access and capabilities.

Curriculum Integration Challenges

Integrating digital entrepreneurship into established curricula faces several significant challenges. The primary challenge stems from a rigid and difficult-to-modify curriculum structure, exacerbated by a lack of interdisciplinary approaches. Furthermore, limited time allocated for experiential or experience-based learning poses a practical obstacle. Furthermore, conventional assessment methods are often not aligned with the competency-based approach needed to measure learning outcomes in digital entrepreneurship.

Resource Constraints

The financial limitations faced include several crucial aspects:

1. Software Licensing Costs: The need for specialized software requires significant licensing costs.
2. Hardware Upgrade Needs: Adequate technological infrastructure requires continuous investment in hardware upgrades.
3. Internet Infrastructure Limitations: The availability of a fast and stable internet connection, the backbone of digital activities, remains a challenge.

4. Limited Funding for Startup Projects: Inadequate funding for start-up capital for student entrepreneurial projects limits the scalability and realization of ideas.

The human resource challenges can be broken down as follows:

1. Shortage of Qualified Instructors: There is a scarcity of qualified instructors with adequate qualifications and expertise in digital entrepreneurship.
2. Need for Professional Development: Existing instructors require ongoing competency development programs to keep pace with the dynamics of digital technology and business.

Critical Success Factors

The cross-case analysis identified the following critical success factors:

1. Industry Mentoring: The existence of a robust mentorship program that directly involves industry practitioners.
2. Iterative Development Process: Implementing an iterative product development process, continuously refined based on user feedback.
3. Access to Resources: Easy access to relevant technology and adequate funding.
4. Institutional Support: Creating an institutional environment that fully supports entrepreneurial initiatives.
5. Market Focus: Formulating a clear value proposition and finding market fit are the primary focus.

Discussion

Heterogeneity in Students' Digital Literacy Levels

This study revealed significant variation in digital literacy levels among university students, with only 31% achieving a high level of digital literacy, while the majority (48%) were at a moderate level and 21% were still in the low category. This distribution indicates that not all students, despite entering higher education in the digital era, possess optimal digital literacy competencies. This disparity aligns with findings by (Laar et al., 2017), which report that digital literacy among the younger generation varies widely, influenced by factors such as differences in access to technology, previous educational background, intensity of technology use, and socioeconomic disparities.

The presence of a segment of students with low digital literacy levels (21%) is of particular concern, considering that they will face difficulties in participating in learning that is increasingly integrated with digital technology. Similar findings were reported by (Ilomäki, L., Kantosalo, A., & Lakkala, 2016) in their cross-cultural research, which showed that

around 20-25% of students in higher education institutions still experience deficiencies in fundamental digital literacy. This condition creates the risk of a digital divide that widens academic and professional inequalities, in line with the theory (Warschauer, M., & Matuchniak, 2010) about how digital literacy functions as a gatekeeper in accessing economic and social opportunities.

Patterns of Consumption Over Production: Implications for Digital Agency and Creativity

In-depth interviews provided a qualitative perspective that enriched our understanding of the behavioral dimensions of students' digital literacy. Data showed that students tended to use digital technology for information consumption and entertainment, rather than for content production or creation. Informant MS-15's statement, "I can use various applications, but if I'm asked to create my own application or website, I still don't know where to start," reflected a self-awareness of their limitations and revealed that the technical expertise needed to create digital solutions was still beyond their capabilities.

This phenomenon reflects what is known in the literature as "passive digital literacy," or a consumer orientation toward technology, a pattern documented by researchers such as (Jenkins, 2006) in his concept of "participatory culture." Jenkins argues that digital literacy should empower individuals not only as consumers but also as content producers and creators of digital solutions. Conversely, the findings of this study indicate that students have not yet utilized digital technology as a medium for active participation in the digital creative economy. All components of the variables social media, entrepreneurship education, and innovation have a significant positive influence on students' entrepreneurial intentions (Harisand et al., 2023).

This dominant consumption pattern aligns with research (Livingstone, 2008) that distinguishes between "access," "skills," and "literacy" as layered dimensions. The students in this study have achieved a fairly good level of access and skills for consumption activities, but remain stagnant at the level of true literacy, which should encompass critical thinking, creative production, and informed participation. This limitation has serious implications for students' career development, especially in a digital economy that increasingly values the ability to create, develop, and implement technology-based solutions, as analyzed by the World Economic Forum (2020) in its report on the Future of Jobs, which emphasized the importance of digital creativity and innovation skills.

