Development of the Agricultural Competency Learning Design (ACLD-5A): A Conceptual Model of Competency-Based Instructional Design to Support the Transformation of Agricultural Education in the Agriculture 4.0 Era

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ABSTRACT

The transformation of the agricultural sector toward the Agriculture 4.0 era has significantly increased the demand for a workforce equipped with digital competencies, adaptability, and skills aligned with technological advancements and the evolving needs of industry. Although various instructional design models, Competency-Based Education (CBE), and Outcome-Based Education (OBE) have been widely adopted in educational settings, there remains a lack of an integrated instructional framework that comprehensively combines industry competency requirements, digital transformation, authentic learning, competency-based assessment, and continuous competency development within the context of agricultural education. Addressing this gap, this study proposes the Agricultural Competency Learning Design (ACLD-5A) as a conceptual competency-based instructional framework to support human capital development in the Agriculture 4.0 era.

This study employed a conceptual paper approach by conducting a critical synthesis of the literature on instructional design, Competency-Based Education, Outcome-Based Education, constructive alignment, Agriculture 4.0, and human competency development. The analysis involved identifying research gaps, comparing existing instructional design models, and integrating key theoretical concepts into a novel conceptual framework.

The study resulted in the development of the ACLD-5A framework, which comprises five interconnected phases: Analyze, Align, Apply, Assess, and Advance. The framework systematically links industry competency needs analysis with curriculum alignment, authentic learning implementation, competency-based assessment, and lifelong learning within a continuous competency development cycle. Unlike existing instructional design models, ACLD-5A explicitly integrates industry-driven competency analysis, constructive alignment, authentic learning, competency-based assessment, and lifelong learning into a unified framework specifically designed for Agriculture 4.0. Theoretically, this study extends the instructional design literature by integrating the

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perspectives of CBE, OBE, and Agriculture 4.0 into a coherent competency development framework. Practically, ACLD-5A provides a strategic reference for higher education institutions, agricultural training providers, and policymakers in designing curricula, instructional strategies, and assessment systems that are responsive to digital transformation and the evolving demands of the agricultural sector. Future studies are encouraged to empirically validate the proposed framework across diverse agricultural education and training contexts using quantitative, qualitative, or mixed-method research designs.

Keywords: *Agricultural Competency Learning Design (ACLD-5A); Agriculture 4.0; Competency-Based Education; Instructional Design; Outcome-Based Education; Agricultural Education.*

I. INTRODUCTION

The global transformation of food systems, rapid advances in digital technologies, climate change, and the growing demand for sustainable agricultural development have fundamentally reshaped the competency requirements of the agricultural workforce. Modern agriculture is no longer viewed as a production activity relying primarily on empirical knowledge and manual labor; rather, it has evolved into a knowledge-based agricultural system that integrates Artificial Intelligence (AI), the Internet of Things (IoT), big data analytics, robotics, cloud computing, Geographic Information Systems (GIS), smart sensors, and precision agriculture technologies to enhance productivity, efficiency, resilience, and sustainability across agrifood systems (FAO, 2022; OECD, 2023; Javaid et al., 2023). This paradigm shift has positioned human capital as a critical determinant of agricultural transformation in the era of Agriculture 4.0.

For Indonesia, these global challenges are compounded by persistent structural issues, including an aging farming population, limited adoption of digital technologies, workforce competency gaps, and increasing pressure to strengthen national food security. Recent Agricultural Census data indicate that Indonesian agriculture continues to be dominated by older farmers, while the proportion of young farmers remains relatively low, highlighting a significant challenge in agricultural workforce regeneration (BPS, 2023). These demographic issues are further intensified by climate change, land degradation, volatile food markets, and the growing demand for professionals capable of operating digital agricultural technologies. At the same time, Indonesia is entering a demographic dividend period that presents substantial opportunities to strengthen national competitiveness, provided that this demographic potential is transformed into a digitally competent, innovative, and adaptive agricultural workforce (Bappenas, 2023; FAO, 2023).

These challenges suggest that agricultural modernization requires more than investments in infrastructure, mechanization, and technological innovation. Equally important is the transformation of agricultural education and training systems to produce graduates whose competencies correspond to the evolving requirements of industry and the digital economy. International organizations consistently emphasize that successful digital transformation depends on educational institutions' ability to cultivate digital competencies, critical thinking, creativity, collaboration, problem-solving skills, and lifelong learning capabilities that prepare graduates for rapidly changing work environments (UNESCO, 2021; OECD, 2023; World Economic Forum, 2023).

