

CO-CREATING AI MICRO-CREDENTIALS THROUGH INDUSTRY– ACADEMIA PARTNERSHIPS: PEDAGOGICAL IMPLICATIONS FOR PHARMACY EDUCATION

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Abstract

The rapid development of artificial intelligence (AI) in the healthcare sector is transforming professional competency needs, creating an urgent need for adaptive, theory-based pedagogical models in pharmacy education. This paper analyzes how AI-based micro-credentials can be co-created as a result of industry-academia collaborations and how they impact the process of developing competencies and curriculum development. A quantitative survey of 450 stakeholders (faculty, students, and industry professionals) is followed by a qualitative analysis of 70 interviews and focus groups; a sequential explanatory mixed-methods approach the matter with a mix of quantitative and qualitative elements is identified as explanatory mixed-methods. Quantitative data were analyzed using descriptive and inferential statistics, but the qualitative data were analyzed in terms of themes.

The results show that AI micro-credentials co-created have a positive impact on perceived workforce relevance, assist in building AI literacy, interpreting data, and making ethical decisions, and facilitate flexible, competency-oriented learning routes that are in line with professional practice. The qualitative observations also reveal that the industry-academia co-

creation works as a pedagogical facilitator through installing real-world AI applications within curriculum design and evaluation.

This research contributes to the field of micro-credential scholarship by explicitly connecting co-creation processes, competency development, and pedagogical outcomes by reframing AI micro-credentials as design-based curriculum processes, as opposed to additional training credentials, and having direct implications on curriculum reform and accreditation-based pharmacy education.

Keywords: Artificial Intelligence, Micro-Credentials, Pharmacy Education, Industry–Academia Collaboration, Competency-Based Education, Curriculum Design, Workforce Readiness

1. Introduction

1.1. Pharmacy Digital Transformation and AI.

The pharmacy profession is undergoing changes driven by the structural shift brought by artificial intelligence (AI), data analytics, and digital health technologies (Davenport and Kalakota, 2019; Topol, 2019). The use of AI-driven systems is spreading into the pharmacy practice sectors of clinical decision support, medication therapy management, pharmacovigilance, drug discovery, and personalized medicine (Rasmy et al., 2021). These systems can help pharmacists detect drug-drug interactions, anticipate adverse drug reactions, optimize therapeutic plans and enhance patient safety outcomes.

Pharmacists will become critical participants in the algorithm-driven decision processes instead of being inactive users of technology, as AI has become part of standard care practices. This change requires the ability to interpret data and make algorithmic decisions and ethical choices concerning AI use (Fédération Internationale Pharmaceutique [FIP], 2020). Pharmacy education should therefore transform to meet these new professional demands.

1.2. Limitations of Traditional Pharmacy Curricula

Although the use of AI has increasingly become a significant part of today's pharmacy practice, traditional pharmacy education programs have been ineffective in adapting to the technological change. Current schemes are still content-focused and discipline-oriented and do not systematically integrate digital health and AI skills (Goundrey-Smith and Wright, 2019). The

regulatory requirements and long approval cycles that may limit curriculum revision often decrease institutional agility (Accreditation Council for Pharmacy Education [ACPE], 2016).

Consequently, there is an ongoing discrepancy between the skills needed in AI-enabled pharmacy practice and those gained with the help of traditional models of education (Mak and Tran, 2022). Without sufficient training in data-based decision-making or responsible use of AI, graduates may enter technologically advanced practice environments unprepared.

1.3. Emergence of Micro-Credentials in Health Professions Education

There has been an educational reaction to the fast-changing workforce requirements in the form of micro-credentials. Micro-credentials are usually short, modular, and competence-driven learning outcomes, and they are not bound to traditional time-based structures (Oliver, 2019). They have found a place in the health professions field as instruments of lifelong learning, continuing professional development, and expedited upskilling in digital health and AI (Wheelahan and Moodie, 2021; Fawns et al., 2023).

In the field of pharmacy, AI-oriented micro-credentialing provides a flexible tool to embed the recently developed skills into the curriculum without replacing existing curricular content. However, they can be of value to educators when they are systematically aligned with competency frameworks and professional practice expectations.

1.4. Rationale for Industry–Academia Collaboration

It is well-known that industry - academia collaboration is one of the methods used to increase the relevance of curricula and the employability of graduates (Plewa et al., 2015; Jackson, 2017). The industrial allies give feedback on the practical use of AI and changing labour demands, and institutions of higher learning offer teaching and curriculum skills and quality.

This collaboration is especially relevant to the context of pharmacy education, where the gap between theoretical and technology-facilitated practice environments is to be bridged (Mak & Tran, 2022). Industry-academia partnerships in co-creation of AI micro-credentials are a more holistic approach to curriculum innovation, where practice relevance is embedded in competency development.

Objectives and Research Question.

The current research, in this regard, considers the co-creation of AI micro-credentials based on industry-academia connections and the ways in which they have pedagogical implications in the context of pharmacy education. The objectives of the study are specific, as they are to:

