From Educational Tools to Collaboration Outcomes: The Mediating Role of Integration Depth in Industry-Academia Collaborations

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Abstract: University-industry collaboration has become a central strategy for increasing graduate employability and aligning higher education with labor market needs. While educational and institutional tools such as project-based learning and credit transfer systems have been widely promoted, empirical evidence on how these tools link to university-industry collaboration outcomes remains unclear. This study fills this gap by examining the mediating role of integration depth in university-industry collaboration (Barachino et al., 2025; Cohen et al., 2025; Council of the European Union, 2022; Eimer et al., 2023; Etzkowitz & Leydesdorff, 2000; Naseer et al., 2025; OECD, 2023; Varadarajan et al., 2023). Based on survey, institutional, and employer assessment data from 12 applied universities, this study uses structural equation modeling to analyze the relationships between project-based learning intensity, access to credit banks, integration depth, and collaboration outcomes. Collaboration outcomes are conceptualized as a latent construct indicated by graduate employment quality, employer satisfaction, and the commercialization of student projects (Naseer et al., 2025; Kline, 2016; Hair et al., 2019; Zhang & Li, 2023).

The results show that both project-based learning intensity and access to credit banks are positively correlated with collaboration outcomes, primarily through their effects on integration depth. When integration depth is considered, the direct impact of these tools on outcomes is significantly reduced. Furthermore, supplementary analyses show that governance synergies strengthen the relationship between integration depth and collaboration outcomes, highlighting the importance of a supportive institutional environment. This study advances a process-oriented understanding of the effectiveness of university-industry collaborations by highlighting the depth of integration as a mediating mechanism. Our findings suggest that educational and institutional innovations improve collaboration outcomes by fostering deeper integration between university and industry partners, rather than by increasing the volume of activities (Cohen et al., 2025; Etzkowitz & Leydesdorff, 2000).

Keywords: University-Industry Collaboration; Depth of Integration; Project-Based Learning; Credit Transfer; Applied Higher Education

1. Introduction

Enhancing university-industry collaboration has become a central goal of higher education reforms worldwide, particularly in applied and professionally oriented universities. As labor markets demand graduates with practical skills, industry understanding, and innovation capabilities, universities are under pressure to more closely align their educational processes with industry practices. In response, educational innovations such as project-based learning and institutional arrangements such as credit banks have been widely adopted to bridge the gap between education and employment. However, despite the widespread adoption of these tools, empirical evidence on how these tools produce meaningful collaboration outcomes remains fragmented.

Strengthening university-industry collaboration has become a central goal of higher education reform worldwide, particularly in applied and professionally oriented universities. As labor markets demand graduates with practical skills, industry understanding, and innovation capabilities, universities are under pressure to more closely align their educational processes with industry practices. In response, educational innovations such as project-based learning (PBL) and institutional arrangements such as credit banks have been widely adopted to bridge

the education-employment gap. However, despite the widespread adoption of these tools, empirical evidence on how they produce meaningful collaboration outcomes remains fragmented.

Existing research tends to evaluate PBL and credit systems primarily in terms of student learning outcomes and employability indicators. By immersing students in real-world tasks, PBL has been shown to enhance problem-solving skills, teamwork, and career readiness. Similarly, credit banks have been promoted as a mechanism to recognize diverse learning experiences and facilitate flexible learning pathways across organizations and work environments. Although these studies demonstrate a positive association with individual-level outcomes, they often treat university-industry collaboration as a background condition rather than the focus of their analysis.

More importantly, previous research has not adequately considered the process mechanisms through which educational and institutional reforms lead to collaborative outcomes. At many applied universities, collaboration with industry remains superficial, with minimal joint governance and resource sharing, such as internships and short-term projects. Under these circumstances, even carefully designed project courses and credit transfer systems may fail to produce sustainable collaborative outcomes. This suggests that the effectiveness of educational and institutional tools may depend not so much on their implementation alone, but on whether they contribute to deeper integration between universities and industry partners.