Within this context, instructional design plays a strategic role in bridging the gap between educational practices and industry competency requirements. Over the past three decades, several instructional design models—including ADDIE (Branch, 2009), Dick and Carey (Dick et al., 2015), the Kemp Model (Morrison et al., 2019), and Backward Design (Wiggins & McTighe, 2005)—have been widely adopted because they provide systematic procedures for designing effective learning experiences. Likewise, Competency-Based Education (CBE) and Outcome-Based Education (OBE) have shifted educational practice toward measurable competency achievement and learner-centered outcomes (Harden, 2007; Gervais, 2016).

Despite their significant contributions, existing instructional design frameworks have generally been developed as generic educational models and have not explicitly addressed the emerging competency demands associated with digital agricultural transformation. Most frameworks emphasize instructional processes, curriculum planning, or learning outcomes, while paying limited attention to integrating industry competency analysis, Agriculture 4.0 technologies, authentic learning, competency-based assessment, and continuous professional development into a unified instructional framework. Consequently, a persistent mismatch remains between graduate competencies and the workforce requirements of modern agriculture, as evidenced by studies on vocational education, digital transformation, and agricultural skills development.

The literature also reveals considerable fragmentation. Some studies focus primarily on implementing Competency-Based Education without systematically integrating instructional design principles. Others emphasize technological innovations such as smart farming, precision agriculture, artificial intelligence, or IoT while overlooking the pedagogical mechanisms required to develop the competencies needed to utilize these technologies effectively. Conversely, instructional design research has largely evolved within general education contexts and rarely considers the distinctive characteristics of agricultural vocational education, which requires the integration of classroom instruction, experiential learning, field practice, industry collaboration, professional certification, and lifelong learning. These limitations reveal a significant research gap, namely the absence of a comprehensive instructional framework that simultaneously integrates instructional design theory, CBE, OBE, Agriculture 4.0 competency requirements, digital transformation, and authentic learning strategies within a coherent conceptual model.

Beyond this research gap, a notable knowledge gap also exists. Current literature predominantly conceptualizes competency as an educational outcome rather than explaining the instructional mechanisms through which competencies are systematically developed. Although numerous studies identify the competencies required for Agriculture 4.0, considerably less attention has been devoted to explaining how educational systems should be designed to cultivate these competencies through the integration of industry needs analysis, curriculum alignment, authentic learning experiences, competency-based assessment, and continuous professional development. Consequently, the question is no longer what competencies are needed, but rather how educational systems should be designed to develop those competencies effectively.

Responding to these gaps, this study addresses the following conceptual research question:

How can a competency-based instructional framework be designed to integrate industry competency requirements, digital transformation, authentic learning, and continuous competency development to prepare an adaptive agricultural workforce for the Agriculture 4.0 era?

To answer this question, the study develops the Agricultural Competency Learning Design (ACLD-5A) framework, a conceptual instructional design model consisting of five interconnected phases: Analyze, Align, Apply, Assess, and Advance. The framework is developed through a critical synthesis of instructional design theories, Competency-Based Education, Outcome-Based Education, constructive alignment, human capital development, and Agriculture 4.0 literature.

The novelty of this study lies in proposing ACLD-5A as an integrated competency development framework rather than merely adapting existing instructional design models. Specifically, ACLD-5A incorporates five dimensions that have largely been addressed separately in previous studies: (1) industry-driven competency needs analysis as the starting point of instructional design; (2) curriculum alignment based on the principles of constructive alignment; (3) authentic learning through project-based learning, digital technologies, and industry engagement; (4) competency-based authentic assessment; and (5) continuous competency development through lifelong learning. By integrating these dimensions into a single conceptual framework, ACLD-5A offers a more contextually relevant instructional design for agricultural education and training than existing generic models.

This study contributes to both theory and practice. Theoretically, it extends the instructional design literature by integrating perspectives from instructional design, Competency-Based Education, Outcome-Based Education, constructive alignment, and Agriculture 4.0 into a unified competency development framework tailored to agricultural education. Practically, ACLD-5A provides a strategic reference for universities, agricultural polytechnics, vocational training centers, extension institutions, and policymakers in designing curricula, instructional strategies, assessment systems, and human capital development programs that are responsive to digital transformation, industry expectations, and sustainable agricultural development.

