

Future AI Competency and Skill-Gap Analysis for Strengthening AI Talent Development in Undergraduate Education

Kanda Sorn-In¹, Manussawee Nokkaew¹, Chayada Surawanitkun¹,
Satit Kravenkit², and Nongram Mueanrit^{1†}, Non-members

ABSTRACT

This study introduces an integrated analytical framework to identify essential AI competencies and diagnose skill gaps critical for future AI workforce development. Evidence was synthesized from five sources: international competency standards, stakeholder requirements, national AI and digital policies, labor-market intelligence derived from text mining, and global future-skills trends. The analysis produced an AI Master Competency Taxonomy comprising 50 competencies across four domains: Knowledge Foundations, AI Literacy, Ethics & Responsible AI, and Career & Innovation Skills. The findings reveal urgent gaps in data storytelling, AI-driven innovation, version control, data engineering, ETL pipeline development, cloud ML deployment, AI product design, AI-driven prototyping, API integration, and pre-trained AI model usage. These results indicate that undergraduate AI curricula should place stronger emphasis on applied AI engineering, workflow-based development, responsible AI awareness, and industry-aligned innovation skills. The proposed taxonomy provides evidence-based guidance for designing future-ready AI curricula that support workforce readiness, national strategic priorities, and responsible AI development.

Keywords: AI Competency, Skill Gap Analysis, Text Mining, Labor-Market Intelligence, Undergraduate Curriculum

1. INTRODUCTION

The rapid expansion of Artificial Intelligence (AI) is reshaping workforce demands and increasing the need for new competencies across sectors. International frameworks emphasize technical AI proficiency, data

literacy, ethical reasoning, and human-centered innovation as essential capabilities for future professionals [1], [2], [3]. Higher education therefore needs to realign undergraduate curricula with emerging AI workforce requirements.

Despite growing AI adoption, persistent gaps remain between academic training and industry needs. Global evidence, including the World Economic Forum's *Future of Jobs Report 2023*, indicates rising demand for machine learning operations (MLOps), large language model (LLM) engineering, cloud-based AI pipelines, and responsible AI governance, while these competencies remain underrepresented in many undergraduate programs [4], [5].

Thailand's national policy context further reinforces this need. The National AI Strategy and Action Plan (2022–2027) identifies human capital development, responsible AI, digital infrastructure, and workforce competitiveness as key priorities [6]. These priorities align with the Digital Economy and Society Development Plan, the 20-Year National Strategy (2018–2037), and international AI governance principles emphasizing transparency, accountability, and inclusiveness [7], [8], [9], [10], [11].

Academic literature also indicates that universities often lack systematic mechanisms for integrating labor-market intelligence, national policy imperatives, stakeholder expectations, and global AI trends into curriculum planning. Students may receive strong theoretical foundations but limited exposure to industry workflows, cloud-based AI deployment, ethical AI practices, LLM engineering, prompt engineering, and AI governance [12], [13], [14]. This gap is also consistent with Thailand's Digital Manpower Development Framework, which reports that AI capabilities remain underdeveloped across the national workforce [15].

Strengthening AI talent development therefore requires a comprehensive, multi-source approach to competency synthesis. This study integrates global standards, national strategies, stakeholder perspectives, labor-market analytics, and future-skill forecasts to support evidence-based undergraduate AI curriculum design. Accordingly, this study aims to:

1. Integrate and synthesize AI competencies across multiple evidence sources and
2. Analyze skill gaps to support the development

Manuscript received on December 26, 2025; revised on February 5, 2026; accepted on May 26, 2026. This paper was recommended by Associate Editor Chanon Warisarn.

¹The authors are with Center of Multidisciplinary Innovation Network Talent (MINT Center), Faculty of Interdisciplinary Studies, Khon Kaen University, Nong Khai Campus, Nong Khai, Thailand.

²The author is with Department of Computer Science, College of Computing, Khon Kaen University, Khon Kaen, Thailand.

[†]Corresponding author: nongmu@kku.ac.th

©2026 Author(s). This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License. To view a copy of this license visit: <https://creativecommons.org/licenses/by-nc-nd/4.0/>.

Digital Object Identifier: 10.37936/ecti-ec.2026243.262993

of a future-oriented undergraduate curriculum that strengthens AI talent pipelines in alignment with workforce demands, national strategies, and ethical AI principles.

2. LITERATURE REVIEW

2.1 Global AI Competency Frameworks

The ACM/IEEE/AAAI Computing Curricula 2023 (CS2023) provides undergraduate computing guidelines covering algorithms, machine learning workflows, data analysis, human-centered computing, and AI ethics [1]. UNESCO's Artificial Intelligence Competency Framework emphasizes digital literacy, societal impact, ethical AI development, and responsible innovation [2]. The OECD AI skills framework further highlights computational thinking, socio-technical understanding, and data-driven reasoning as essential workforce capabilities [3].

Recent AI literacy studies extend these frameworks by emphasizing generative AI, multimodal AI, ethical AI education, and equitable AI literacy development [16], [17], [18], [19]. However, existing frameworks remain limited in connecting technical, ethical, and innovation competencies with empirical labor-market demands and industry expectations.

2.2 National AI Policies and Strategic Directions

Thailand's National AI Strategy (2022–2027) prioritizes human capital development, responsible AI adoption, and digital readiness [6]. These priorities align with broader national agendas on digital literacy, ethical AI, innovation-driven workforce development, and long-term economic competitiveness [7], [8], [9]. International and regional frameworks, including UNESCO, OECD, and the ASEAN Digital Masterplan 2025, further emphasize transparency, accountability, trustworthy AI, workforce preparedness, and responsible technological advancement [10], [11], [20].

Although these policy frameworks define strategic priorities, they provide limited guidance on how such priorities can be translated into a unified undergraduate AI competency structure.