Effectiveness of Learning Programs in Improving Identification of Digital Business Opportunities

This study shows that 84% of students were able to identify digital business opportunities in vocational education after participating in a structured learning program. This high success rate indicates the significant effectiveness of the learning program in developing entrepreneurial opportunity recognition skills. This finding aligns with research (Souitaris et al., 2007), which demonstrated that entrepreneurship education programs significantly improve students' ability to recognize and exploit business opportunities. Structured learning programs designed with an experiential learning approach appear effective in facilitating the transition from passive knowledge consumption to active opportunity identification.

This success also aligns with findings (Cope, 2007), which show that entrepreneurial learning involving practical problem-solving and real-world case analysis improves students' opportunity recognition skills. Therefore, educational institutions' investment in designing comprehensive digital entrepreneurship learning programs has been proven to yield measurable positive results. Entrepreneurship education has a significant and beneficial impact on public interest in entrepreneurship (Tannady & Nusantara, 2023).

Mapping Business Opportunities: Convergence between Technology and Vocational Education Needs

Further analysis of the types of opportunities identified by students revealed an interesting pattern. Online learning platforms dominated, with 67% of students identifying them, followed by skills assessment apps (54%), vocational product marketplaces (43%), and virtual training simulators (38%). This distribution reflects a deep understanding of the digital ecosystem of vocational education and the gaps in the market.

The dominance of online learning platforms aligns with global trends in digital education, as analyzed by (Bates, 2015) on the role of technology in educational transformation. The high demand for online learning solutions, particularly in the context of practical vocational education, creates substantial opportunities for digital entrepreneurs. This finding is consistent with a report from the European Commission (2018) that identified edtech as one of the fastest-growing sectors in the digital economy.

The identification of skills assessment apps by 54% of students indicates their understanding of the importance of measurable competency verification in the modern workplace. This aligns with (Kalsbeek, D. H., & Brodie, 2014), who emphasized that employers demand reliable and transparent assessment methods to identify prospective

employees' competencies. Thus, students have identified genuine market needs that have not been fully met by existing solutions.

The Role of Digital Exposure and Creativity in Opportunity Recognition

Learning observations revealed significant findings regarding the relationship between exposure to digital technology and the ability to identify business opportunities. Students with high exposure to digital technology tended to be more creative in identifying opportunities, demonstrating superior ability to see the gap between industry needs and available technological solutions. This pattern reinforces the theoretical framework proposed by (Shane, 2000) regarding entrepreneurial opportunities as the intersection of market needs and technological capabilities.

Creativity is revealed in the opportunity identification process, which explains that alert entrepreneurs are those who are sensitive to market changes and able to see incongruencies between supply and demand. Digital exposure appears to increase entrepreneurial alertness by providing students with broader knowledge of technological possibilities and the competitive landscape.

Temuan ini didukung oleh penelitian (Giones, F., & Brem, 2017) yang menunjukkan bahwa digital transformation competence berhubungan positif dengan opportunity discovery. Mahasiswa dengan exposure tinggi terhadap teknologi tidak hanya familiar dengan tools yang available, tetapi juga memiliki mental models yang lebih sophisticated tentang bagaimana teknologi dapat dikombinasikan untuk menciptakan nilai baru. Mereka dapat melakukan analogical reasoning, mentransfer solusi dari satu domain ke domain lain, capabilities yang essential dalam innovation entrepreneurship.

This finding is supported by research (Giones, F., & Brem, 2017) which shows that digital transformation competence is positively related to opportunity discovery. Students with high exposure to technology are not only familiar with available tools but also possess more sophisticated mental models of how technologies can be combined to create new value. They can perform analogical reasoning, transferring solutions from one domain to another a capability essential in innovation entrepreneurship.

Effectiveness of Learning Programs in Improving the Ability to Identify Digital Business Opportunities

This study shows that 84% of students were able to identify digital business opportunities in vocational education after participating in a structured learning program. This high success rate indicates the significant effectiveness of the learning program in developing

entrepreneurial opportunity recognition skills. This finding aligns with research (Hassan et al., 2020)which demonstrated that entrepreneurship education positively impacts opportunity recognition among students, with a beta coefficient of 0.483. Furthermore, a study by (Rodriguez & Lieber, 2020) showed that students who received entrepreneurship education experienced significant improvements in their entrepreneurial mindset, particularly in communication, collaboration, opportunity recognition, and critical thinking and problem-solving.