Unlike existing instructional design models that primarily emphasize instructional processes or learning outcomes, ACLD-5A introduces an integrated competency development framework that explicitly connects industry competency analysis, curriculum alignment, authentic learning, competency-based assessment, and lifelong learning within the context of Agriculture 4.0.

II. LITERATURE REVIEW

2.1 Instructional Design in the Era of Digital Transformation

Instructional design refers to a systematic process of planning, developing, implementing, and evaluating learning experiences to enable learners to achieve predefined competencies effectively, efficiently, and measurably. Since its emergence in the 1970s, instructional design has evolved into a well-established discipline that provides structured frameworks for aligning learning objectives, instructional strategies, learning resources, assessment methods, and evaluation within an integrated educational system (Branch, 2009; Dick et al., 2015).

The rapid advancement of digital technologies has fundamentally reshaped the philosophy and practice of instructional design. Traditional teacher-centered approaches have gradually shifted toward learner-centered, experiential, collaborative, and technology-enhanced learning environments. Contemporary instructional systems extend beyond conventional classrooms by incorporating online learning platforms, virtual simulations, digital laboratories, artificial intelligence (AI), learning analytics, adaptive learning systems, and data-driven educational ecosystems (Bond et al., 2024; Zawacki-Richter & Qayyum, 2023). These developments require instructional design to become increasingly flexible, personalized, and responsive to rapidly changing technological and workforce demands.

Consequently, instructional design should no longer be viewed merely as a process for organizing instructional content. Instead, it has become a strategic mechanism for developing competencies that are relevant to digital transformation and the future of work. Recent studies emphasize that effective instructional design should integrate digital technologies, authentic learning experiences, collaborative learning, and competency development to prepare graduates with the knowledge, skills, and adaptability required in the twenty-first century.

Despite these advances, most existing instructional design models remain generic in nature and were not specifically developed to address the unique characteristics of agricultural education. Agricultural education requires the integration of classroom instruction, experiential field practice, industry engagement, digital agriculture technologies, and competency certification within a coherent instructional framework. Existing models provide systematic instructional procedures but offer limited guidance on integrating these contextual dimensions into competency development for Agriculture 4.0. This limitation highlights the need for a more context-specific instructional framework tailored to the transformation of agricultural education.

2.2 Competency-Based Education and Outcome-Based Education

The digital transformation of industries has accelerated the transition from content-oriented education toward Competency-Based Education (CBE), where educational success is determined by learners' demonstrated mastery of competencies rather than by instructional time or course completion (Gervais, 2016). CBE emphasizes measurable competencies that reflect learners' ability to apply knowledge, skills, and professional attitudes in authentic contexts.

This paradigm has been further strengthened through Outcome-Based Education (OBE), which positions learning outcomes as the foundation for curriculum design, instructional activities, and assessment practices (Harden, 2007). Guided by the principle of constructive alignment, OBE ensures consistency among intended learning outcomes, learning experiences, teaching strategies, and assessment methods so that graduates achieve competencies aligned with professional and industry expectations (Biggs & Tang, 2011)

Previous studies have demonstrated that CBE and OBE enhance graduate employability and improve alignment between higher education and labor market demands across various professional disciplines. Nevertheless, their implementation has predominantly focused on defining learning outcomes and competency assessment, while considerably less attention has been devoted to explaining how authentic learning experiences should be systematically designed to cultivate those competencies. Furthermore, digital competencies, project-based learning, industry collaboration, and lifelong competency development are rarely incorporated as integral components within existing CBE and OBE frameworks.

These limitations suggest the need for an instructional framework that extends beyond competency attainment by explicitly connecting industry competency requirements, curriculum alignment, authentic learning experiences, competency-based assessment, and lifelong learning into a coherent competency development process.

2.3 Competency Framework for Agriculture 4.0

The emergence of Agriculture 4.0 has substantially transformed the competency profile required of agricultural professionals. Beyond conventional technical expertise in crop production and farm management, contemporary agricultural practitioners are increasingly expected to possess digital literacy, data analytics capabilities, innovation management skills, entrepreneurial competencies, environmental sustainability awareness, and the ability to operate within digitally connected agricultural ecosystems.