2.3 Stakeholder Needs in AI Education

Recent workforce and education studies indicate increasing demand for applied AI competencies, including MLOps, cloud-based AI architectures, data engineering, advanced machine learning, LLM engineering, and prompt engineering [11], [12], [13], [14]. Cross-sector workforce analyses also emphasise hybrid technical, adaptive, creative, and human-centred capabilities for AI-enabled work environments [21], [22].

These findings suggest that undergraduate AI education should move beyond conceptual AI knowledge and provide stronger exposure to industry-grade AI workflows, ethical AI practices, and applied AI development.

2.4 Labor-Market Intelligence and AI Skill Trends

Labor-market text-mining approaches using TF-IDF, Named Entity Recognition (NER), and clustering have been used to identify high-demand AI skills such as ML pipelines, Python, cloud-based AI platforms, and data engineering [14], [23]. Global AI workforce studies also report rising demand for LLM engineering, responsible-AI specialists, human-centered AI design, MLOps, model deployment, and workflow-oriented AI engineering [11], [12], [24]. These studies confirm the value of labor-market analytics for identifying current and emerging AI competency needs, but their findings are often not fully integrated into curriculum-level competency models.

2.5 WEF Future Skills and Global Trends

The World Economic Forum identifies AI literacy, analytical reasoning, creativity, and digital adaptability as important future workforce competencies [4], [13]. These priorities align with recent AI-skills literature emphasizing higher-order thinking, multimodal AI capabilities, and generative-AI literacy for responsible and future-aligned education [17].

2.6 Research Gap and Synthesis

Existing literature provides insights into global competency frameworks, national AI policies, stakeholder expectations, and labor-market trends, yet these dimensions are typically examined in isolation. Studies on AI literacy, generative-AI skills, and higher-education readiness similarly emphasize fragmented perspectives rather than integrated analyses [16], [17], [21]. Limited prior research has systematically consolidated international frameworks, national strategies, stakeholder needs, labor-market intelligence, and WEF future-skill forecasts into a unified competency structure. This study addresses this gap by synthesizing multi-source evidence into a coherent AI competency model and skill-gap analysis to inform undergraduate curriculum design.

3. RESEARCH METHODOLOGY

3.1 Research Design

This study employed a multi-source mixed-methods design to synthesize AI competencies and identify skill gaps for undergraduate curriculum development. Five evidence sources were analyzed: international competency frameworks, stakeholder requirements, national AI and digital policies, labor-market intelligence, and global future-skills trends. The extracted competencies were mapped into four domains: (1) Knowledge Foundations, (2) AI Literacy, (3) Ethics & Responsible AI, and (4) Career & Innovation Skills.

This design enabled triangulation across policy documents, academic frameworks, stakeholder perspectives, and labor-market data, ensuring that the resulting taxonomy reflected global standards, national priorities, workforce expectations, and emerging AI trends.

Table 1: Summary of Multi-Source Data and Analytical Methods.

Data Source	Description	Method Used	Output
International Competency Frameworks (CS2023, UNESCO 2024, OECD 2022)	Global AI standards covering technical, ethical, and future-skill competencies	Document analysis, competency coding, domain alignment	Initial competency clusters mapped to four core domains
Stakeholder Requirements (n = 353)	High-school students, CS undergraduates, faculty members, and industry professionals	Survey analysis, descriptive statistics, thematic coding	Importance ratings, readiness gaps, and priority competencies
National AI & Digital Policies	National strategies for AI governance, ethics, human capital, and digital economy	Policy review, thematic extraction	Policy-aligned competency requirements
Labor-Market Intelligence (LinkedIn, JobsDB, JobThai)	Industry AI skill demands from job advertisements	TF-IDF, Named Entity Recognition (NER), clustering analysis	Industry-required competencies and emerging roles mapped to four domains
WEF Future Skills & Global Trends	Future workforce capabilities related to AI literacy, analytical reasoning, creativity, and digital adaptability	Comparative analysis, thematic mapping	Future-skill indicators integrated into competency taxonomy

3.2 Multi-Source Data Foundations Aligned with Four Core Domains

Evidence from five data sources was systematically examined through document analysis, thematic coding, policy analysis, and quantitative text mining. The extracted evidence was then aligned with four core domains: Knowledge Foundations, AI Literacy, Ethics & Responsible AI, and Career & Innovation Skills. Table 1 summarises the data sources, analytical methods, and resulting outputs.

3.2.1 International Competency Frameworks

Three global competency frameworks were reviewed: ACM/IEEE/AAAI CS2023, UNESCO's AI Competency Framework (2024), and OECD's Artificial Intelligence and the Future of Skills [1], [2], [3]. Document analysis and competency coding were applied to extract domain-aligned AI competencies.

3.2.2 Stakeholder Requirements

Stakeholder needs were collected from 353 respondents representing high school students, computer science undergraduates, alumni, faculty members, employers, and industry professionals. The responses were analyzed using descriptive statistics and thematic coding to identify perceived importance, readiness gaps, and priority competencies.

3.2.3 National AI & Digital Policies

Thailand's National AI Strategy, the Digital Economy and Society Development Plan, the 20-Year National Strategy, and the Thirteenth National Economic and Social Development Plan were reviewed to extract policy-aligned AI and digital workforce competencies [6], [7], [8], [9].

3.2.4 Labor-Market Intelligence (Text Mining)

AI-related job postings from LinkedIn, JobsDB, and JobThai were analyzed using TF-IDF, Named Entity Recognition (NER), and K-Means clustering. The extracted skill terms, tools, platforms, and role clusters were mapped into the four competency domains [14], [23].

3.2.5 World Economic Forum Future Trends

The WEF Future of Jobs Report 2023 and related global skill-trend evidence were analyzed to identify future-oriented competencies, particularly AI literacy, analytical reasoning, creativity, and digital adaptability [4], [13].