Structured learning programs with an experiential learning approach appear effective in facilitating the transition from passive knowledge consumption to active opportunity identification. This is supported by research by Pittaway and (Cope, 2007), which showed that entrepreneurship learning involving practical problem-solving and real-world case analysis substantially improves students' opportunity recognition skills. Therefore, educational institutions' investment in designing comprehensive digital entrepreneurship learning programs has been shown to yield measurable positive results in the context of vocational education.

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Further analysis of the types of opportunities identified by students revealed an interesting pattern. Online learning platforms dominated, with 67% of students identifying them, followed by skills assessment apps (54%), vocational product marketplaces (43%), and virtual training simulators (38%). This distribution reflects a deep understanding of the digital vocational education ecosystem and the gaps in the market.

The dominance of online learning platforms aligns with global trends in digital education, as analyzed by (Bates, 2015) regarding the role of technology in educational transformation. The high demand for online learning solutions, particularly in practical vocational education contexts, creates substantial opportunities for digital entrepreneurs. This confirms the argument (Wright, 2018) that digital platforms, the internet, and mobile technology support the development of new, more accessible and scalable business models.

The identification of skills assessment applications by 54% of students indicates their understanding of the importance of measurable competency verification in the modern workplace. This finding aligns with research (Imjai et al., 2024), which emphasizes that digital literacy enables students to identify specific market needs, particularly related to the assessment and verification of technical competency.

Meanwhile, the identification of vocational product marketplaces (43%) and virtual training simulators (38%) indicates that students focus not only on content delivery platforms but also on the need for a broader ecosystem. Marketplaces can facilitate the exchange of products and services between vocational practitioners, while virtual training simulators address the need for cost-effective and scalable experiential learning, a solution that (Neumeyer et al., 2020), argues is essential for enhancing competitiveness and fostering innovation in vocational education.

The Role of Digital Exposure and Creativity in Opportunity Recognition

Learning observations revealed significant findings regarding the relationship between exposure to digital technology and the ability to identify business opportunities. Students with high exposure to digital technology tended to be more creative in identifying opportunities, demonstrating superior ability to see the gap between industry needs and available technological solutions. This pattern reinforces the theoretical framework of entrepreneurial opportunities as the intersection of market needs and technological capabilities.

The creativity revealed in this opportunity identification process aligns with a meta-analysis by (Hou, 2024), which explains that entrepreneurial creativity produces positive entrepreneurial outcomes, including opportunity recognition, through the mediation mechanism of entrepreneurial alertness. Students with high digital exposure were not only familiar with available tools but also possessed more sophisticated mental models of how technologies can be combined to create new value, a capability that (Park, J. S., Shim, M. S., & Park, 2016), refer to as technological recombination capability.

This finding is supported by empirical research from (Olanrewaju et al., 2020) and (H. Zhang & Chen, 2023), which shows that digital literacy positively influences the recognition of entrepreneurial opportunities because the ability to use social media and online tools facilitates information seeking, gathering, and sharing, which are crucial in the entrepreneurial development process. Digital exposure provides students with broader knowledge of technological possibilities and the competitive landscape, increasing their entrepreneurial awareness of supply-demand mismatches.

Digital Technology Adoption Level in Prototype Development: An Indicator of Entrepreneurial Readiness

This study shows that 78% of students successfully implemented digital technology in the business prototypes they developed, a significant achievement considering the complexity of the digital transformation process in the context of entrepreneurship. This high adoption

rate indicates that the learning program successfully facilitated students' transition from the conceptual stage to the practical implementation stage, a progression that, according to (Davidsson & Recker, 2017) , is a critical milestone in the digital entrepreneurship journey. The ability to implement technology in prototype development demonstrates that students have gone beyond theoretical understanding and achieved the level of practical competence required for venture creation.

This finding aligns with research (Steininger, 2018) which states that digital technology's inherent capacity to manage uncertainty drastically reduces the time and effort required to generate and evaluate ideas, develop opportunities, and create prototypes. Therefore, the students in this study have leveraged digital affordances to accelerate their entrepreneurial process, an essential capability in a competitive digital economy. Furthermore, these results confirm the argument (Nambisan, 2017) that digital technologies enable entrepreneurs to iterate faster, test assumptions more efficiently, and pivot when necessary, characteristics that are hallmarks of successful startups in the digital era.