International organizations, including the Food and Agriculture Organization (FAO), the Organisation for Economic Co-operation and Development (OECD), UNESCO, and the World Economic Forum (WEF), consistently argue that future agricultural workforce development should integrate three complementary competency domains: technical competencies, twenty-first-century competencies, and digital competencies. The integration of these competency domains enables professionals not only to operate advanced agricultural technologies such as artificial intelligence, precision agriculture, IoT, robotics, and geographic information systems but also to foster innovation, resilience, and sustainable agricultural development.

Although competency frameworks for Agriculture 4.0 have received increasing scholarly attention, most studies conceptualize competencies as collections of knowledge and skills expected from graduates rather than examining the instructional processes through which such competencies are systematically developed. Consequently, limited theoretical attention has been given to connecting competency frameworks with instructional design models capable of translating competency requirements into coherent educational practices. This unresolved issue highlights an important conceptual gap and underscores the necessity of developing an integrated instructional framework that explicitly links industry competency requirements, curriculum design, authentic learning, competency-based assessment, and continuous professional development within the context of agricultural education.

2.4 Synthesis of Previous Studies

Tabel 1

Research Gap Matrix

Author	Focus	Main Findings	Limitation	Gap Addressed by This Study
Branch (2009)	ADDIE	Systematic instructional design	Generic across disciplines	No agriculture-specific competency integration
Dick et al. (2015)	Systems approach	Alignment of instructional components	Limited industry orientation	Does not incorporate Agriculture 4.0 competencies

Harden (2007)	OBE	Outcome-oriented curriculum	Focuses mainly on learning outcomes	Lacks authentic learning implementation
Gervais (2016)	Competency-Based Education	Competency mastery	Limited instructional design perspective	No integrated learning framework
Klerkx et al. (2019)	Digital agriculture	Competency implications of Agriculture 4.0	Does not propose pedagogical model	Missing instructional design model
Javaid et al. (2023)	AI in agriculture	Emerging digital competencies	Technology-oriented	Learning process not discussed
UNESCO (2021)	Future education	Lifelong learning	Generic educational framework	Agriculture context absent
OECD (2023)	Skills Outlook	Future workforce skills	Macro-level analysis	No instructional implementation
FAO (2022)	Agricultural transformation	Human capital importance	Policy orientation	No learning design framework
This Study	ACLD-5A	Integrated competency-based instructional design	–	Integrates Instructional Design, CBE, OBE, Industry Needs, and Agriculture 4.0

Tabel 2

Comparison of Existing Instructional Design Models and ACLD-5A

Model	**Industry-driven**	**Competency-based**	**Authentic Learning**	**Digital Agriculture**	**Lifelong Learning**	**Agriculture-specific**
ADDIE	✗	Partial	Partial	✗	✗	✗

Dick & Carey	Partial	Partial	Partial	✗	✗	✗
Kemp	Partial	Partial	Partial	✗	✗	✗
Backward Design	Partial	✓	Partial	✗	✗	✗
CBE	✓	✓	Partial	✗	Partial	✗
OBE	✓	✓	Partial	✗	Partial	✗
ACLD-5A	✓	✓	✓	✓	✓	✓

III. METHODS

This study adopts a conceptual paper approach to develop the Agricultural Competency Learning Design (ACLD-5A) framework as a competency-based instructional design model for supporting agricultural education and training in the era of Agriculture 4.0. Unlike empirical studies that examine relationships among variables using primary data, conceptual papers aim to generate new theoretical insights through the critical synthesis and integration of existing knowledge, resulting in the development of a coherent conceptual framework (Jabareen, 2009; Torraco, 2016).

The development of the ACLD-5A framework followed a five-stage conceptual development process. The first stage involved problem identification and research gap analysis, focusing on contemporary challenges in agricultural human capital development and the limitations of existing instructional design models in addressing the competency demands of Agriculture 4.0. The second stage comprised a systematic literature exploration covering instructional design, Competency-Based Education (CBE), Outcome-Based Education (OBE), constructive alignment, Agriculture 4.0, digital competencies, and lifelong learning. The literature was drawn from peer-reviewed international journal articles, academic books, reports published by international organizations, and policy documents, with emphasis placed on publications released between 2020 and 2025, while seminal works were retained to provide theoretical foundations.