3.3 Qualitative and Quantitative Integration

Qualitative evidence from policy documents, competency frameworks, and stakeholder responses was integrated with quantitative labor-market signals using matrix merging and cross-source triangulation, following convergence procedures commonly applied in AI competency and workforce-skill analysis [12], [13], [14]. TF-IDF feature extraction, Named Entity Recognition (NER), and K-Means clustering were used to identify skill patterns from job-market data, while thematic coding was used to synthesize policy, framework, and stakeholder inputs.

The integrated convergence matrix enabled systematic comparison across evidence sources and provided the basis for competency synthesis. This process reduced reliance on a single data source and strengthened the validity of the AI Master Competency Taxonomy.

3.4 Competency Mapping and Synthesis into Four Domains

Table 2 presents representative examples of competency mapping across the four domains. Competencies from the five evidence sources were consolidated through duplicate removal, synonym resolution, and hierarchical alignment. Open coding grouped semantically related skills, while axial coding mapped them into Knowledge Foundations, AI Literacy, Ethics & Responsible AI, and Career & Innovation Skills [12]. The mapped evidence was then synthesised into a unified competency taxonomy.

3.5 Skill Gap Analysis

Table 3 summarizes the skill-gap categories, definitions, competency examples, and evidence sources used

Table 2: Competency Mapping Across the Four Core Domains.

Domain	Sample Competencies	Evidence Source(s)
Knowledge Foundations	Python programming, data preprocessing, machine learning algorithms, database systems	CS2023, Labor-market data
AI Literacy	Model interpretation, LLM literacy, cloud AI usage, NLP fundamentals	UNESCO 2024, WEF skills, Job postings
Ethics & Responsible AI	Fairness, transparency, explainability, privacy, responsible AI governance	UNESCO Ethical AI, OECD AI skills, National policies
Career & Innovation Skills	Teamwork, problem-solving, communication, innovation planning, AI project prototyping	Stakeholder survey, Industry trends

Table 3: Skill Gap Analysis and Example Competencies.

Gap Category	Definition	Example Competencies	Evidence Source
Missing Skills	Required by industry but absent in the curriculum	MLOps, Model deployment, Cloud ML pipelines	Job postings, Industry stakeholders
Emerging Skills	Increasingly important for the future workforce	LLM engineering, Prompt engineering, Generative AI literacy	WEF 2023, Labor-market trends
Over-Taught Skills	Overused relative to workforce needs	Basic coding drills, Classical ML theory (without practice)	Stakeholder survey, Expert validation
Sustainability-Oriented Skills	Support ethical, inclusive, responsible AI	Fairness, Digital citizenship, Responsible AI governance	UNESCO, OECD, and National policies

for taxonomy-based classification.

Skill gaps were evaluated using a weighted analytical model combining four evidence dimensions: industry demand, stakeholder importance, future significance, and policy alignment. Competencies were triangulated across all data sources and classified into the four gap categories to identify high-priority curriculum enhancement areas.

3.6 Output Integration: Master Competency Taxonomy and Skill Gap Matrix

The analytical workflow produced two outputs: the AI Master Competency Taxonomy and the Skill Gap Matrix. The taxonomy was constructed through competency extraction, normalisation, and domain mapping across the five evidence sources, resulting in 50 competencies across Knowledge Foundations, AI Literacy, Ethics & Responsible AI, and Career & Innovation Skills.

The Skill Gap Matrix was generated using weighted indicators of labor-market demand, stakeholder importance, future-skill relevance, and policy alignment. It identified urgent competencies requiring curriculum at-

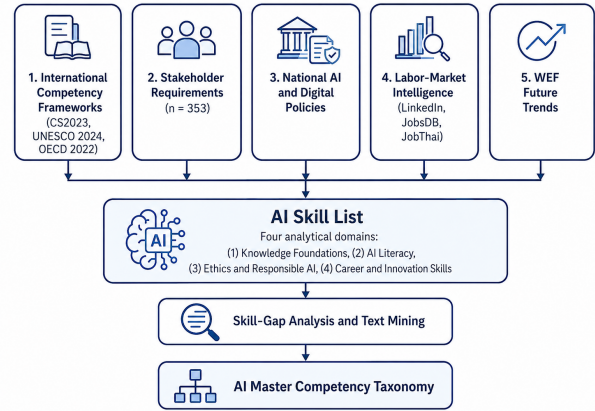


Fig. 1: Conceptual Framework for Multi-Source AI Competency Synthesis and Skill-Gap Integration.

tention, including ETL pipelines, cloud ML deployment, data engineering, AI prototyping, pre-trained model usage, basic NLP/CV, and API integration.

3.7 Conceptual Framework

To clarify the overall analytical workflow, a conceptual framework was developed to show how multi-source evidence was transformed into competency and skill-gap outputs. Fig. 1 presents the framework, which integrates five evidence streams: international standards, national policies, stakeholder needs, labor-market intelligence, and future-skill trends. These inputs are processed through thematic analysis, text mining, competency mapping, normalization, and skill-gap analysis to generate the AI Master Competency Taxonomy and curriculum design recommendations.

The final output supports sustainable undergraduate AI curriculum design by linking competency synthesis with workforce readiness, ethical governance, and future-oriented AI talent development.

4. RESULTS

4.1 Survey Findings: Stakeholder Competency Needs

Across four stakeholder groups, including high school students, computer science undergraduates, alumni, and industry representatives, the findings show consistent demand for data-driven competencies, AI-engineering skills, and applied AI capabilities.

1. Employer Needs: Employers reported the highest demand for practical and applied competencies, including Database Systems (4.56), Data Analysis (4.47), ETL / Power BI / Dashboard / Power Query (4.42), Artificial Intelligence (4.31), Data Science (4.31), Machine Learning (4.20), and Data Mining (4.16). These results indicate strong labor-market demand for data engineering, AI engineering, and analytics-oriented skills.