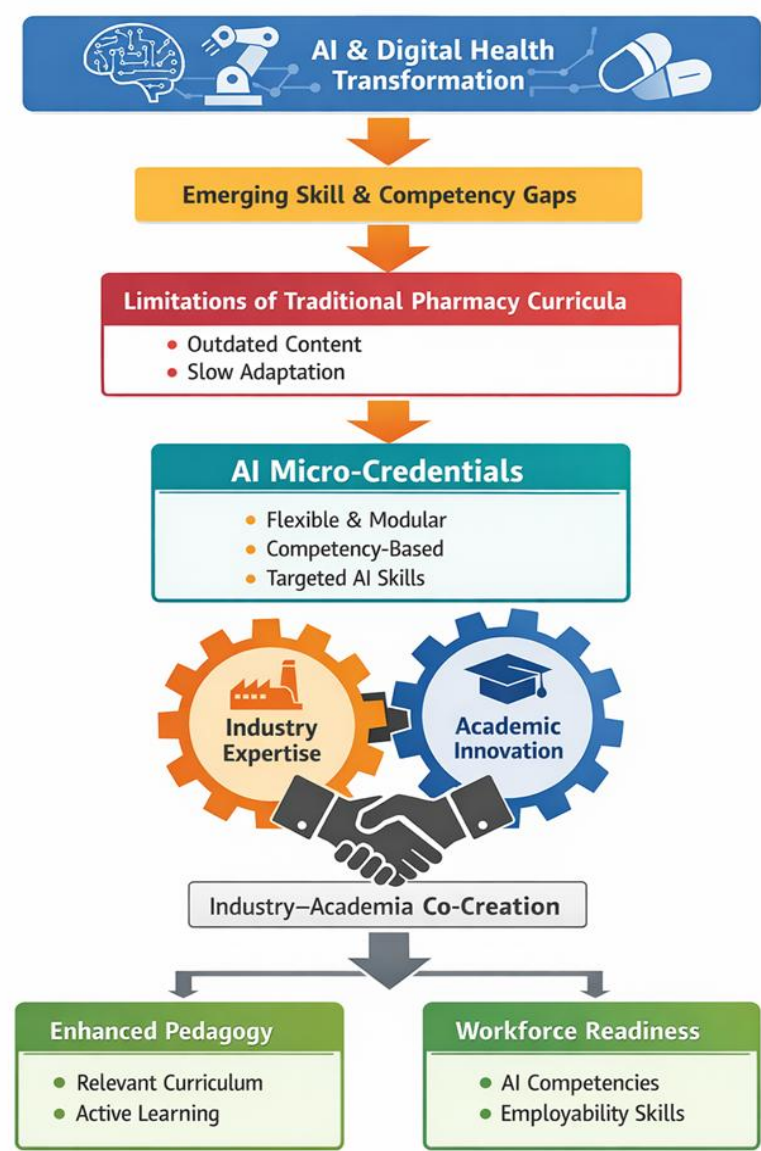
1. Research attitude towards AI micro-credentials among pharmacy students, faculty and industry professionals.
2. Determine the perceived usefulness of industry-academia co-developed AI micro-credentials in helping to achieve competency-building and workforce preparedness.
3. Identify pedagogical approaches and institutional aspects of incorporating AI micro-credentials into pharmacy courses.

Based on this, the following research questions are addressed in the study:

- How do the major stakeholders see the utility and applicability of AI micro-credentialing to pharmacy education?
- How can AI micro-credentials co-created help in competency-based learning and workforce preparedness?
- What is the pedagogical and institutional context to support and/or obstruct the adoption of AI micro-credentialing in pharmacy programs?

Figure 1 gives a conceptual map showing how accelerated digital transformation and growth in the use of AI in pharmacy practice have introduced new competency requirements that are not met by conventional curricula. The figure also shows AI micro-credentials as an alternative, competency-based approach, and the importance of industry-academic partnership in managing the content of education and the level of the workforce market and improving pedagogical efficiency in pharmacy education.

Figure 1. Rationale for Co-Created AI Micro-Credentials in Pharmacy Education



2. Literature Review

The section is a synthesis of previous studies of artificial intelligence (AI) in pharmacy education, micro-credentialing as part of competency-based education (CBE), and industry-academia partnership. Instead of considering these strands separately, the section incorporates them together to detect conceptual intersections and empirical gaps that underlie the design-oriented framework in Section 3.

2.1 Artificial Intelligence in Pharmacy Education

The past few years have seen the emergence of artificial intelligence in pharmacy education as a significant scholarly topic (Rosco, 2021). Pharmacy practice is gradually coming to be transformed using artificial intelligence, which may change the way pharmacists interact with clinical information, decision-support systems, pharmacogenomics, and personalized medicine (Topol, 2019; Davenport and Kalakota, 2019). As a result, the pharmacy graduates are expected to have the ability to display the competencies that go beyond the technical knowledge to include AI literacy, data interpretation, ethical judgment, and interprofessional collaboration. Despite increasing relevance, empirical research has always indicated that there is a lack of linkage between the role of AI in professional practice and its systematic part in pharmacy education. Although the overall attitude of students toward AI and digital health is positive, formal curricular exposure is underdeveloped, irregular, and often offered as an elective and not a core course of study (Mak and Tran, 2022). The presence of structural constraints, such as inflexibility in the curriculum, lack of faculty knowledge, and the lack of uniform AI competency models, still discourage meaningful integration (Goundrey-Smith and Wright, 2019).

Notably, a significant portion of the available literature deals with the question of the integration of AI into pharmacy education, and relatively little is said about how AI capabilities can be framed for teaching, assessment, and maintenance in accredited courses. Such a gap highlights the necessity of design-based models of curriculum that move beyond content inclusion to pedagogical innovation.

2.2 Micro-Credentialing and Competency-Based Learning.

The idea of micro-credentials has become widespread as both a means of operationalising competency-based education. Generally identified as mini, goal-oriented courses in accordance with clear outcomes, micro-credentials focus on mastery, transparency and performance-based assessment (Oliver, 2019). They aid the modular learning routes and lifelong learning in professional growth in the context of CBE (Wheelahan and Moodie, 2021).

micro-credentials are increasingly adopted in health professions education to support the quickly changing skills like digital health and AI, where traditional programs have a hard time keeping up (Fawns et al., 2023). Micro-credentials are more flexible and have shorter update timeframes in comparison to the traditional pharmacy programs and are more aligned with the practice in the industry. Nonetheless, researchers have warned that the lack of solid theoretical foundation and governance systems can make micro-credentialing one of the causes of curricular fragmentation, inflation of credentials, and diminished coherence (Wheelahan and Moodie, 2021).

To explain these differences, Table 1 has provided a comparative summary of conventional pharmacy curricula and AI micro-credential schemes, with particular attention being given to why micro-credentials should be considered as complementary curriculum strategies and not substitutes.

Table 1.
Comparison of Traditional Pharmacy Curricula and AI Micro-Credential Approaches

Dimension	Traditional Pharmacy Curriculum	AI Micro-Credential Approach
Curriculum structure	Semester-based, fixed	Modular, stackable
Learning focus	Knowledge-intensive	Competency-based
Industry involvement	Limited or advisory	High (co-creation model)
Curriculum update cycle	Slow and regulated	Rapid and flexible
Assessment approach	Exams and coursework	Performance-based
Workforce alignment	Moderate	High

Although these differences have been well conceptualized, there is limited empirical evidence in the literature of how micro-credentials can be effectively integrated into accredited pharmacy programs, a problem specifically considered in this study.

2.3 Industry-Academia Partnerships in Health Professions Education.

The relevance of curricula, experiential learning, and graduate employability in health professions education have been extensively studied as being improved through industry-based academic collaborations (Plewa et al., 2015). The industry partners bring the information about the changing technologies and the practice requirements, and the academic institutions protect the pedagogical levels and the accreditation congruence (Jackson, 2017).