The third stage consisted of conceptual analysis, in which theories and prior studies were critically compared and synthesized to identify the essential components of a competency-based instructional framework. The fourth stage involved the construction of the ACLD-5A conceptual framework, resulting in five interconnected phases: Analyze, Align, Apply, Assess, and Advance. The final stage comprised theoretical validation, whereby the proposed framework was systematically compared with established instructional design models—including ADDIE, Dick and

Carey, the Kemp Model, Backward Design, CBE, and OBE—to evaluate its conceptual coherence, internal consistency, and theoretical contribution.

Data were analyzed using a critical integrative literature analysis approach, which involved identifying, comparing, synthesizing, and integrating key concepts from diverse scholarly sources into a unified conceptual framework. The findings are presented through a Research Gap Matrix, a comparative analysis of existing instructional design models, and the proposed ACLD-5A framework as the principal theoretical contribution of this study. As the framework has been developed conceptually, future research is recommended to empirically validate its effectiveness and applicability across different contexts of agricultural education and training using qualitative, quantitative, or mixed-method research designs.e.

IV. RESULTS

The literature analysis indicates that competency-based instructional design has evolved through various approaches, including ADDIE, Dick and Carey, the Kemp Model, Backward Design, Competency-Based Education (CBE), and Outcome-Based Education (OBE). These frameworks have made substantial contributions to improving educational quality by providing systematic, structured, and outcome-oriented approaches to curriculum planning, instructional delivery, assessment, and evaluation.

However, the critical synthesis of the literature reveals four major gaps.

First, most instructional design models have been developed as generic educational frameworks and do not explicitly address the unique characteristics of the agricultural sector, which is undergoing rapid transformation due to digitalization and the emergence of Agriculture 4.0.

Second, CBE and OBE primarily emphasize competency achievement as an educational outcome, but provide limited explanation regarding how instructional processes should be designed to facilitate authentic competency development through industry-based learning experiences.

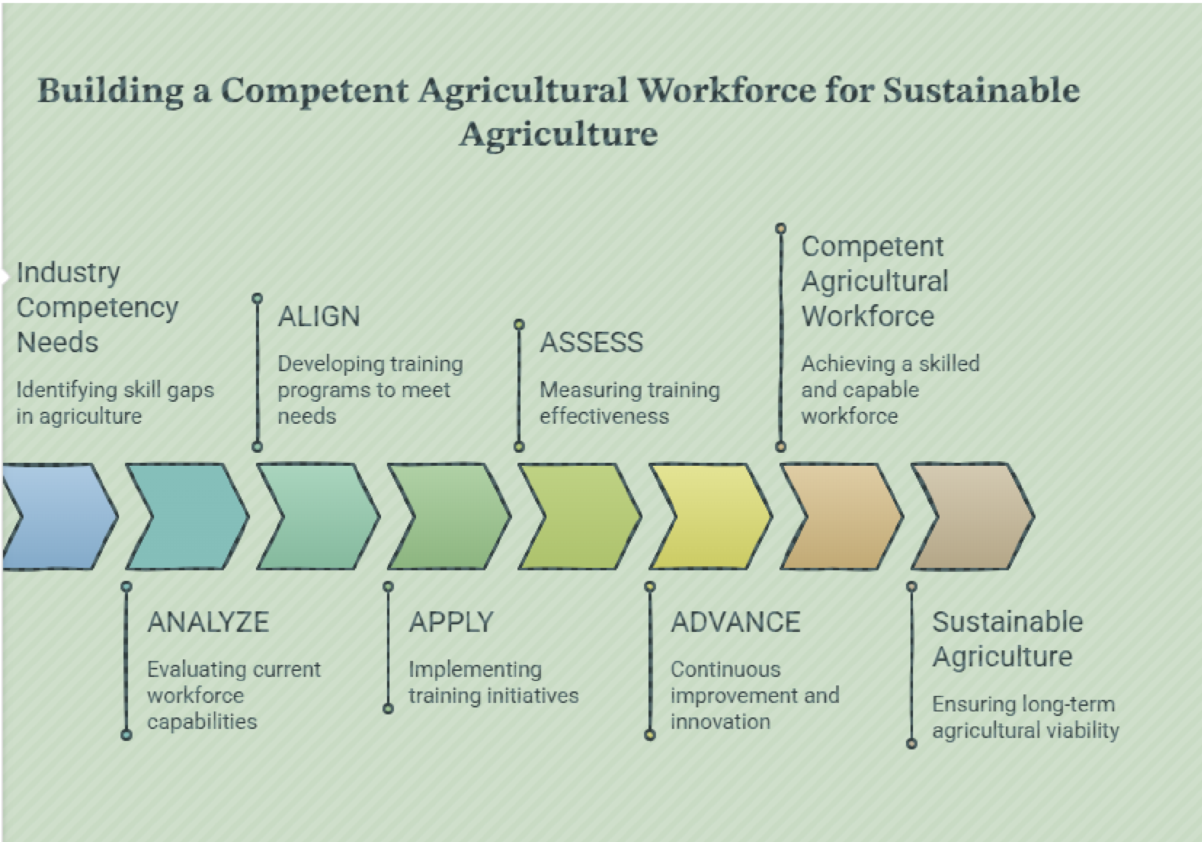
Third, the literature on smart farming, artificial intelligence, the Internet of Things (IoT), drones, and precision agriculture largely focuses on technological innovation rather than the pedagogical strategies required to prepare a workforce capable of effectively utilizing these technologies.