Table 4: Knowledge Foundations Domain.

Knowledge Foundations Domain	
Skill name	Alignment Level
Programming Fundamentals	High
Data Structures & Algorithms	High
Database Systems (SQL, MySQL)	High
Statistics & Probability	High
Data Analytics	High
Machine Learning (ML) Fundamentals	High
Big Data Concepts	High
Cloud Computing Basics	High
Cybersecurity Foundations	High
Distributed Systems Basics	Medium

Table 5: AI Literacy Domain.

AI Literacy Domain	
Skill name	Alignment Level
Understanding AI Workflows	High
Data-driven Decision Making	High
AI Tools Usage	High
Big Data Literacy	High
Understanding AI Limitations	High
AI Application in Business	High
Basic Natural Language Processing (NLP) Concepts	High
Basic Computer Vision Concepts	High
Using Pre-trained AI Models	High
Model Interpretation	Medium

- Student Perspectives: Students expressed strong interest in Artificial Intelligence (62%), AI & Robotics (43.7%), Data Science (40.8%), Data and Database competencies (54.9%), and Data Analysis & Decision-Making (57.7%). These findings reflect high learner interest in AI-related career pathways.
- Alumni Perspectives: Alumni identified Data Analytics (88.1%), Big Data (54.2%), Machine Learning (47.5%), Business Intelligence (45.8%), and Data Representation (35.6%) as the most relevant competencies in their workplaces. These results confirm the importance of practical, industry-ready skills for graduate performance.
- Ethical and Responsible AI Awareness: Awareness and perceived importance of Responsible AI, AI Governance, and Ethical AI remained relatively low across all groups, despite their increasing importance in international and national AI governance frameworks [2], [6], and [10]. This gap indicates the need to strengthen responsible AI content in the curriculum.

Overall, stakeholder findings indicate that curriculum enhancement should prioritize applied AI engineering, data analytics, cloud AI, industry workflow skills, and responsible AI awareness.

Table 6: Ethics & Responsible AI Domain.

Ethics & Responsible AI Domain	
Skill name	Alignment Level
Ethical Use of AI	High
Data Privacy & Security	High
Bias & Fairness Awareness	High
AI Governance Concepts	High
Responsible Data Handling	High
AI Risk Assessment	High
Explainable AI Principles	Medium
Academic Integrity	Medium
Professional Ethics	Medium
Transparency in AI	Medium

Table 7: Career & Innovation Skills Domain.

Career & Innovation Skills Domain	
Skill name	Alignment Level
ML Model Development	High
Data Engineering Skills	High
Extract, Transform, and Load (ETL) Pipeline Skills	High
Business Intelligence Skills	High
Cloud ML Deployment	High
AI Product Design	High
Creative Problem Solving	High
Teamwork	High
Technical Communication	High
AI-driven Prototyping	High
Data Storytelling	High
AI-driven Innovation	High
Project Management for AI Projects	High
Software Development Lifecycle	High
Agile & Scrum for AI Projects	High
Using Version Control (Git)	High
API Integration for AI Solutions	High
UX/UI Principles for AI Products	High
Critical Thinking	High
Continuous Learning	High

4.2 AI Skill List

The AI competency structure consists of 50 synthesized skills organized into four domains: Knowledge Foundations, AI Literacy, Ethics & Responsible AI, and Career & Innovation Skills. These domains represent key areas required for undergraduate AI education, covering foundational computing, AI application literacy, responsible AI, and career-oriented innovation skills.

The skills were derived from international AI frameworks [1], [2], [3], national AI policy priorities [6], labor-market intelligence, stakeholder ratings, and WEF future-skill indicators [4], ensuring alignment with academic standards and workforce expectations.

Tables 4–7 summarize the consolidated taxonomy and show the relative priority level of each competency as high or medium.

Table 8: Market Demand Summary.

Domain	Avg Market Demand	Priority
Career & Innovation Skills	2.2	High
Knowledge Foundations	2.1	Medium-High
AI Literacy	1.9	Medium
Ethics & Responsible AI	1.1	Low

4.3 Skill Gap Analysis Findings

AI competencies extracted from all evidence sources were normalized through duplicate removal, synonym resolution, and hierarchical mapping. A weighted scoring model was then applied using three indicators: (1) labor-market frequency, (2) stakeholder importance, and (3) national policy relevance.

4.3.1 Market Demand Analysis

Job-market analysis indicates the highest demand for AI engineering, data pipelines, cloud deployment, API integration, and AI-driven prototyping.

Foundational competencies, including programming, machine learning fundamentals, database systems, and data analytics, also remain consistently required across job postings.

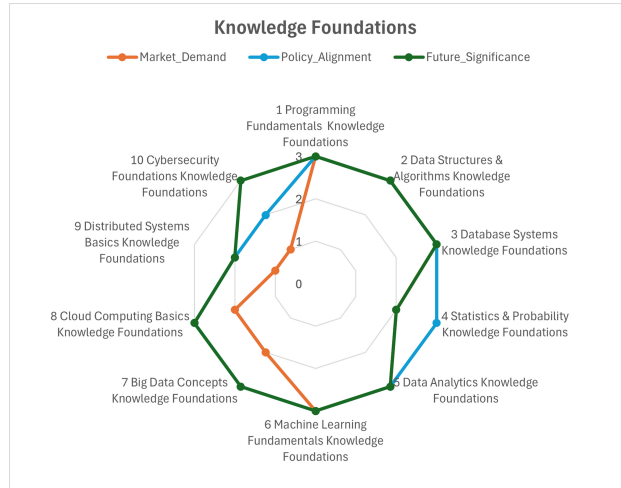
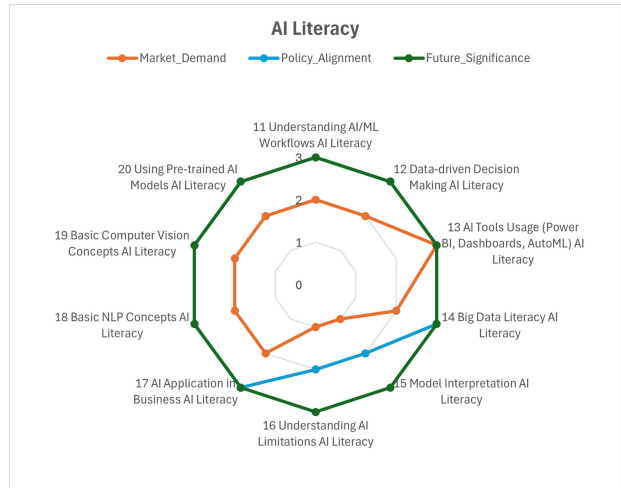
In contrast, Responsible AI shows lower near-term demand but rising importance with expanding AI governance. Table 8 summarizes demand scores and priority levels across all four competency domains.