Such partnerships have aided pharmacy education through clinical informatics, pharmaceutical technologies, and digital health initiatives (Mak and Tran, 2022). Most of the current research, however, views the involvement of industry in terms of advisory or supplementary, instead of an integrated pedagogical process.

The creation of AI micro-credentials involves a co-creation, which is a significant change in this relationship. Co-creation instead of making industry an external stakeholder entrenches industry involvement in the very heart of competency definition, learning design, and assessment development. There is still limited empirical research on the pedagogical consequences of this more profound design-integrated type of collaboration, especially in pharmacy education.

2.4 Competency Frameworks and Theoretical Foundations.

Pedagogical integration of AI micro-credentials is based on the competency-based learning, the constructivist theory of learning, and the concept of experiential learning (Frank et al., 2010). These methodologies focus on the idea of outcomes-based learning, authentic assessment, and working with real-world issues, which are the characteristics that AI competencies development has in common.

The Accreditation Council on Pharmacy Education (ACPE) Standards or the International Pharmaceutical Federation (FIP) Global Competency Framework are professional frameworks that can guide the competencies of pharmacists, like digital health capabilities, ethical practice, and interprofessional collaboration (ACPE, 2016; FIP, 2020). These frameworks are necessary to align AI micro-credentials to achieve compatibility of accreditation and coherence of the curriculum.

Table 2 maps the core AI competency domains on ACPE and FIP standards to show the ways AI micro-credential can be introduced into the known pharmacy education frameworks instead of placed as the peripheral innovations.

Table 2.

Core AI Competency Domains Relevant to Pharmacy Education (Mapped to ACPE/FIP Frameworks)

AI Competency Domain	Description	ACPE Alignment	FIP Alignment
AI literacy	Understanding AI concepts and applications	Standard 1 (Foundational Knowledge)	Domain 1 (Professional Knowledge)
Data literacy	Interpretation of clinical and healthcare data	Standard 2 (Essentials for Practice)	Domain 2 (Pharmaceutical Care)
Clinical decision support	Use of AI tools in therapeutic decisions	Standard 3 (Approach to Practice)	Domain 3 (Public Health & Patient Safety)
Ethical and legal use of AI	Privacy, bias, accountability	Standard 4 (Personal & Professional Development)	Domain 4 (Professional & Ethical Practice)
Digital collaboration	Interdisciplinary, technology-enabled teamwork	Standard 3	Domain 5 (Collaboration & Leadership)

2.5 Regional Context: South Indian Pharmacy Education

These gaps are especially applicable in the South Indian pharmacy education situation. The pharmacy programs are carried out in this region where accreditation systems are highly controlled with prescribed curricula, less choice of electives and a large number of students to faculty ratios. Even though South India is the site of a booming pharmaceutical manufacturing, clinical research and health IT ecosystem, there is a lack of formal curricular integration of AI.

All these circumstances increase the necessity of adaptive learning processes and the risks of a discontinuous implementation. Micro-credentials have a possible flexibility, but their failure to be organized in a governing structure and integrated with pedagogy can make this approach result in curricular incoherence. South India, therefore, offers an important empirical context in which to explore how the AI micro-credentialing, which is designed by industry-academia

consortia, can lead to integrative, but not incidental, curriculum design and, in that regard, can serve as a key benefit of incorporating AI into teaching and learning processes.

2.6 Synthesis and Research Gap

Combined, these gaps in the literature indicate three gaps that are interrelated:

- (1) the lack of scalable pedagogical approaches to integrate AI competencies in the education of pharmacy;
- (2) lack of theoretical and empirical basis of micro-credentials as consistent curriculum processes; and
- (3) the under-theoreticalization of industry-academia collaboration as an inherent pedagogic practice but not an implementation strategy.

Filling these gaps, the current research empirically investigates the co-creation of AI micro-credentials in the partnership with industry and academia in a regulated South Indian setting and develops a conceptual framework that connects collaboration, competency mapping and pedagogical outcomes (Section 3). Although certain regulatory and institutional factors are context-specific, the design principles described within the framework can be transferred to other professional education systems experiencing technological disruption to the same extent.

3. Conceptual Framework: AI Micro-Credential Co-Creation Model.

The paper is directed by a conceptual, design-oriented framework that describes the process of AI micro-credential co-creation by implementing organized industry-academia relationships to improve the effectiveness of pedagogy, as well as the relevance of workforce in the field of pharmacy education. Instead of promoting a causal model, the framework is a mid-range pedagogical design contribution, which combines the principles of competency-based education (CBE), learning by doing, and curriculum design informed by industrial knowledge. The framework adds to the current theory by proceeding with the competency-based education into AI-driven pharmacy education via formalized co-creation logic. It theorizes industry-academia collaboration not as an advisory input, but as a form of in-built pedagogy that defines competencies, informs the design of learning and assessment and iterative curriculum development. By doing it, the framework provides an integrative synthesis and provide a transferable logic of curriculum innovation in the fast-changing professional fields.