Fourth, no existing model has been identified that explicitly integrates industry competency needs analysis, curriculum alignment, authentic learning, competency-based assessment, and continuous competency development within a single comprehensive instructional framework.

These findings demonstrate that significant conceptual space remains for the development of an instructional design framework capable of bridging the gap between the competency requirements of modern agriculture and educational practice. In response to these gaps, this study proposes the Agricultural Competency Learning Design (ACLD-5A) framework as an integrated conceptual model that combines instructional design principles, Competency-Based Education, Outcome-Based Education, and the competency demands of Agriculture 4.0..

Picture 1

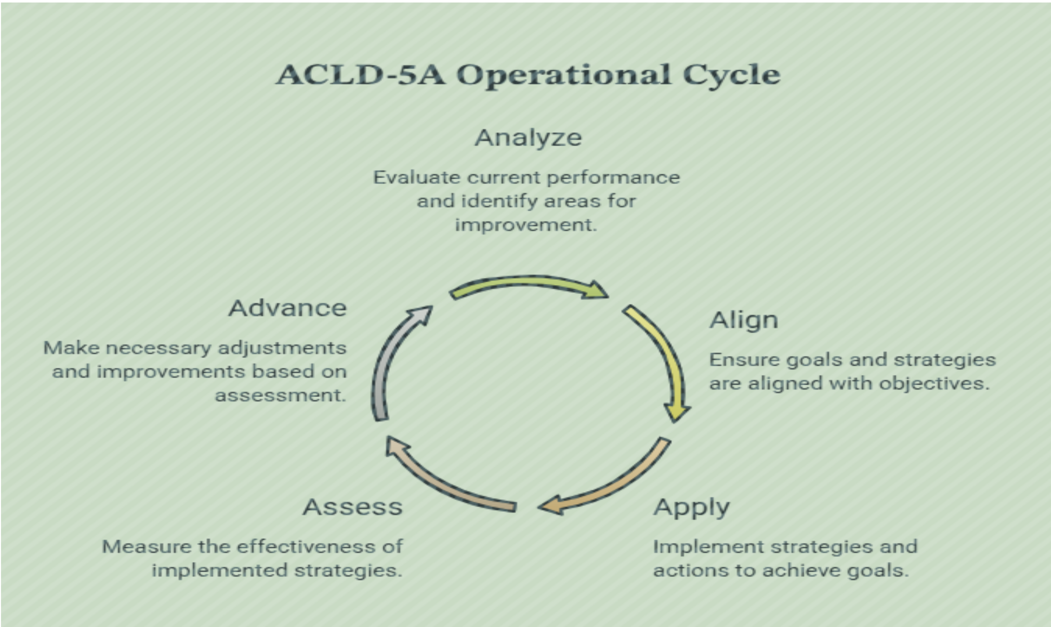
Conceptual Framework of ACLD-5A



Tabel 4

Operational Characteristics of ACLD-5A

Phase	Learning Activities	Digital Technology	Assessment
Analyze	Industry survey	Labour analytics	Competency mapping
Align	Curriculum design	LMS	Curriculum validation
Apply	Project-based learning	IoT, AI, Drone	Performance assessment
Assess	Portfolio	e-Assessment	Competency certification
Advance	Upskilling	MOOC, Microcredential	Professional development



This diagram confirms that ACLD-5A is a competency development cycle (continuous improvement), not a linear process that ends with evaluation.

4.3 Theoretical Contributions

This study makes several important theoretical contributions to the literature on instructional design, Competency-Based Education (CBE), and agricultural education in the context of Agriculture 4.0.