4.3.2 Market Demand, Future Significance (WEF), and Policy Alignment Analysis

The multidimensional alignment analysis (market $\times$ WEF $\times$ policy) reveals clear domain-specific patterns:

- Knowledge foundations show strong alignment across all indicators, reaffirming their role as core prerequisites for AI learning.
- AI literacy ranks highest in future significance (WEF) but moderate in market and policy alignment, reflecting the rapid evolution of AI tools, platforms, and workflows.
- Ethics & Responsible AI exhibits low current market demand but strong policy alignment and moderate future significance, consistent with international ethical AI guidelines [2], [10].
- Career & Innovation Skills achieve high scores across all three indicators, demonstrating their critical role in workforce readiness, problem-solving, and innovation capacity.

These comparative patterns are visualized in Fig. 2-5, which presents radar charts across all four competency domains (a) Knowledge Foundations, (b) AI Literacy, (c) Ethics & Responsible AI, and (d) Career & Innovation Skills, highlighting contrasting strengths in market demand, future significance, and policy alignment.

**Fig. 2: Radar Charts of Knowledge Foundations.****Fig. 3: Radar Charts of AI Literacy.****Fig. 4: Radar Charts of Ethics & Responsible AI.**

4.3.3 Skill Gap Results

Evidence synthesis shows the largest gaps in AI engineering, data engineering, and applied AI, reflecting

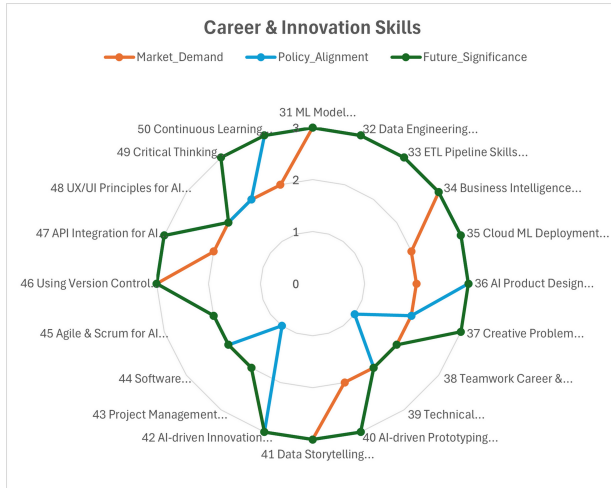


Fig. 5: Radar Charts of Career & Innovation Skills.

expanding industrial AI ecosystems and increasingly complex ML workflows relative to student readiness and future-skill and policy requirements.

A central finding is that competencies such as ETL pipeline development, data-engineering workflows, cloud-based machine-learning deployment, natural language processing (NLP), computer vision, and the use of pre-trained AI models score highly across labor-market demand, future significance, and policy alignment. However, students exhibit low readiness in these areas, indicating that they represent the most urgent and high-priority targets for curriculum enhancement.

In addition to advanced technical skills, the analysis identifies several practice-oriented competencies, including business intelligence (BI), API integration, AI-driven prototyping, version-control workflows (Git), and data storytelling, that are insufficiently covered in the current curriculum. These competencies are considered essential for building production-level AI systems and highlight the growing need for applied, workflow-based learning experiences.

Furthermore, professional competencies such as continuous learning, technological adaptation, and AI-driven innovation also register high gap scores. These results mirror global workforce analyses, which emphasise adaptability, creativity, and interdisciplinary problem-solving as core requirements for professionals in the AI era. These high-priority gaps are summarised in Table 9, which presents the urgent skill gaps derived from the weighted scoring analysis.

Table 9 presents the urgent skill gaps, ranked using the weighted scoring model that integrates labor-market data, stakeholder perspectives, future-skills forecasts, and national policy relevance.

Summary: The findings collectively indicate that the curriculum must prioritize hands-on, engineering-oriented, and industry-aligned AI competencies, particularly those related to data engineering, cloud deployment, workflow-based development, and applied AI

Table 9: Urgent Skill Gaps.

Skill Name	Gap
Data Storytelling	8
AI-driven Innovation	8
Version Control (Git)	8
Data Structures & Algorithms	7.25
Database Systems (SQL, MySQL)	7
Cloud Computing Basics	7
AI Tools Usage (Power BI, Dashboards, AutoML)	7
AI Application in Business	7
Basic NLP Concepts	7
Basic Computer Vision Concepts	7
Pre-trained AI Models Usage	7
Data Engineering Skills	7
ETL Pipeline Skills	7
Business Intelligence Skills	7
Cloud ML Deployment	7
AI Product Design	7
AI-driven Prototyping	7
API Integration for AI Solutions	7
Continuous Learning & Technology Adaptation	7

prototyping. At the same time, embedding Responsible AI principles remains essential to ensure long-term alignment with national policy directions and global governance frameworks.