3.1 Framework Development Process.

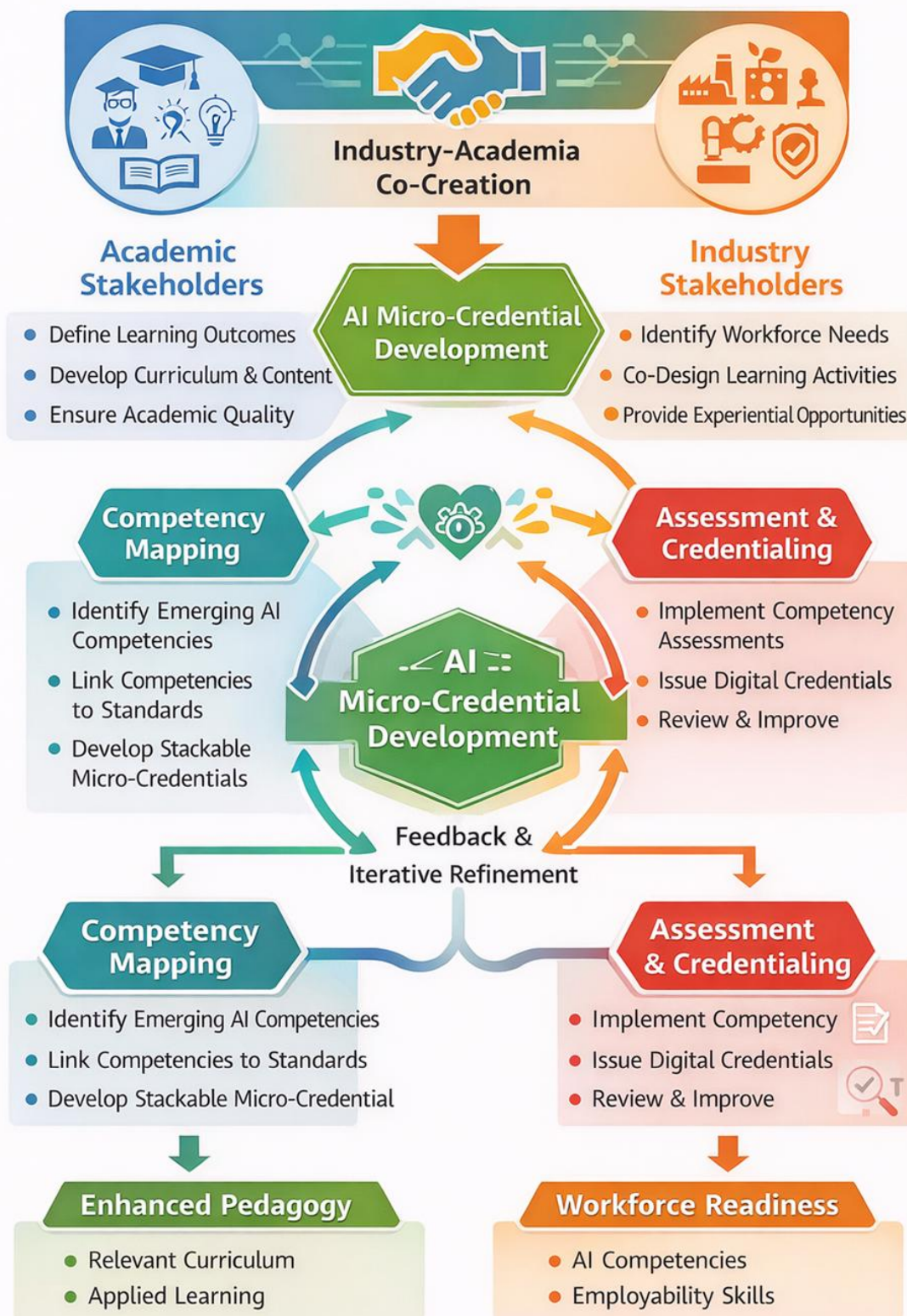
The conceptual framework was coined because of the integrative and design-based review process by relying on three interdependent bodies of literature:

- (i) AI in pharmacy and education of health professions
- (ii) micro-credentialing and competency-based learning and
- (iii) academic industry partnership in curriculum development.

Simultaneously, the main professional and regulatory documents of the Accreditation Council of Pharmacy Education (ACPE) and the International Pharmaceutical Federation (FIP) were reviewed to make them consistent with the established competency requirement and accreditation requirements. To enhance workforce relevance, the industry reports on digital health, pharmaceutical informatics, and AI-enabled clinical decision support were considered to come up with priority competencies and real-life practice scenarios.

In line with the design-based research approach, the paradigm focuses on the iterative nature of development, feedback of stakeholders, and ongoing curriculum refinement, as opposed to a linear curriculum planning. The resulting AI Micro-Credential Co-Creation Model (Figure 2) depicts the interactions between stakeholders' collaboration, competency mapping, and assessment feedback loops, which contribute to the adaptive and responsive pharmacy education.

Figure 2. AI Micro-Credential Co-Creation Framework for Pharmacy Education



3.2 Roles of Academic and Industry Stakeholders

The framework models AI micro-credential development as a participatory process where academic and industry players play the roles of complementary and interdependent partners. Pedagogical stewards (faculty members, curriculum committees and instructional designers) are academic stakeholders and have the following responsibilities:

- Setting learning outcomes in accordance with accreditation and competency systems.
- There is a need to ensure that there is pedagogical coherence, academic rigor and constructive alignment.
- Constructing assessment plans that facilitate competency and reflective learning.

Pharmaceutical companies, health IT vendors, clinical AI solutions vendors and professional organizations, as industry stakeholders, operate as practice informants and co-designers by:

- Determining new skills requirements and real-world applications of AI.
- Co-designing learning activities, simulations and case scenarios.
- Promoting experiential exposure by projects, mentorship or practice-based contributions.

In the paradigm, industry academia collaboration acts as pedagogical facilitating mechanism, not as a result variable, to determine the relevance of the curriculum and the authenticity of an assessment. The conceptualization of stakeholder interaction is constructed as an iterative and constant process that allowed the curriculum to be responsive to technological change and constant disconnect between the academic preparation and the workplace requirement in pharmacy practice.

3.3 Competency Mapping and Assessment Logic.

One of the key elements of the framework is the explicit competency mapping, according to which AI-related knowledge, skills, and professional attitudes are organized in accordance with the accepted pharmacy competency frameworks. The framework concentrates on the four competency areas that relate with each other:

- Digital health and AI literacy
- Clinical decision making based on data.

- Responsible and ethical application of AI.
- Interprofessional and collaborative practice.

AI micro-credentials are organized as units of learning, which can be stacked into modules, and each of them is aligned with the competency profile and associated performance metrics. This design reflects what CBE principles emphasize and underline mastery and transparency of learning outcomes and flexibility in the learning process.

The assessment logic is more focused on genuine performance-based appraisal, such as applied case analysis, simulated activities, and projects reviewed by the industry. The results of the assessment are integrated into the feedback processes and connected with the improvement of the curriculum, which makes assessment a process of development and change, not an endpoint.

3.4 Empirical Anchoring of the Conceptual Framework

Despite the design-oriented viewpoint of the framework, the main elements are empirically confirmed by mixed-method results of the study, which helps to improve its explanatory and practical significance.

Quantitative findings showed that there were strong positive correlations among industry-academia collaboration, pedagogical effectiveness, competency development, and workforce readiness, which directly test the assumption of the framework that collaboration is a focal enabling mechanism. The empirical evidence of the framework in terms of stressing practice-based competency design and tests authenticity is supported by significant differences between groups of stakeholders, with higher ratings being made by industry professionals.