To fill this gap, this study introduces the concept of depth of integration as a central explanatory mechanism. Depth of integration refers to the degree to which universities and industry partners are substantively and deeply involved in each other's educational and production processes, including joint curriculum design, co-mentoring students, joint project implementation, and shared responsibility for outcomes. Rather than viewing collaboration as a binary condition, depth of integration captures qualitative differences in how collaboration is organized and implemented. From this perspective, educational and organizational innovations are important insofar as they can foster deeper integration and thus materialize the results of collaboration.

Based on this framework, this study examines two widely adopted tools in applied higher education: the intensity of project-based learning and the accessibility of credit banks. Project-based learning may foster integration by requiring continuous industry involvement in teaching and assessment, while credit banks may institutionalize collaboration by formally recognizing work-based learning and aligning educational standards with industry standards. However, empirical research remains open as to whether these tools directly affect collaboration outcomes or function primarily through deepening integration.

Using data from applied universities in creative and digital fields, this study develops and tests a mediation model to explore the following research questions: How do the intensity of project-based learning and the accessibility of credit banks improve the outcomes of university-industry collaboration, and does the depth of integration act as an important mediating mechanism?

Despite the rapid spread of collaboration-oriented reforms, the debate over why similar initiatives produce uneven outcomes across universities remains ongoing. At many applied universities, collaborations with industry remain event-based and transactional, with limited joint decision-making and weak alignment between academic requirements and workplace standards. Under these circumstances, educational reforms may increase student engagement but fail to generate meaningful collaboration outcomes for external partners. This gap highlights the need for an analytical focus on the collaboration process rather than the mere existence of collaborative activities.

We conceptualize this process dimension using the concept of depth of integration, which is defined as the degree to which industry partners are structurally integrated into the design and delivery of education, and conversely, the degree to which universities are integrated into companies' talent development and innovation processes.

Depth of integration differs from the breadth of collaboration (number of partners) and frequency of collaboration (number of activities). It captures the degree of co-production in curriculum design, supervision, evaluation, and ownership of outcomes. This

distinction is crucial for interpreting the effectiveness of project-based learning and credit transfer systems. Both can increase collaboration frequency without necessarily deepening integration.

The empirical context for this study, a creative and digital applied university, provides a suitable setting given that these fields rely heavily on project workflows, portfolio-based assessment, and industry-standard production pipelines. These characteristics increase the feasibility of true project engagement and allow for direct observation of collaboration outcomes such as employer evaluation and project continuity. At the same time, the analytical focus of this study is not limited to a specific field, but rather emphasizes deep integration as a transferable mechanism across the higher education system.

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature and develops hypotheses; Section 3 describes the research design, measurement indicators, and analytical strategy; Section 4 reports the empirical results, including mediation and robustness analyses; and Section 5 discusses theoretical and practical implications, limitations, and future research directions.
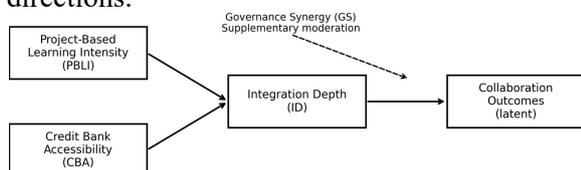
Figure 1. Conceptual Model

Note: Governance synergy is examined as a contextual moderator in supplemental analyses.
PBLI ->
-> Integration depth -> Collaboration outcomes (potential)
CBA ->
(Supplemental) Integration depth x Governance synergy -> Collaboration outcomes
Note: Governance synergy is examined as a contextual moderator in supplemental analyses. Platform-related factors are not included in the main model.

2. Literature Review and Hypotheses

2.1 Industry-Academic Collaboration and Depth of Integration

Industry-academia collaboration has been widely recognized as an important mechanism for aligning higher education with labor market demands, particularly in applied and professional-oriented universities. Previous research has documented various forms of industry-academia collaboration, ranging from student internships and special lectures to joint curriculum development and collaborative research. However, a growing literature suggests that not all forms of collaboration produce equal outcomes. Superficial or temporary collaboration often fails to deliver lasting benefits to either students or industry partners.