5. DISCUSSION AND CONCLUSION

5.1 Discussion

The findings show that AI competency development requires a balanced integration of technical foundations, applied AI engineering, and responsible-AI principles. This pattern is consistent with CS2023, UNESCO, and OECD frameworks, which emphasize computational thinking, data literacy, ethical reasoning, and socio-technical understanding as essential capabilities for AI-era professionals [1], [2], [3].

The study extends prior AI competency research by synthesizing five evidence sources rather than relying on a single framework or stakeholder group. International standards, national strategies, stakeholder needs, labor-market analytics, and future-skill projections were integrated into one competency structure. This approach addresses the fragmentation found in previous AI literacy and workforce-readiness studies [12], [13], [16], [17], [21].

The results indicate that career & innovation skills show strong alignment across market demand, future significance, and policy relevance. Skills such as ETL pipelines, cloud ML deployment, business intelligence, API integration, AI product design, and AI-driven prototyping reflect current industry expectations for workflow-based AI development. These findings support recent work emphasizing deployable AI systems, MLOps,

system integration, and practice-centered AI education [21], [24].

AI literacy also shows high future significance, especially in AI tool usage, NLP, computer vision, pre-trained model usage, model interpretation, and generative-AI-related competencies. These results suggest that undergraduate curricula should move beyond foundational AI concepts and include practical exposure to modern AI workflows, AI platforms, and multimodal AI applications [16], [17], [19].

Ethics & Responsible AI shows lower short-term labor-market demand but strong alignment with national and international governance frameworks. This finding confirms that responsible AI, privacy, fairness, transparency, explainability, and AI governance should be embedded across the curriculum, even when these topics are less visible in job advertisements [6], [10], [11], and [30].

Overall, the findings suggest that future AI curricula should combine foundational computing knowledge, applied engineering practice, responsible AI awareness, and innovation-oriented learning. This balance is necessary for preparing graduates who can develop AI solutions that are technically sound, ethically responsible, and responsive to workforce needs.

5.2 Implications, Limitations, and Future Work

1) Implications for Curriculum Design

The AI Master Competency Taxonomy provides a practical foundation for curriculum redesign by supporting the restructuring of core courses, specialization pathways, hands-on laboratories, dataset-based activities, and project-based modules. Priority areas include AI Engineering, Data Engineering, Responsible AI, Cloud ML Deployment, Business Intelligence, API Integration, and AI-driven Prototyping. These directions align with recent studies emphasizing blended learning, game-based learning, end-to-end AI workflows, and practice-centered AI education [21], [24], [29]. The taxonomy also supports embedding responsible AI principles across the curriculum, consistent with global governance frameworks emphasizing transparency, accountability, and risk-aware development [10], [11], [30].

2) Implications for Policy and Workforce Development

The proposed competency model aligns with Thailand's National AI Strategy, the Digital Economy and Society Development Plan, the 20-Year National Strategy, and the Thirteenth National Economic and Social Development Plan, which emphasize digital workforce readiness, ethical AI, innovation capacity, and human capital development [6], [7], [8], [9]. It also supports regional priorities under the ASEAN Digital Masterplan 2025, particularly cross-border digital innovation, upskilling, and responsible AI ecosystems [20].

3) Limitations

This study is limited by its focus on the Thai higher-education and labor-market context, which may affect generalizability. Labor-market analytics based on TF-IDF and NER represent a time-specific snapshot, while AI skill requirements continue to evolve rapidly. Stakeholder insights were collected from 353 respondents within specific academic and professional contexts. The proposed taxonomy was conceptually developed and still requires validation through curriculum implementation and learning-outcome assessment.

4) Future Research Directions

Future studies should validate the taxonomy across institutions, disciplines, and international contexts using broader labor-market datasets and comparative policy frameworks. Longitudinal research should examine curriculum outcomes, graduate readiness, employer satisfaction, and responsible AI practice. Future revisions of the taxonomy should also integrate emerging competencies related to generative AI, multimodal AI systems, AI agents, and human-AI collaboration [17], [21], [24].

5.3 Conclusion

This study developed an integrated, evidence-based AI master competency taxonomy and skill-gap analysis for undergraduate AI curriculum development. By synthesizing global competency frameworks [1], [2], [3]; national AI and digital-policy directions [6], [7], [8], [9]; stakeholder perspectives, labor-market analytics, future-skill projections [4], and recent AI education literature [16], [17], [24], the study identified 50 AI and machine-learning competencies across four domains: Knowledge Foundations, AI Literacy, Ethics & Responsible AI, and Career & Innovation Skills.

The findings indicate that AI Engineering, Data Engineering, Business Intelligence, Cloud AI, AI Prototyping, and Innovation Skills are the highest-priority areas for curriculum enhancement. These competencies reflect strong convergence across labor-market demand, stakeholder needs, future-skill trends, and policy alignment. Foundational computing competencies remain essential, while AI literacy requires stronger emphasis on AI tools, multimodal AI, pre-trained model usage, and model interpretation [17].

Ethics & Responsible AI showed lower immediate labor-market demand but strong alignment with national and global governance frameworks [6], [10], [11], [30]. This confirms the need to embed responsible AI, privacy, fairness, transparency, explainability, and AI governance across undergraduate curricula to support long-term curriculum sustainability and responsible technology development.

Overall, the proposed taxonomy provides a structured foundation for designing future-ready undergraduate AI curricula that integrate technical rigor, applied AI practice, ethical responsibility, and workforce adaptability. The framework supports evidence-based curriculum transformation aligned with national strategies, regional

digital priorities [20], and global AI workforce trends.

ACKNOWLEDGEMENT

The authors wholeheartedly thank the Center of Multidisciplinary Innovation Network Talent (MINT Center), Faculty of Interdisciplinary Studies, Department of Technology and Engineering, Khon Kaen University, Thailand, for providing research knowledge, tools, equipment, and computer software.