First, it introduces the Agricultural Competency Learning Design (ACLD-5A) framework, an integrated conceptual model that synthesizes instructional design theory, Outcome-Based Education (OBE), Competency-Based Education (CBE), constructive alignment, and the emerging paradigm of digital agricultural transformation into a unified competency development framework. Unlike conventional instructional design models, which primarily focus on instructional processes or learning outcomes, ACLD-5A positions industry competency needs analysis as the starting point for curriculum development and instructional planning. This shift establishes a stronger alignment between educational practices and the competency requirements of the modern agricultural workforce.

Second, this study extends the scope of instructional design by reconceptualizing it as a competency ecosystem rather than a linear instructional process. Instead of viewing learning as a sequence that concludes with assessment, ACLD-5A conceptualizes competency development as a continuous and iterative cycle consisting of five interconnected phases: Analyze, Align, Apply, Assess, and Advance. The inclusion of the Advance phase represents the framework's principal theoretical innovation by embedding lifelong learning, upskilling, and reskilling as integral components of instructional design rather than post-educational activities.

Third, ACLD-5A bridges several streams of literature that have traditionally evolved independently. Existing research on instructional design, digital competencies, authentic learning, and industry collaboration has generally been discussed in isolation. By integrating these perspectives within a single conceptual framework, ACLD-5A advances instructional design theory while simultaneously enriching scholarship on vocational education, workforce development, and human capital development for digitally transformed agricultural systems.

4.4 Practical Contributions

From a practical perspective, ACLD-5A provides an implementation framework that can assist agricultural education and training institutions in designing curricula, instructional strategies, and assessment systems that are more responsive to technological change and industry expectations.

For universities and agricultural polytechnics, the framework offers systematic guidance for aligning graduate learning outcomes with the competencies demanded by modern agriculture, including digital literacy, entrepreneurship, sustainability, innovation, and data-driven decision-making. The Analyze phase enables institutions to conduct periodic competency mapping based on labor market trends and stakeholder expectations, thereby facilitating continuous curriculum improvement.

For agricultural training centers, extension institutions, and human resource development agencies, ACLD-5A supports the integration of project-based learning, experiential field practice, industry internships, competency certification, and emerging digital technologies such as the Internet of Things (IoT), artificial intelligence, Geographic Information Systems (GIS), smart sensors, and precision agriculture. Such integration is expected to improve graduate employability while strengthening collaboration between educational institutions and industry partners.

Furthermore, the Advance phase provides a strategic foundation for developing microcredential programs, continuing professional development, upskilling, and reskilling initiatives, ensuring that competency development continues throughout individuals' professional careers rather than ending with formal education.

4.5 Policy Implications

The findings of this study have several implications for strengthening agricultural education and training as part of broader agricultural transformation policies.

The ACLD-5A framework demonstrates that improving agricultural human capital requires more than curriculum revision. Effective competency development depends on the systematic integration of industry competency analysis, curriculum alignment, authentic learning, competency-based assessment, and continuous professional development within an integrated educational ecosystem.

For the Ministry of Agriculture and other government agencies responsible for agricultural education and workforce development, ACLD-5A provides a conceptual reference for developing national competency standards, competency-based vocational curricula, industry-oriented training programs, and stronger partnerships among higher education institutions, training providers, extension services, and agricultural industries. The framework's emphasis on digital technologies also supports national strategies for accelerating smart farming adoption, strengthening agricultural innovation ecosystems, and promoting digital transformation across the agrifood sector.

More broadly, the implementation of ACLD-5A contributes to several strategic national and global priorities, including food security, digital agricultural transformation, human capital competitiveness, the Sustainable Development Goals (particularly SDGs 2, 4, 8, and 9), and Indonesia Emas 2045, which recognizes high-quality human resources as the cornerstone of sustainable national development.

4.6 Limitations

Despite its contributions, this study has several limitations that should be acknowledged.

First, as a conceptual paper, ACLD-5A was developed through theoretical synthesis and has not yet been empirically validated within agricultural education and training contexts. Consequently, its effectiveness in improving learner competencies remains to be examined through empirical investigation.

Second, the framework is primarily grounded in literature related to instructional design, competency-based education, and digital transformation. Although these perspectives provide a robust theoretical foundation, the framework has not yet been evaluated across the diverse institutional contexts that characterize agricultural education systems. Therefore, its applicability may vary depending on institutional characteristics and educational settings.