Recent research has increasingly emphasized the importance of integration, rather than mere interaction. Integration refers to the deep involvement of university and industry partners in each other's organizational and educational processes, sharing responsibilities, resources, and risks. From this perspective, the quality of collaboration depends not only on the existence of a partnership but also on its depth. Depth of integration captures the extent to which collaboration extends beyond formal agreements to substantive co-design of curricula, co-teaching of students, and joint ownership of educational and innovation outcomes.

Deep integration can be understood as relational capabilities built through repeated coordination and common routines. As partners co-design curricula and jointly teach students, shared expectations regarding competency standards and assessment criteria are formed. Such collaboration reduces information asymmetries, lowers coordination costs, and enables collaboration to extend from peripheral activities (e.g., guest lectures) to core educational processes (e.g., credit-bearing modules and capstone projects).

A depth perspective not only captures the intensity of interactions but also emphasizes the internalization of common routines and the co-evolution of organizational practices. In higher education, deep integration is often achieved through boundary-spanning roles (e.g., co-supervisors, industry mentors) and boundary objects (e.g., jointly developed assessment rubrics, project outlines, competency standards) that stabilize expectations across organizational boundaries. These elements reduce translation loss between educational goals and workplace requirements, increasing the likelihood that collaborative activities will produce sustained performance outcomes.

From a measurement perspective, deep integration is best operationalized as a multidimensional construct. In this study, this includes joint curriculum design, jointly developed courses and assessments, joint mentoring structures, shared platforms for practice or research, and shared responsibility for outcomes. This operationalization aligns with calls to move beyond binary indicators of partnership, emphasizing substantive collaborative content and organizational embeddedness.

Theoretically, focusing on the depth of integration shifts the unit of analysis from individual student experiences to the inter-organizational interface between universities and industry partners. This shift is important because many collaboration outcomes (e.g., employer satisfaction and project commercialization) depend not only on student-level participation but also on sustained interaction and shared governance.

Empirical evidence suggests that deeper integration leads to improved graduate employability, employer satisfaction, and knowledge transfer. The involvement of industry stakeholders in curriculum design and project evaluation more closely ties educational content to workplace practice. Similarly, ongoing collaborative projects create opportunities for students to engage in authentic problem-solving and facilitate the translation of academic learning into professional competencies.

Hypothesis 1 (H1). The depth of integration is positively correlated with the outcomes of university-industry collaboration.

2.2 Intensity and Depth of Integration of Project-Based Learning

Project-based learning (PBL) has been widely adopted as an educational strategy to enhance experiential learning and bridge the gap between theory and practice. By engaging students in complex, open-ended challenges, PBL promotes active learning, collaboration, and the application of knowledge to realistic situations. In applied higher education, PBL is often implemented through industry-related projects that require input from external partners.

Previous research has shown that PBL has a positive impact on student learning and employability, but few studies have examined its role in shaping collaborative structures. High-intensity PBL, characterized by frequent project courses, long project durations, and substantial industry participation, often requires close collaboration between universities and industry partners. Industry stakeholders may be involved in defining project challenges, mentoring students, and evaluating project outcomes.

Two particularly important mechanisms are apparent. First, PBL functions as a boundary-crossing pedagogy, establishing a structured interface for collaborative problem definition and solution development. Industry partners can provide real constraints (time, budget, standards) and tacit knowledge that are difficult to replicate in a classroom environment. Second, high-intensity PBL can institutionalize industry involvement through repeated cycles of project assignment, mentoring, and evaluation, gradually normalizing co-production routines and incorporating partners into academic governance.

However, the literature also cautions that the benefits of PBL are incidental. When industry involvement is symbolic or limited to one-off projects, PBL may only increase student workload without improving collaborative outcomes. This supports our assertion that PBL contributes to outcomes primarily through deepening integration, rather than simply increasing the volume of activities.