AUTHOR CONTRIBUTIONS

The manuscript was written with contributions from all authors. They discussed the results and commented on the manuscript. All authors approved the final version of the manuscript.

REFERENCES

- [1] ACM, IEEE, and AAAI, *Computer Science Curricula 2023 (CS2023) Guidelines*. New York: Association for Computing Machinery, 2023.
- [2] UNESCO, *AI Competency Framework for Students*. Paris: UNESCO Publishing, 2024.
- [3] OECD, *AI and the Future of Skills, Volume 1: Capabilities and Assessments*. Paris: OECD Publishing, 2021, doi: 10.1787/5ee71f34-en.
- [4] World Economic Forum, *The Future of Jobs Report 2023*. Geneva: WEF, 2023.
- [5] B. Memarian and T. Doleck, "Teaching and learning artificial intelligence: Insights from the literature," *Education and Information Technologies*, vol. 29, pp. 21523-21546, 2024, doi: 10.1007/s10639-024-12679-y.
- [6] Ministry of Digital Economy and Society (MDES) and Ministry of Higher Education, Science, Research and Innovation (MHESI), "Thailand National Artificial Intelligence (AI) Strategy and Action Plan 2022-2027," AI Thailand. Accessed on: Oct. 25, 2025. [Online]. Available: <https://www.ai.in.th/wp-content/uploads/2022/12/20220726-AI.pdf>
- [7] Office of the National Digital Economy and Society Commission (ONDE), *Digital Economy and Society Development Plan (2018-2037)*. Bangkok: ONDE, 2018.
- [8] Office of the National Economic and Social Development Council (NESDC), *The National Strategy (2018-2037)*. Bangkok: NESDC, 2018.
- [9] Office of the National Economic and Social Development Council (NESDC), *The Thirteenth National Economic and Social Development Plan (2023-2027)*. Bangkok: NESDC, 2022.
- [10] UNESCO, *UNESCO's Recommendation on the Ethics of Artificial Intelligence: Key Facts*. Paris: UNESCO Publishing, 2023.
- [11] A. Green, "Artificial intelligence and the changing demand for skills in the labour market," *OECD Artificial Intelligence Papers*, no. 14, Paris: OECD Publishing, 2024, doi: 10.1787/88684e36-en.
- [12] M. Rojas-Contreras, L. C. Quintana, O. A. Villamizar, J. L. Mendoza Bejarano, and L. Villamizar Carrillo, "Frameworks for Artificial Intelligence Literacy in Higher Education," in *Proc. 23rd LAC-CEI International Multi-Conference for Engineering, Education, and Technology*, Mexico City, Mexico, 2025, doi: 10.18687/LACCEI2025.1.1.1620.
- [13] M. Mahmud, W. K. Monib, A. Qazi, S. F. Wong, C. Ramachandiran, and S. N. Azizan, "Developing AI Education Competency Framework: A Systematic Literature Review," *Open Praxis*, vol. 17, pp. 730-748, 2025, doi: 10.55982/openpraxis.17.4.1012.
- [14] OECD, "Bridging the AI skills gap: Is training keeping up?," Paris: OECD Publishing, 2025, doi: 10.1787/66d0702e-en.
- [15] National Digital Economy and Society Commission (NDESC), *Thailand Digital Manpower Development Framework*. Bangkok: NDESC, 2021.
- [16] W. Goosen, "Designing AI Literacy Curricula for Higher Education: A Comparative Framework," *International Journal of Research and Innovation in Social Science*, vol. 9, no. 26, pp. 8439-8448, Nov. 2025, doi: 10.47772/IJRISS.2025.903SEDU0637.
- [17] A. Deroncele-Acosta, R. M. E. Sayán-Rivera, A. D. Mendoza-López, and E. D. Norabuena-Figueroa, "Generative Artificial Intelligence and Transversal Competencies in Higher Education: A Systematic Review," *Applied System Innovation*, vol. 8, no. 3, Art. no. 83, Jun. 2025, doi: 10.3390/asi8030083.
- [18] L. J. Wiese, I. Patil, D. S. Schiff, and A. J. Magana, "AI ethics education: A systematic literature review," *Computers & Education: Artificial Intelligence*, vol. 8, Art. no. 100405, 2025, doi: 10.1016/j.caeai.2025.100405.
- [19] S. Shirzad and M. A. Darazi, "AI literacy in education: Balancing innovation, ethics, and equity in the digital age," *Journal of New Trends in English Language Learning*, vol. 4, Special Issue, Art. no. si-02, Oct. 2025, doi: 10.57647/JNTELL.2025.si-02.
- [20] ASEAN, *ASEAN Digital Masterplan 2025*. Jakarta: ASEAN Secretariat, 2021.
- [21] S. Bankins, X. Hu, and Y. Yuan, "Artificial intelligence, workers, and future of work skills," *Current Opinion in Psychology*, vol. 58, Art. no. 101828, Aug. 2024, doi: 10.1016/j.copsyc.2024.101828.
- [22] V. P. Gupta, "AI-Driven Skill Development: Bridging Students With Industry 5.0," in *Infrastructure Possibilities and Human-Centered Approaches With Industry 5.0*, Hershey, PA, USA: IGI Global Scientific Publishing, 2024, pp. 56-68, doi: 10.4018/979-8-3693-0782-3.ch004.
- [23] O. Zawacki-Richter, V. I. Marín, M. Bond, and F. Gouverneur, "Systematic review of research on artificial intelligence applications in higher education - where are the educators?," *International Journal of Educational Technology in Higher*

Education, vol. 16, Art. no. 39, Oct. 2019, doi: 10.1186/s41239-019-0171-0.