Qualitative results also provide a base to the framework in the sense that they shed light on the working mechanisms of the proposed processes. Themes of alignment to industry requirements, increased competence building, co-developing curriculum, and flexibilities and lifelong learning give experiential support to the feedback loops and co-creating logic of the framework. The description of the refinement of the curriculum as described by the participants involved the application of learning tasks through iteration, and the standards of industry

informed assessment are an explicit expression of the assumptions of the cyclical nature of the design.

Combined, both the combination of quantitative patterns and qualitative explanations reveals that the AI Micro-Credential Co-Creation Model is not just an abstract concept, yet a design logic based on the patterns of observed pedagogical practices, and experiences of stakeholders. This empirical anchoring makes the framework more applicable in other contexts of professional education that are experiencing a rapid technological change.

4. Research Methodology

4.1 Study Design

The explanatory mixed-method design was a sequential design used to investigate the pedagogical implication of co-created AI micro-credentials in pharmacy education. In the design, the quantitative data collection and analysis followed by the qualitative inquiry to identify initial patterns and then examine them in detail (Creswell and Plano Clark, 2018).

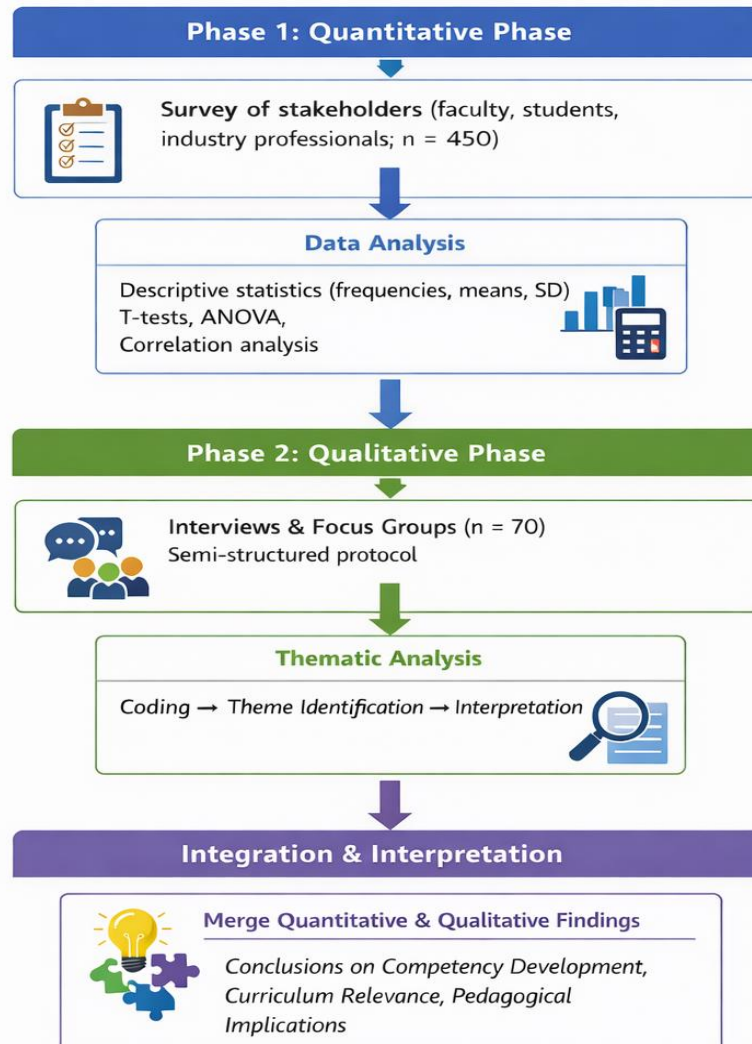
The choice of the mixed-methods approach was based on the need to:

- Measurably estimate the perception of stakeholders regarding the relevance, development of competencies and pedagogy effectiveness.
- Qualitatively investigate how and why these perceptions were generated between the stakeholder groups.
- Combine results to build up a subtle conceptualization on AI micro-credential co-creation.

Figure 3 represents the research design and shows how the quantitative analysis of surveys would lead to the qualitative interviews and focus groups, and then to the interpretation

integration.

Figure 3. Sequential Explanatory Mixed-Methods Research Design
for AI Micro-Credential Study



4.2 Participants and Sampling

The participants were recruited among three groups of stakeholders involved in the AI micro-credential co-creation:

1. Faculty of pharmacy curriculum design and teaching.
2. Postgraduate and undergraduate students of pharmacy.

3. Pharmaceutical and digital health organization industry professionals.

The questionnaire was elaborated and given to about 600 possible respondents in the pharmacy institutions of Andhra Pradesh, Telangana and Karnataka and industry professionals of the regional and national organizations. The eligibility/completeness screening allowed retaining 450 responses (faculty = 50; students = 300; industry professionals = 100) to be analyzed.

There was a purposive sampling strategy that was used to ensure that participants had appropriate exposure to AI, digital health, or pharmacy education innovation. In the case of the qualitative phase, it was decided to use maximum variation sampling to select 70 participants as diverse representatives of the various groups of stakeholders, the institutional context, and the level of experience.

4.3 Development of Instrument, Pilot Study and validation.

The conceptual framework and the literature concerning the AI competency, micro-credentialing, and pharmacy education standards (ACPE, 2022; FIP, 2020) were directly converted to the structured questionnaire. Measures were made in constructs:

- Relevance of AI micro-credential perceived.
- Competencies development (AI literacy, data literacy, ethical awareness)
- Pedagogical (engagement, flexibility, learning outcomes) effectiveness.
- Workforce readiness

Everything was assessed on five-point Likert scales, where strongly disagree (1) to strongly agree (5). The items used to operationalize each construct were 4-6 items.

Expert review was the means of content validity that compared the assessment of five experts (academia and industry). Clarity, feasibility, and reliability were evaluated in a pilot study involving 30 participants (10 representatives of each group of stakeholders). The Cronbach's alpha between 0.78-0.87 was found to be acceptable internal consistency (Tavakol and Dennick, 2011). There were minor wording refinements before going to full scale administration.

Qualitative tools were composed of semi-structured interview and focus group guides that would be used to probe into experiences with learning in AI-related contexts, the views on

industry participation, and the possibilities of curriculum improvement. These tools were confirmed by review and piloting.

4.4 Data Collection Procedures

The data collection was done in two phases:

1. Quantitative phase:

The questionnaire was tested and 450 participants were put online and the questionnaire was given out after four weeks with the informed consent.