From an integration perspective, PBL serves as a collaborative platform that incorporates industry practices into the educational process. As project-based activities become more central to the curriculum, universities have greater incentives to formalize partnerships with industry partners, align assessment criteria, and establish joint teaching mechanisms.

Hypothesis 2 (H2): Project-based learning intensity is positively correlated with integration depth.

2.3 Accessibility and Depth of Integration of Credit Banks

Credit banks have developed as an institutional mechanism for accrediting and accumulating learning outcomes across diverse educational and work environments. By formally accrediting credits earned through internships, specialized training, and industry certifications into degree programs, credit banks aim to increase learning flexibility and permeability

across the education and employment systems.

From the perspective of industry-academia collaboration, accessibility to credit banks can play a structural role in institutionalizing collaboration. To achieve high accessibility characterized by transparent accreditation rules, user-friendly systems, and broad student participation, universities and industry partners must jointly define learning standards and assessment criteria.

Furthermore, credit banks can transform workplace learning from an informal supplement to an integral part of formal education. When industry training and project experience are formally recognized, collaboration becomes embedded within an institutional framework rather than relying on ad hoc arrangements.

Hypothesis 3 (H3): Accessibility to credit banks is positively correlated with depth of integration.

2.4 Depth of Integration as a Mediating Mechanism

Project-based learning and credit transfer systems are often assumed to directly improve collaboration outcomes, but their effectiveness may depend on deeper integration. Without substantial integration, project activities may remain isolated educational interventions, and credit transfer systems may function as a management tool with limited impact on collaboration outcomes.

Depth of integration provides a theoretical perspective for understanding how educational and organizational innovations lead to outcomes. High project-based learning intensity and easy access to credit banks may increase collaboration capacity, but whether this capacity is effectively realized depends on depth of integration. Through joint curriculum design, co-teaching, and joint projects, depth of integration enables university and industry partners to align expectations, coordinate actions, and facilitate the realization of collaboration outcomes.

Hypothesis 4 (H4): Depth of integration mediates the relationship between (a) project-based learning intensity and collaboration outcomes, and (b) access to credit banks and collaboration outcomes. The literature suggests that project-based learning and credit transfer systems likely influence collaboration outcomes by reshaping the inter-organizational interface between universities and industry partners.

Therefore, this study examines a mediation model in which depth of integration is a central pathway linking educational and organizational tools to collaboration outcomes.

2.5 Governance Synergy as a Contextual Moderator (Supplementary Note)

Governance synergy refers to the degree to which universities, industry partners, and government agencies collaborate and cooperate through supportive policies, common decision-making structures, and aligned incentives. High governance synergy may enhance the ability of integrated partnerships to translate collaborative processes into tangible outcomes.

Hypothesis 5 (H5): Governance synergy strengthens the positive relationship between integration depth and collaboration outcomes.

3. Methods

3.1 Study Background and Sample

Ethical approval was obtained through the lead university's institutional review process. All participants were informed of the study objectives, the voluntary nature of their participation, and confidentiality measures. No personally identifiable information was collected, and matching across data sources was based on anonymized identifiers generated by the participating institutions.

To further mitigate common methodological biases, primary outcome measures were triangulated with employer ratings and institutional records, where available. Employer ratings were collected from the immediate supervisors of graduates who participated in collaborative projects, and commercialization outcomes were verified through program-level documentation (e.g., project logbooks and recruitment reports). This mixed-source design reduces reliance on a single respondent group and strengthens measurement validity (Podsakoff et al., 2003; Baumgartner & Weijters, 2021).

Data collection followed standardized protocols at each institution. The research team worked with program directors to distribute surveys during capstone project presentations and final seminars, ensuring that respondents had opportunities to engage deeply in industry-academia collaboration activities. Participation was voluntary and anonymous. To improve response quality, the survey included attention

checks and excluded responses with a high number of missing values or linear patterns.

This study targeted applied universities in China that are implementing industry-academia collaboration reforms, particularly in creative and digital fields such as animation, digital media, and game design. Data were collected from 12 applied universities located in eastern, central, and western China. All participating universities had formal collaboration agreements with industry partners and implemented project-based curricula and credit transfer systems.