Digital Platform Adoption Patterns: Marketing and E-Commerce Dominance as Entry Points

Analysis of the types of platforms used reveals a very interesting pattern in technology implementation strategies. Social media marketing dominates, with 89% of students using it, followed by e-commerce platforms (67%), digital payment systems (56%), cloud-based collaboration tools (45%), and website development (34%). This distribution reflects a logical strategic prioritization in digital venture creation, where students start with tools that have low barriers to entry but a high impact on market reach and customer acquisition.

The dominance of social media marketing indicates that digital entrepreneurship education positively influences social media usage for entrepreneurial purposes, with social media serving as a mediator between entrepreneurship education and digital entrepreneurial intention. Furthermore, these findings confirm arguments from research on homemade food startups, which showed that perceived ease of use, perceived usefulness, and interactivity have a significant positive impact on social media marketing adoption, which in turn significantly impacts business performance. With an adoption rate of 89%, students have identified social media as low-hanging fruit that provides maximum reach with minimal investment, a strategic choice that aligns with the resource constraints typically faced by early-stage ventures.

The high adoption of e-commerce platforms (67%) reflects students' understanding of the importance of establishing an online presence and facilitating transactions in the digital economy. This aligns with the global trend where e-commerce has become a fundamental infrastructure for business operations, as analyzed in literature on the role of social media and e-commerce for business entrepreneurship. E-commerce platforms give students the capability to reach broader markets, reduce operational costs, and provide convenient shopping experiences to customers advantages that are particularly important in a vocational education context where products and services often have specialized target markets.

Meanwhile, the adoption of digital payment systems (56%) demonstrates students' awareness of the importance of seamless transaction experiences for customer satisfaction and retention. Digital payment integration not only facilitates convenience but also enhances trust and professionalism in business operations. The use of cloud-based collaboration tools (45%) indicates an understanding of the importance of team coordination and remote work capabilities, aspects that are increasingly important in the modern business environment. The relatively low level of website development (34%) can be explained by its higher complexity and technical requirements compared to other platforms, although websites still represent an important channel for establishing brand credibility and providing comprehensive information to stakeholders.

Innovation Level in Digital Products: From Problem-Solving to Solution Creation

The finding that 71% of students successfully created innovative solutions that address real-world problems in vocational education is a strong indicator of the learning program's effectiveness in developing entrepreneurial creativity and problem-solving capabilities. This figure shows that the majority of students are not simply replicating existing solutions but are actively engaging in innovative thinking to address genuine pain points in the vocational education ecosystem.

The ability to create innovative solutions reflects what (Chang & Chen, 2020) call creative entrepreneurship, where creativity leads to positive entrepreneurial outcomes through opportunity recognition. Students who successfully develop innovative solutions have demonstrated entrepreneurial alertness in identifying gaps, creativity in designing solutions, and technical competence in implementing prototypes. The variation in technological complexity (although 71% created innovative solutions with different levels of technological sophistication) demonstrates that innovation is not only about technical complexity but also about relevance, usability, and problem-solution fit.

This pattern confirms the framework proposed by research on innovation and entrepreneurship education reform in digital media art design majors, which emphasizes that successful innovation requires integration between technological innovation and artistic/pedagogical development. Students in this study demonstrated the ability to balance technological possibilities with practical constraints, creating solutions that are feasible to implement yet innovative enough to provide competitive advantages. This also aligns with (Wright, 2018) concept of digital affordances, which enable entrepreneurs to experiment with new business models and value propositions with relatively low risk and cost.

Integrated Learning Framework: Integrated Digital Entrepreneurship Learning (IDEL) Model

Based on data analysis and best practices identified, this study produced the Integrated Digital Entrepreneurship Learning (IDEL) Model, which consists of five main components designed sequentially and integratively. This model represents a comprehensive approach to digital entrepreneurship education that addresses the fragmented learning often found in conventional programs. This five-stage framework aligns with research (H. Zhang & Chen, 2023)on digital transformation in entrepreneurship education through the conceptual curriculum development framework in TVET, which emphasizes the importance of a process-oriented approach in integrating digital transformation, entrepreneurship education, and curriculum development as a coherent whole.

The first phase, the Foundation Building Phase, is designed to build a solid competency foundation through digital literacy assessments and remediation programs to bridge skill gaps. This phase is crucial because, as identified in previous research, heterogeneity in students' digital literacy levels can be a significant barrier to digital entrepreneurship learning. This approach adopts the competency-based learning principle proposed by the EntreComp framework, where entrepreneurial competency must be understood within an interdisciplinary framework encompassing behavioral, cognitive, and social dimensions. Research by (Park & Kim, 2025) in a systematic literature review on entrepreneurial competencies in the era of digital transformation emphasized that competency must be developed through complex learning experiences that begin with foundational skills such as digital literacy, self-awareness, and self-efficacy.