- [24] T. Balart and K. J. Shryock, "A Framework for Integrating AI into Engineering Education, Empowering Human-Centered Approach for Industry 5.0," in *2024 IEEE Global Engineering Education Conference (EDUCON)*, Kos Island, Greece, 2024, pp. 1-10, doi: 10.1109/EDUCON60312.2024.10578796.
- [25] Y. Filo, E. Rabin, and Y. Mor, "An artificial intelligence competency framework for teachers and students: Co-created with teachers," *European Journal of Open, Distance and E-Learning*, vol. 26, no. S1, pp. 93-106, 2024, doi: 10.2478/eurodl-2024-0012.
- [26] I. Tenberga and L. Daniela, "Artificial Intelligence Literacy Competencies for Teachers Through Self-Assessment Tools," *Sustainability*, vol. 16, no. 23, Art. no. 10386, Dec. 2024, doi: 10.3390/su162310386.
- [27] J. Watthananon and P. Chintanaporn, "Analyzing and Developing Competency-Based Assessment of Persons with Disabilities in Thailand," *ECTI Transactions on Computer and Information Technology*, vol. 12, no. 1, pp. 40-52, 2018, doi: 10.37936/ecti-cit.2018121.96755.
- [28] E. Sawasate, P. Wongsanpakarn, V. Singseetha, S. Rainchin, K. Hathaiwuttipun, N. Kuesuk, N. Rienthong, and S. Phetkham, "The ability to apply artificial intelligence technology to become a digital graduate of Sarasas Suvarnabhumi Institute of Technology," *Journal of Social Science Development*, vol. 8, no. 7, pp. 1-12, Jul. 2025. Accessed on: Oct. 12, 2025. [Online]. Available: <https://so07.tci-thaijo.org/index.php/JSSD/article/view/8594>
- [29] J. Karee, M. Phadung, and A. Yejehnih, "Developing a curriculum to enhance students' competencies in artificial intelligence through blended learning using collaborative game-based learning," *Southern College of Technology Journal*, vol. 18, no. 1, pp. 96-107, Jan.-Jun. 2025. Accessed on: Oct. 12, 2025. [Online]. Available: https://so04.tci-thaijo.org/index.php/journal_sct/article/download/272819/187474
- [30] C. Wu, H. Zhang, and J. M. Carroll, "AI Governance in Higher Education: Case Studies of Guidance at Big Ten Universities," *Future Internet*, vol. 16, no. 10, Art. no. 354, Sep. 2024, doi: 10.3390/fi16100354.



KANDA SORN-IN received the B.Sc. and M.Sc. degrees in Computer Science in 2002 and 2005, respectively, and the Ph.D. degree in Information Studies in 2014, all from Khon Kaen University, Thailand. She is currently an Assistant Professor in the Computer and Information Science Program, Department of Technology and Engineering, Faculty of Interdisciplinary Studies, Khon Kaen University, Thailand. Her research interests include data analytics, information systems design, artificial intelligence and machine learning, explainable AI, business intelligence, recommender systems, sentiment analysis, and digital

innovation for decision support in business, education, and healthcare contexts.



MANUSSAWEE NOKKAEW received the Ph.D. degree in Electrical and Computer Engineering from Khon Kaen University, Thailand, in 2024. From 2015 to 2025, he worked as an analyst and consultant at Software Park Thailand under the National Science and Technology Development Agency (NSTDA). During this period, his work focused on managing projects to empower software and digital entrepreneurs in accessing domestic and international markets, and driving digital transformation among industrial enterprises. Currently, he is a Lecturer in the Computer and Information Science Program, Technology and Engineering Sector, at Khon Kaen University, Nong Khai Campus. His research interests include artificial intelligence (AI), particularly generative AI and natural language processing (NLP), as well as machine learning, deep learning, big data analytics, and sustainability.



CHAYADA SURAWANITKUN received the B.Eng. degree in Electrical Engineering (1st class honor) and the Ph.D. degree in Electrical Engineering from Khon Kaen University, Thailand, in 2009 and 2013, respectively. She was granted the B.Eng. Scholarship from the Industrial/University Cooperative Research Center in HDD Component, supported by the Ministry of Science and Technology, and a Ph.D. scholarship from the Royal Golden Jubilee Ph.D. Program under The Thailand Research Fund. She is Program Chair of Master's and Doctoral programs in Electrical and Computer Engineering of the Faculty of Interdisciplinary Studies, Department of Technology and Engineering, Khon Kaen University, Nong Khai Campus, Thailand. Her research interests include power systems, Smart IoTs, data storage technology, magnetic random-access memory, thermal analysis of nanodevices, nanotechnology, renewable and sustainable energy, and energy management systems.



SATIT KRAVENKIT received the B.Sc., M.Sc., and Ph.D. degrees in Computer Science from Khon Kaen University, Thailand, in 2001, 2006, and 2017, respectively. He has experience as a researcher in semantic web technology and previously served as a lecturer in the Department of Computer and Information Science, Faculty of Interdisciplinary Studies, Khon Kaen University, Nong Khai Campus. From 2023 to 2026, he worked with the College of Computing, Khon Kaen University. His Ph.D. research focused on a GS1 EPCglobal-compliant traceability system for cloud-based Electronic Product Code Information Services (EPCIS). His research interests include RFID, cloud computing, supply-chain traceability, blockchain technology, and cybersecurity.



NONGRAM MUEANRIT received her Ph.D. in Information Studies from Khon Kaen University, Thailand, in 2013. She is currently serving as an Assistant Professor in the Department of Technology and Engineering, Faculty of Interdisciplinary Studies, Khon Kaen University. Her research interests encompass a broad spectrum of interdisciplinary domains, including information behavior analytics, consumer behavior analysis, user experience design, business data analytics, and smart tourism systems. She has contributed to the academic community through publications in internationally recognized peer-reviewed journals, including *Energy*, among others.