At the student level, a structured questionnaire was administered to final-year undergraduates and graduates. A total of 2,400 valid student responses were obtained. To reduce common-source bias, student survey data was supplemented with institutional records and employer evaluations. Employer feedback questionnaires were collected from a subset of graduates (n = 768), and institutional data was obtained from education management systems and collaboration platforms.

3.2 Measures

Collaboration outcomes are conceptually multifaceted and may not be fully captured by a single indicator, so they were modeled as latent constructs. Employment quality, employer satisfaction, and project commercialization are complementary indicators of collaboration effectiveness, including labor market fit, industry competency assessment, and persistence or applicability of student outcomes to practice. Modeling these indicators as latent constructs reduces measurement error and allows for a more theoretically consistent assessment of collaboration outcomes.

All constructs were measured using reflective indicators. In addition to Cronbach's alpha, composite reliability (CR) and average variance extracted (AVE) were calculated to assess internal consistency and convergent validity. Discriminant validity was assessed by comparing the square root of AVE with inter-construct correlations and examining cross-loadings. Results indicate good reliability and validity across constructs.

Measure development proceeded in three steps. First, we adapted an item pool from previous research on the integration of experiential learning, credit transfer, and collaboration and reworded it for the applied higher education context. Next, a panel of three academic experts and four industry mentors reviewed the items to assess content validity and clarity of terminology. Finally, we conducted a pilot test with 86 students to refine the wording and remove ambiguous items.

All perceptual indicators were rated using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Measures were adapted from existing rating scales and refined for a higher education context.

Exam wording was translated and back-translated as needed and piloted with a small group of students to ensure clarity. Minor adjustments were made to fit the university context (e.g., replacing common industry terminology with partner-based project descriptions).

Construct validity was assessed using confirmatory factor analysis. Internal consistency and convergent validity were assessed using Cronbach's alpha, as well as composite reliability and mean variance. Discriminant validity was assessed by comparing the square root of the average mean (AVE) values with the correlations between constructs. Results indicated sufficient reliability and validity across constructs.

Project-Based Learning Intensity (PBLI). PBLI measures the extent to which project-based instruction is integrated into the curriculum (e.g., frequency, reliability, and industry involvement) (Cronbach's alpha = 0.86).

Credit Bank Accessibility (CBA). CBA measures students' perceptions of the accessibility and ease of use of credit transfer services (e.g., transparency of transfer rules and ease of use of the system) (alpha = 0.83).

Depth of Integration (ID). Depth of integration reflects the degree of substantial collaboration between universities and industry partners, including joint curriculum design, co-developed courses, joint supervision, and shared platforms (alpha = 0.89).

University-Industry Collaboration Outcomes (UIC Outcomes). Collaboration outcomes were modeled as a latent construct, represented by job quality, employer satisfaction, and commercialization of student projects (alpha = 0.85). Governance Synergy (GS). Governance synergy is an indicator that captures the degree of collaboration between universities, industry partners, and public institutions (alpha = 0.81).

3.3 Analytical Strategy

Robust standard errors were used in all analyses. Missing data were handled using full-information maximum likelihood estimation in SEM, which is appropriate under the assumption of missing at random and avoids listwise deletion, which can reduce statistical power.

Because endogeneity is a common concern in collaboration research (e.g., institutions with better outcomes are more likely to adopt reforms), we conducted sensitivity analyses by controlling for institutional characteristics that serve as proxies for collaboration capacity, such as program size and prior partnership duration (where available). Our main findings regarding mediation were robust, suggesting that the results are not driven solely by institutional selection effects.