2. Qualitative phase:

The selected participants were interviewed through semi-structured interviews ($n = 38$) and focus groups ($n = 6$; total participants = 26) interviews. The sessions were conducted either face-to-face or through safe virtual platforms, and audio-taped with permission and transcribed verbatim. Quantitative results helped to inform areas of qualitative inquiry, which then facilitated the investigation of emergent patterns.

4.5 Data Analysis Techniques

Descriptive statistics and inferential tests (t-tests and ANOVA) were used to test the differences between the groups of stakeholders. Correlation was used to determine the associations between key constructs. Assessment was done on assumptions of normality and homogeneity of variance before analysis, which were found to be acceptable.

Further multivariate analyses were also not conducted because the main aim of the study was not any prediction or causal modelling, but comparative and exploratory.

Thematic analysis was made to analyze the qualitative data through six phases of the six-stage approach of Braun and Clarke (2006). The data were coded by two researchers and differences were addressed by discussion to ensure higher analytic credibility. Thematic saturation was reached when new themes were no longer observed.

The quantitative and qualitative results were integrated at the stage of interpretation, and the results of the surveys could be explained, nuanced, and extended by the insights of the quantitative and qualitative results.

4.6 Ethical Considerations

Data collection was done with the approval of the institutional ethics committee on ethics. The involvement was voluntary and informed consent was obtained and confidentiality ensured by anonymization and safe storage of data. Respondents were made aware of their right to drop out at any point free of charge.

5. Results

The findings are discussed in accordance with the sequential explanatory mixed-methods design, in which the quantitative analysis will be introduced first (descriptive and inferential), followed by the findings of qualitative analysis and synthesis of the results.

5.1 Participant Demographics

Table 3.
Participant Demographics (n = 450)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Stakeholder Group	Faculty	50	11.1
	Students	300	66.7
	Industry Professionals	100	22.2
Gender	Male	260	57.8
	Female	190	42.2
Age Group	18–25	200	44.4
	26–35	150	33.3
	36–50	80	17.8
	51+	20	4.5
Location	Andhra Pradesh	180	40.0
	Telangana	150	33.3
	Karnataka	120	26.7
Experience (Industry/Faculty)	<5 years	100	22.2
	5–10 years	180	40.0
	>10 years	70	15.6
Education Level	Undergraduate	250	55.6

	Postgraduate	150	33.3
	Doctoral / Faculty	50	11.1

Note: Students were categorized by year of study; faculty and industry professionals by years of experience.

5.2 Quantitative Findings

5.2.1 Descriptive Statistics

Table 4.

Stakeholder-Specific Perceptions of AI Micro-Credentials (Mean $\pm$ SD)

Variable	Faculty	Students	Industry	Overall
AI Micro-Credential Relevance	4.28 $\pm$ 0.60	4.33 $\pm$ 0.62	4.52 $\pm$ 0.55	4.35 $\pm$ 0.62
Competency Development	4.18 $\pm$ 0.57	4.21 $\pm$ 0.60	4.30 $\pm$ 0.56	4.22 $\pm$ 0.58
Pedagogical Effectiveness	4.10 $\pm$ 0.55	4.28 $\pm$ 0.53	4.38 $\pm$ 0.50	4.25 $\pm$ 0.55
Industry–Academia Collaboration	4.32 $\pm$ 0.56	4.42 $\pm$ 0.59	4.47 $\pm$ 0.55	4.40 $\pm$ 0.58
Workforce Readiness	4.20 $\pm$ 0.58	4.25 $\pm$ 0.61	4.38 $\pm$ 0.57	4.28 $\pm$ 0.60

5.2.2 Inferential Statistics

Table 5.

ANOVA Results for Differences Across Stakeholder Groups

Variable	F-value	p-value	Interpretation
AI Micro-Credential Relevance	5.23	0.006	Significant; Industry > Faculty/Students
Competency Development	3.45	0.033	Significant differences among groups
Pedagogical Effectiveness	6.12	0.003	Significant; Students < Industry
Industry–Academia Collaboration	2.85	0.058	Not significant at 0.05 level
Workforce Readiness	4.01	0.018	Significant; Industry > Faculty/Students

Post-hoc Tukey tests confirmed that **industry participants consistently rated variables higher** than faculty and students for relevance, competency, and workforce readiness.

5.2.3 Correlation Analysis

Table 6.
Correlation Between Key Study Variables (Pearson r)

Variable 1	Variable 2	r	p-value
Industry–Academia Collaboration	Workforce Readiness	0.68	<0.001
AI Micro-Credential Relevance	Competency Development	0.55	<0.001
Pedagogical Effectiveness	Competency Development	0.61	<0.001

Significant positive correlations indicate that better collaboration and pedagogically effective micro-credentials are associated with higher competency development and workforce readiness.

5.2.4 Competency Domain Ratings

Table 7.
Core AI Competency Domain Ratings (Mean $\pm$ SD)

Competency Domain	Faculty	Students	Industry	Overall
AI Literacy	4.20 $\pm$ 0.55	4.22 $\pm$ 0.57	4.35 $\pm$ 0.52	4.27 $\pm$ 0.55
Data Interpretation	4.15 $\pm$ 0.53	4.20 $\pm$ 0.55	4.32 $\pm$ 0.50	4.23 $\pm$ 0.53
Ethical Awareness	4.22 $\pm$ 0.56	4.25 $\pm$ 0.57	4.30 $\pm$ 0.54	4.26 $\pm$ 0.56
Practical Application	4.10 $\pm$ 0.58	4.28 $\pm$ 0.60	4.42 $\pm$ 0.50	4.26 $\pm$ 0.57

ANOVA confirmed **significant group differences** for practical application ($F=5.01$, $p=0.007$), with **industry > students > faculty**.

5.3 Qualitative Findings

Analysis of **interviews and focus groups (n=60–80)** identified four major themes summarized in **Table 8**.