Third, this study does not explicitly examine contextual factors such as organizational culture, institutional readiness, digital infrastructure, faculty competencies, resource availability, or policy support, all of which may influence the successful implementation of ACLD-5A. These contextual variables should be incorporated into future empirical studies to provide a more comprehensive understanding of the framework's implementation and effectiveness.

4.7 Future Research

Future research should focus on empirically validating the ACLD-5A framework using multiple methodological approaches.

One promising direction is the application of Design-Based Research (DBR) to evaluate the implementation of ACLD-5A in authentic educational settings while iteratively refining the framework through stakeholder feedback and practical experience.

Quantitative studies employing Structural Equation Modeling (SEM) or Partial Least Squares Structural Equation Modeling (PLS-SEM) are also recommended to examine the relationships among the five ACLD-5A components and their influence on competency development, learning performance, graduate employability, and workforce readiness. In addition, experimental or quasi-experimental studies could compare ACLD-5A with established instructional design models, such as ADDIE or Backward Design, to assess its effectiveness in enhancing digital competencies, problem-solving skills, and professional preparedness.

Future studies may also extend the application of ACLD-5A across diverse educational contexts, including vocational schools, universities, agricultural extension training, non-formal education, and microcredential programs. Furthermore, adapting the framework to related sectors such as fisheries, livestock, forestry, and agro-industry would provide valuable evidence regarding its flexibility, scalability, and transferability in supporting competency development across the broader agricultural and bioeconomy sectors.

V. CONCLUSION AND SUGGESTION

The transition toward Agriculture 4.0 requires a fundamental transformation in agricultural human capital development through education and training systems capable of producing graduates with competencies that are responsive to technological advancement, industry demands, and sustainable development challenges. The critical synthesis conducted in this study demonstrates that established instructional design models—including ADDIE, Dick and Carey, the Kemp Model, Backward Design, Competency-Based Education (CBE), and Outcome-Based Education (OBE)—provide robust foundations for designing effective learning experiences. Nevertheless, these frameworks have not fully integrated the competency requirements of modern agriculture, digital transformation, authentic learning, competency-based assessment, and continuous professional development into a comprehensive instructional framework.

To address this conceptual gap, this study proposes the Agricultural Competency Learning Design (ACLD-5A) framework, which consists of five interconnected phases: Analyze, Align, Apply, Assess, and Advance. The framework begins with industry competency needs analysis and systematically connects curriculum alignment, authentic learning, competency-based assessment, and lifelong learning within a continuous competency development cycle. Consequently, ACLD-5A extends beyond a conventional instructional design model by functioning as an integrated competency development framework that strengthens the linkage between educational institutions, industry partners, and the evolving competency requirements of Agriculture 4.0.

The primary theoretical contribution of this study lies in integrating instructional design theory, Competency-Based Education, Outcome-Based Education, constructive alignment, and Agriculture 4.0 competency requirements into a coherent conceptual framework. This integration broadens the scope of instructional design from a process-oriented perspective toward a competency ecosystem that emphasizes continuous human capital development. From a practical perspective, ACLD-5A offers a strategic reference for universities, agricultural polytechnics, training centers, extension institutions, and policymakers in designing curricula, instructional strategies, assessment systems, and competency development programs that are aligned with technological innovation and labor market demands.

Although ACLD-5A provides a comprehensive conceptual framework, it has not yet been empirically validated. Accordingly, future studies should examine its validity, effectiveness, and applicability through Design-Based Research (DBR), experimental or quasi-experimental studies, and quantitative approaches such as Structural Equation Modeling (SEM) or Partial Least Squares Structural Equation Modeling (PLS-SEM). Empirical validation across diverse educational contexts will be essential to determine the framework's effectiveness in enhancing learner competencies and workforce readiness within the agricultural sector.

Overall, ACLD-5A offers a novel perspective on competency-based instructional design by explicitly integrating industry competency needs analysis, curriculum alignment, authentic learning, competency-based assessment, and lifelong learning into a unified conceptual framework. By bridging instructional design theory with the competency demands of Agriculture 4.0, the framework contributes to the advancement of agricultural education and training while providing a foundation for strengthening workforce competitiveness, accelerating digital agricultural transformation, supporting sustainable food systems, and advancing the broader goals of sustainable development and Indonesia Emas 2045..

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