In addition to the main SEM specification, two alternative models were estimated to assess model validity. The first alternative model included direct paths from project-based learning intensity and accessibility to credit banking to collaboration outcomes. The second alternative model reversed the direction of mediation (i.e., outcomes predicting integration depth) to assess whether the results could be explained by reverse causality in cross-sectional data. The hypothesized mediation model demonstrated superior fit and a more theoretically consistent parameter pattern. Data analysis proceeded in three stages. First, descriptive statistics and correlation analyses were conducted. Second, a mediation model,

specifying depth of integration as the mediating variable, was tested using structural equation modeling (SEM). Model fit was assessed using chi-square/degrees of freedom, CFI, TLI, and RMSEA. The mediation effect was tested using bootstrap methods with 5,000 resamples to generate bias-corrected confidence intervals. Governance synergy was examined as a supplementary contextual moderator of the relationship between depth of integration and collaboration outcomes (Kline, 2016; Hair et al., 2019).

Several steps were taken to mitigate common method variance. First, data sources were separated as much as possible (student surveys, employer assessments, institutional records). Second, questions were designed to mitigate priming effects, ensuring that respondents had no right or wrong answers. Statistical comparison of the single-factor model with the proposed measurement model revealed a significantly lower fit, suggesting that common method variance is unlikely to dominate the results (Podsakoff et al., 2003; Baumgartner & Weijters, 2021).

To assess the validity of the mediation structure, alternative models were estimated, including a direct effects model excluding the mediator and a partial mediation model with direct paths from PBLI and CBA to outcomes. The model comparison results supported the mediation model, which is consistent with the theoretical argument that integration depth constitutes the primary mechanism linking reform measures and collaboration outcomes.

Table 1. Constructs, Measurement, and Reliability

Construct	Description (summary)	Data source	Cronbach's alpha
Project-Based Learning Intensity (PBLI)	Frequency, duration, and industry involvement of project-based instruction	Student survey; teaching records	0.86
Credit Bank Accessibility (CBA)	Transparency, usability, and effectiveness of credit recognition services	Student survey; platform logs	0.83
Integration Depth (ID)	Substantive integration (joint curriculum design, co-supervision, shared platforms)	Institutional records	0.89
Collaboration Outcomes (UIC)	Latent outcome reflected by employment quality, employer satisfaction, and project commercialization	Employer survey; graduate tracking	0.85
Governance Synergy (GS)	Coordination among universities, industry partners, and public authorities	Institutional assessment	0.81

4. Results

4.1 Descriptive Statistics and Correlations

Table 2 presents descriptive statistics and

correlations for key variables. Project-based learning intensity, accessibility to credit banking, and depth of integration are positively correlated. Depth of integration is positively correlated with collaboration outcomes,

providing preliminary support for the existence of a mediating mechanism.

4.2 Measurement Model

To examine whether collaboration outcomes can be treated as a coherent latent construct, we compared a single-factor outcome specification with a three-indicator correlated outcome specification. The latent outcome model provided a concise representation that adequately considered validity and supported treating collaboration outcomes as a unified construct in the mediation analysis.

Standardized factor loadings ranged from 0.62 to 0.88 and were statistically significant ($p < .001$), indicating sufficient convergent validity. Composite reliability exceeded 0.80 for all constructs, and average average values were above or near the 0.50 threshold. Discriminant validity tests showed that the square root of the average average was greater than the correlation between constructs, supporting the uniqueness of the constructs.

Confirmatory factor analysis showed that all indicators loaded significantly onto their intended constructs. The three indicators of collaboration outcomes (job quality, employer satisfaction, and project commercialization) loaded onto a single latent factor, supporting the measurement structure.

4.3 Structural Model and Hypothesis Testing

Substantively, our results suggest that project-based learning and credit bank mechanisms are most effective when they bring about structural changes in how universities and industry partners coordinate, supervise, and evaluate learning. Under shallow collaboration structures, these tools may increase activity but not produce a proportional increase in performance. The model explains significant variance in integration depth and collaboration outcomes. The coefficient of determination for integration depth suggests that project-based learning intensity and credit bank accessibility significantly account for variance in integration quality between respondents and their institutions. The coefficient of determination for collaboration outcomes suggests that integration depth is a significant predictor of collaboration performance, even after accounting for direct effects.