The Exploration Phase facilitates students in identifying digital business opportunities through mastery of opportunity identification techniques, technology trend analysis, and market research methods. Research (Hassan et al., 2020) demonstrated that entrepreneurship

education positively impacts opportunity recognition, with a beta coefficient of 0.483, indicating that structured learning in the exploration phase has a measurable impact on students' ability to identify business opportunities.

The Implementation Phase is the business realization phase, encompassing business model validation, digital marketing strategy deployment, technology implementation, and continuous performance measurement. This phase translates learning into action, a transition that, according to (Mcdonald & Eisenhardt, 2019), is a critical challenge in digital entrepreneurship because ventures can enter the market with inherently unfinished products that require continuous iteration. Research (Nambisan, 2017) on the digital entrepreneurship perspective emphasizes that the implementation phase must integrate capabilities for managing uncertainty, rapid experimentation, and adapting business models based on real-time market feedback.

The Scaling Phase is the culmination of a learning journey that focuses on business escalation through growth strategy implementation, advanced technology integration, strategic partnership development, and sustainability planning. This phase recognizes that entrepreneurial success is not just about launching ventures but also about sustaining and growing them within competitive landscapes. Research (Ács et al., 2019)on digital and spatial affordances in entrepreneurial ecosystems shows that scaling requires orchestration of various resources, capabilities, and networks that extend beyond individual entrepreneur control, necessitating strategic thinking and an ecosystem-building mindset.

Pedagogical Approach: Integration of Proven Effective Learning Methods

Based on research findings, three learning models have proven effective in improving digital entrepreneurial literacy. First, the implementation of Project-Based Learning (PBL) with digital integration through authentic projects that simulate a complete entrepreneurial journey with increasing complexity. This approach aligns with research (Rahmi, 2025) that introduced the Experiential Learning Model with Digital Literacy (EL-DL) in a quasi-experimental design with 120 Indonesian students, showing significant improvements in opportunity recognition, risk-taking, adaptability, and innovation orientation. PBL provides deep inquiry that leads to rich and powerful understanding through authentic experiences, as confirmed by the Buck Institute for Education's Gold Standards, which emphasize driving questions that engage students with content standards.

Empirical research by (Sulistyowati, R., Sutrisno, B., & Widodo, 2023), on Project-Based Entrepreneurial Learning (PBL) shows that students with high entrepreneurial

characteristics and intentions are more likely to be competent in running startups and operating businesses. The constructivist approach in PBL allows students to actively construct knowledge, using and training their ideas, attitudes, and expertise to understand, make decisions, and complete tasks. Educators function as mentors, instructors, and discussion partners, creating a learning environment that encourages active dialogue and collaborative problem-solving.

Second, the Flipped Classroom model optimizes class time by utilizing online resources for theoretical learning, allowing face-to-face sessions to be allocated for practical activities, collaboration, and mentoring. Research (Aydın, G., & Mutlu, 2023) using a quasi-experimental design with 80 sixth-grade students showed that the Flipped Classroom Model (FCM)-supported PBL achieved significantly higher post-test scores compared to the control group, with superior retention scores. The integration between PBL and Flipped Learning creates productive harmony that allows for authentic learning with students in the driver's seat. The flipped approach enables teachers to employ higher-order learning activities at school, facilitating what practitioners refer to as "real learning" at Bloom's highest levels.

The Four Pillars of Flipped Learning Flexible Environment, Learning Culture, Intentional Content, and Professional Educator provide a framework for implementing this approach effectively. Instructional videos can be viewed at home or used for short "explain time" in class, creating opportunities for collaborative work, peer learning, and hands-on experimentation. Research shows that the flipped approach is particularly effective in entrepreneurship education because theoretical concepts can be absorbed individually at students' own pace, while class time is used to apply concepts in realistic scenarios, receive immediate feedback, and engage in peer critique sessions.

Peer learning creates socially constructed knowledge environments where students learn from each other's diverse knowledge and experiences. In international contexts, online entrepreneurial learning frameworks enable students' engagement in collaborative projects with peers from other countries, expanding their perspectives and cultural competencies. Diversity in team composition in terms of technical skills, creative abilities, business acumen, and domain expertise leads to richer discussions, more comprehensive problem analysis, and more innovative solutions. As highlighted in research on managing change modules, team projects that require unique selling propositions to solve real-world problems with digital technologies revolutionize existing practices and demonstrate integration between entrepreneurship and technology literacy.