Table 8.
Summary of Qualitative Themes, Sub-Themes, and Illustrative Quotes

Theme	Sub-Theme / Focus	No. of Participants	Illustrative Quote
Alignment with Industry Needs	Bridging theory and practice	45	<i>“These micro-credentials give students a head start in real-world AI applications.”</i> – Industry participant
Enhanced Competency Development	AI literacy	40	<i>“Students gain confidence in using AI tools for clinical decision-making.”</i> – Faculty participant
	Data analysis skills	38	<i>“Hands-on exercises in AI improved our ability to interpret clinical data.”</i> – Student participant
	Ethical decision-making	32	<i>“Ethics modules make students aware of AI limitations in healthcare.”</i> – Faculty participant
Collaborative Curriculum Design	Iterative co-design	42	<i>“Working together ensures students gain skills immediately applicable in industry.”</i> – Faculty participant
Flexibility and Lifelong Learning	Modular/stackable learning	50	<i>“I could complete the AI modules alongside my regular coursework.”</i> – Student participant

5.4 Integration of Quantitative and Qualitative Findings

- **Quantitative evidence:** High mean scores, significant differences across groups, and positive correlations demonstrated the perceived relevance, effectiveness, and workforce alignment of AI micro-credentials.
- **Qualitative evidence:** Themes explained *why* participants valued micro-credentials: modular design, co-created curriculum, and alignment with industry needs.

- Integration validates the AI Micro-Credential Co-Creation Framework (Figure 2) and the sequential explanatory design (Figure 3).

Overall, both quantitative and qualitative analyses consistently highlight the pedagogical and workforce benefits of industry-aligned AI micro-credentials in pharmacy education.

6. Discussion

This paper explored AI micro-credential co-creation in industry-academia collaborations and their pedagogical consequences of pharmacy education, based on a sequential explanatory mixed-methods design. Instead of repeating the findings of the empirical research, this section puts the findings in a perspective to the existing theory, logic of curriculum design, and professional scholarship of education.

6.1 Interpretation of Empirical Patterns

The results suggest that the stakeholders view AI micro-credentials as an extensively relevant, pedagogical tool, and in line with workforce expectations. Notably, these results are to be viewed not as objective indicators of competency development or employment but of perceptual indicators of pedagogical worth and preparedness. But these perceptions are analytically relevant in the context of professional education where it influences the extent with which learners are engaged, the validity of a curriculum and the adoption of an institution.

The higher ratings offered regularly by the industry participants indicate that co-created micro-credentials are closer to practice logics and workplace norms compared to traditional curriculum elements. Theoretically, this makes AI micro-credentials the boundary objects between academic knowledge structures and professional practice sets-ups. Demonstrations have shown that such an intermediary position is played via applied assignments, complex case design that is informed by the industry and experiential learning components but not content delivery.

6.2 Theoretical Contribution Beyond Pharmacy Education

This work builds upon existing arguments regarding the versatility and applicability of micro-credentials by proving that the development of competencies in the field of AI-enabled fields is not the result of the specification of outcomes or modularization alone. Rather, the results

indicate that competencies are social and pedagogical constructs created in co-creation, through an iterative process of feedback and negotiated meanings of relevance in practice.

In contrast to traditional CBE applications, which are rather faculty-based and assessment-focused, the proposed framework conceptualizes industry-academia partnership as an internal process of pedagogical formulation, which influences competency definition, logic of assessment, and curriculum revision. This builds on the CBE theory by predicting co-creation as an ad hoc disabling requirement in the fast-changing technology fields where professional knowledge and practice standards are being made and remade.

Therefore, AI micro-credential is not the supplementary training unit but design-based curriculum innovation which reorganizes the process of competency identification, teaching, and validation in professional education.

6.3 Boundary Conditions and Design Constraints

Although these results are a strong endorsement of the pedagogical promise of AI micro-credentials, they also demonstrate the existence of critical conditions of boundaries. The relatively low scores on practical application among faculty participants are an indication of the issue of faculty preparedness, teaching load, and assessment complexity. These limitations are important to point out that the efficacy of micro-credentials depends on the capacity of institutions and support of professional development, but not on the nature of the credential format.

Also, the close support of modularity and stackability creates issues of fragmentation of credentials and credential coherence. Micro-credentials will not become cumulative competency-building mechanisms in the absence of clear integration pathways, which will make them disconnected learning experiences. This highlights the need to have governance structures which would make micro-credentials to be aligned to larger curricular and accreditation frameworks.

Collectively, the discussion indicates that AI micro-credentials can only be used pedagogically successfully when they are integrated into organized partnership models and aligned competency frameworks and not using standalone or ad hoc innovations.

7. The Implications on Industry-Academia Collaboration and Workforce Development

The section goes further to discuss the findings of the study in a wider perspective of workforce-oriented curriculum design by interpreting the evidence of the study in terms of implications more than reciting the empirical patterns.

7.1 Industry Academia Collaboration as a Design Principle.

The results indicate that industry-academia collaboration cannot be viewed as an external input or a strategy of implementation, but as one of the fundamental principles of curriculum design. Teamwork defines the nature of relevant knowledge, competency priorities, and learning evaluation. The correlation of perceived collaboration with workforce readiness is robust support of the concept of relevance being created through active co-creation and not as a result of post hoc curriculum alignment.

Meanwhile, collaboration adds complexity to pedagogies, such as coordination requirements, time out of step between the academic and industrial cycles, and inconsistency in partner participation. These strains suggest that successful cooperation must be conducted by formal designs and role definition and institutional mediation, and not informal partnerships.

7.2 Multidimensional Workforce Readiness Construct.

The results of the study indicate that workforce readiness as understood by the stakeholders is beyond technical competence. The respondents pointed out that they were confident about their interaction with AI-enabled systems, were ethically aware and able to work in interdisciplinary and technological frontiers. These dimensions imply that AI micro-credentialing is involved in the formation of professional identity in AI-enabled pharmacy practice, but not merely a part of the skills training mechanism.

Theoretically, this re-conceptualizes workforce readiness as a developmental and socio-professional phenomenon, which is conditioned by learning design, authenticity of assessment, exposure to real-world practice situations. The implication of this reading is on the conceptualization of employability outcomes in the technology mediated areas in the professional education programs.

7.3 Generalizability and External Validity

The regional scope of the study in terms of pharmacy institutions and industry stakeholders in South India presents contextual specificity regarding regulatory environments, institutional agility and industry educational relationships. These are the contextual factors that might have an impact on the speed of adoption and implementation of AI micro-credentials.

Nonetheless, some of the lessons are context-transferrable such as:

- The co-creation logic of linking industry involvement to competency definition,
- The application of micro-credentials (modular and competency-mapped)
- The focus on performance-based assessment that is based on authenticity and feedback loops.

This can be applied in other professional education settings that have to contend with faster technological change, although institutional and regulatory policies are different.

7.4 Risks and Governance Implications

Although there are distinct advantages in workforce-oriented micro-credentials, the results also indicate the dangers of fragmentation, inequity of recognition, and over-congruency to short-term industry demands. The limitations of scalability are also implied by the constraints on the faculty workload and the inconsistency of the institutional capacity.