Assessment Strategy: Competency-Based Assessment and Authentic Evaluation

The assessment in this study was designed based on a Competency-Based Assessment approach to measure students' actual competencies, not merely theoretical knowledge. This approach aligns with the OECD, which states that entrepreneurship education in digital contexts must foster not only technical competencies such as digital literacy, data analysis, and collaboration, but also attitudinal competencies, including creative thinking, autonomy, and ethical awareness. The paradigm shift from traditional knowledge-based assessment to competency-based evaluation reflects the recognition that entrepreneurial success depends on the ability to apply knowledge in complex, ambiguous situations rather than simply recalling facts.

Assessment rubrics were developed specifically to assess key aspects such as creativity, innovation, technical implementation, and business feasibility. These multi-dimensional rubrics are based on the EntreComp framework, which aligns with Winterton's knowledge-skill-attitude (KSA) model, ensuring a comprehensive evaluation of cognitive, socio-emotional, and technology-based competencies.

As the main evaluation instrument, digital portfolios developed by students serve as key artifacts that curate a complete entrepreneurial journey and serve as tangible evidence of learning achievements and professional skill development. Portfolio-based assessments provide comprehensive and authentic measures of student learning compared to traditional assessments because collecting diverse work samples and reflections over time offers a more complete picture of a student's learning trajectory. Research shows that digital portfolio tools support a structured approach to organizing and tracking student learning, with curriculum tags allowing alignment with specific learning objectives.

Portfolio assessment increases student motivation and engagement because it provides opportunities to reflect on learning and set improvement goals. By reviewing their work and reflecting on the learning process, students identify their progress and areas needing improvement, fostering ownership over learning and developing essential metacognitive skills. (Keinänen et al., 2018) in research about measuring students' innovation competences in higher education emphasizes students that assessment tools must be evaluated in authentic learning environments, where portfolios serve as comprehensive documentation of their entrepreneurial development journey from ideation to implementation.

The involvement of industry practitioners in the Authentic Assessment system aims to provide external validation and bridge real-world perspectives in evaluating student work,

thereby enhancing the relevance and credibility of evaluation processes. Industry involvement ensures that assessment criteria reflect current market demands and employer expectations, increasing graduate employability.

Research on entrepreneurial competencies in the digital transformation era emphasizes that performance evaluation frameworks must be recalibrated to reflect core competencies relevant in the digital age. Emerging competencies such as digital ethics, effective data utilization, and collaborative problem-solving are now foundational, transcending basic technical literacy. The World Economic Forum's Future of Jobs Report 2025 emphasizes that interdisciplinary collaboration, adaptability, and ethical governance will be among the most in-demand skills by 2030, underscoring the need for assessment systems that measure these complex, integrated competencies rather than isolated knowledge domains.

The integration of competency-based assessment, portfolio evaluation, and industry validation creates a robust assessment ecosystem that not only accurately measures learning outcomes but also prepares students for real-world expectations. This three-pronged assessment approach ensures that students develop a deep understanding of entrepreneurial concepts, practical skills for implementing ventures, and the professional dispositions needed to succeed in the competitive digital economy.

CONCLUSION

This study produced several important findings regarding the implementation and development of digital technology-based entrepreneurial skills in prospective vocational education teacher students.

a. Existing Conditions Capability

   Vocational education student teachers demonstrated high potential in developing digital entrepreneurship skills, with 84% able to identify business opportunities and 78% successfully implementing technology in prototype development. However, there was a significant gap in advanced digital skills that impacted the sophistication of the solutions they developed.

b. Determinant Factors

   Individual factors such as self-efficacy and prior experience with technology strongly influence success in digital entrepreneurship. Institutional factors, particularly technological infrastructure and faculty competence, act as significant enablers and barriers. Environmental factors such as industry partnerships and stakeholder networks contribute to the quality and innovation of entrepreneurial output.

c. Effective Learning Model

Based on research findings, the Integrated Digital Entrepreneurship Learning (IDEL) Model has proven effective in developing student skills. This effectiveness is achieved through a combination of sequential learning phases based on a competency-based approach and the application of project-based learning with authentic projects that provide meaningful experiential learning experiences that can be applied in real-world contexts.

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