The above-mentioned risks highlight the necessity of institutional governance structures that would incorporate micro-credentials into a coherent curricular trajectory, and quality assurance as well as balance the relationship between workforce relevance and background professional knowledge.

7.5 Synthesis and Transition

Overall, this part places the industry-academia collaboration as a framing mechanism in designing pedagogies and aligning workforce as an alternative to a marginal model of partnership. These reflections lead to direct directions / implications:

Section 8, translating the collaboration into the strategies of curriculum, teaching and assessment; and

Section 9 that deals with policy, accreditation and institutional conditions of sustainable adoption.

8. Pedagogical Implications for Pharmacy Education

Pedagogical implications of this study are to be perceived as design principles as opposed to universal prescriptions. Although it can be concluded that AI micro-credentials are perceived to be of high pedagogical value, their success depends on the institutional preparedness, faculty capacity and the level of industry engagement. Noteworthy, the results support the idea that micro-credentials are not educational because of their format, but due to their pedagogical construction, leadership, and integration into the current curricula.

8.1 Curriculum Design Implications

The most effective position of AI micro-credentialing is to align as an integrative module, and not independently, nor opposing learning units. The mapping of AI literacy and data-informed decision-making, ethical thinking and clinical use should be explicitly mapped to the established pharmacy competency models so that they are not redundant and fragmented in the curricula.

In the context of design-based education, the results indicate that co-creation improves the relevance of the curriculum while it brings about the issue of coordination. Institutions need to thus put in place governance frameworks that are responsive to industry but at the same time curricular coherence and academic rigor. In the absence of such structures, micro-credentials are under the risk to be additive credentials instead of transformative curriculum components.

8.2 Teaching–Learning and Assessment Implications

The paper identifies experiential and applied pedagogies such as industry-informed casework, simulation, and project-based learning as some of the key mechanisms that facilitate perceived pedagogical effectiveness. These methods are ways of operationalizing competency-based education by presupposing application and reflection instead of content coverage.

Nevertheless, the results also highlight the limitations to implementation. Although pedagogically sound, performance-based assessment involves intensive instructional design work as well as assessment literacy. The institutions need to then balance the rigor of

assessment with its feasibility especially in huge or resource-based cohorts to make it sustainable.

8.3 Division and Institutional Implications.

The relatively lower ratings of practical use by faculty participants are indicative of a lack of ability and confidence in the delivery of AI-based pedagogy. This implies that the faculty development is not a fringe support process but structural precursor to successful implementation of micro-credential presence. They need to invest in the upskilling of the pedagogy, workload identification, and working interdisciplinarily to avoid burnout of innovation and unequal adoption.

Collectively, this section supports the idea that the effectiveness of pedagogical design is created through the deliberate design, institutional facilitation and consistent logic of assessment, as opposed to micro-credentials as isolated innovations.

9. Policy and Accreditation Implications

The results are evidently applicable to the accreditation and policy frameworks, especially related to the competency alignment and relevance to the workforce. Nevertheless, AI micro-credentials must be perceived as innovations that are policy relevant as opposed to policy ready.

9.1 Accreditation Alignment and Structural Tensions

The conformity to the ACPE and FIP competency areas to digital health, ethics, and practice readiness, justifies the validity of AI micro-credentialing in the formal pharmacy education. However, the accrediting bodies might face some obstacles associated with credit equivalence, standardization, and quality assurance, especially with the industry differences in participation and institutional capability.

These strains indicate that accreditation systems need to be changed by no longer depending on fixed credit models of recognition to more dynamic outcome-based models of evaluation, but ensure the protection of the standards of academic quality.

9.2 Policy Risks and Implementation Constraints

The high growth in micro-credentials is also policy risky due to the risk of credential inflation, the lack of equality, and learning fragmentation. In the absence of explicit regulatory standards to determine the quality of design and integration as well as the cycles of review, micro-credentials can potentially harm rather than improve the sense of coherence in the curricula. The policymakers should thus contextualize micro-credentials in the context of systematic qualification ecosystems, and not as an individual workforce tool.

In general, the policy implications focus on the careful, gradual implementation, which is facilitated by institutional governance and accreditation advice to guarantee the long-term educational value.

10. Conclusion

This study demonstrates that AI micro-credentials that are co-designed by organized industry-academia collaborations can have perceived pedagogical and workforce-related value in pharmacy education. The evidence on stakeholder groups has shown that there is high perceived relevance, competency growth, and correspondence with professional practice and especially when credentials are based on applied learning and authentic assessment.

The main contribution of the study is that it will develop a conceptual framework of design-based that will enhance the competency-based education to AI-enabled professional learning by developing a co-creation, explicit competency mapping, and feedback-driven assessment. Instead of serving as additive credentials, AI micro-credentials can be integrative curriculum design processes when instituted in coherent institution and partnership arrangements.

Presenting both enabling conditions and boundary constraints, the study offers a balanced base of the future curriculum innovation in the process of AI-driven pharmacy education.

11. Limitation and Future Research Trends.

11.1 Analytical Implications of Limitations.

The dependence on self-reported perceptions of the stakeholder's limit inferences regarding actual competency acquisition in competency or at work a limitation. Based on this, "pedagogical effectiveness," and workforce readiness, among others, need to be viewed as how things seemed to work, rather than the actual performance metrics. Besides this, regional focus

brings in situational factors in terms of regulatory systems, institutional flexibility and acting in the industry.

Although these are limiting factors to direct generalization, it should not undermine the analytical value of the study. They, instead, emphasize the necessity to focus on the differences between context-specific outcomes (e.g., accreditation settings, institutional capacities), and context-portable concepts (e.g., co-creation logic, competency mapping, assessment feedback loops).

11.2 Future Research Directions

Future studies are advised to go beyond the perceptual findings to study:

- Long-term impacts of AI micro-credentials on the professional performance and employability.
- Cross-institutional and cross-national comparisons to find out policy and curricular transferability.
- Modelling governance, cost, and scalability of maintaining industry-academia partnerships.
- The development patterns of the faculty as facilitators of pedagogical performance.

These directions are based directly on tension identified in the results and especially between scalability, curricular coherence, and institutional capacity.

Consent for Publication:

The final manuscript is read and approved by all the authors, and they agree that it can be published in the journal.

Conflict of Interest:

The authors do not mention any conflicts of interest in the study.

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