SEM results strongly support the mediated model. Project-based learning intensity positively predicts integration depth (beta = 0.41, $p < .05$), and credit bank accessibility positively predicts integration depth (beta = 0.29, $p < .05$). Depth of integration strongly predicts collaboration outcomes (beta = 0.47, $p < .01$). When considering depth of integration, the direct effects of project-based learning intensity and accessibility to credit banks on collaboration outcomes are weak and insignificant, suggesting a mediating mechanism prevails.

4.4 Supplementary Analysis: Governance Synergy

Supplementary analyses suggest that governance synergy strengthens the impact of integration depth on collaboration outcomes (interaction beta = 0.11, $p < .01$).

4.5 Robustness Check

Finally, we assessed whether results differed by respondent cohort (current final-year students vs. recent graduates). Multigroup comparisons revealed consistent patterns of mediation pathways across cohorts, suggesting that this mechanism is not specific to a particular academic stage.

Robustness tests also examined whether the mediating effect was sensitive to the weighting of outcome measures. We re-estimated the model using standardized versions of the three indicators and an alternative approach in which the loading of one indicator was fixed at 1. Our conclusions regarding the mediation effect remained unchanged.

The alternative specifications and additional controls did not substantively change our main

Table 2. Descriptive Statistics and Correlations

Variable	Mean	SD	PBLI	CBA	ID	Gov
PBLI	3.87	0.66	1			
CBA	3.54	0.71	0.42***	1		
Integration Depth (ID)	3.68	0.59	0.56***	0.45***	1	
Governance Synergy (GS)	3.75	0.81	0.37***	0.33***	0.50***	1

Note: *** $p < .001$. Collaboration outcomes are modeled as a latent construct and are therefore not included in this correlation table.

Table 3. Structural Equation Modeling Results

Path	Std. beta	p-value	Conclusion
PBLI -> ID	0.41	< .05	Supported
CBA -> ID	0.29	< .05	Supported
ID -> Collaboration Outcomes	0.47	< .01	Supported
PBLI -> Collaboration	0.08	n.s.	Not

Outcomes (direct)			supported
CBA -> Collaboration Outcomes (direct)	0.04	n.s.	Not supported

Model fit: chi-square/df = 2.87; CFI = 0.962; TLI = 0.950; RMSEA = 0.037.

Table 4. Bootstrap Mediation Effects (5,000 resamples)

Indirect path	Indirect effect	95% CI
PBLI -> ID -> Outcomes	0.193	[0.142, 0.252]
CBA -> ID -> Outcomes	0.137	[0.091, 0.193]

Table 5. Moderating Effect of Governance Synergy (Supplementary Analysis)

Interaction term	Outcome	Std. beta	p-value
ID x Governance Synergy	Collaboration Outcomes	0.11	< .01

5. Discussion and Implications

5.1 Discussion of Key Findings

Taken together, these findings support a process perspective on collaboration effectiveness. Collaborative outcomes stem not simply from a collection of project activities and credit transactions, but from deeper organizational couplings that enable joint problem definition, joint oversight, and mutual learning.

The moderating role of governance synergies reinforces the view that integration is a organizational and institutional outcome. Deep integration is more likely to produce sustainable outcomes when governance structures reduce coordination costs and provide stable incentives. This does not mean that governance can compensate for shallow integration; rather, it determines whether deep integration is productive.

Notably, the weak direct effects suggest that collaboration-oriented reforms may suffer from an "implementation gap" when treated as stand-alone interventions. PBL courses can be designed in a teacher-centered or detached from industry routines, and credit banks can be implemented as managed services without restructuring learning standards. The results suggest that the crucial difference lies in whether these reforms help build common structures, routines, and accountabilities between universities and industry partners.

This study examines how educational and institutional tools contribute to university-industry collaboration outcomes through the mediating role of integration depth. Results show that both project-based learning intensity and credit bank accessibility improve collaboration outcomes, primarily by deepening integration between universities and industry partners. The direct impact of these tools on outcomes weakens when integration depth is taken into account, highlighting the importance of integration mechanisms.

5.2 Theoretical Implications

Methodologically, modeling collaboration outcomes as latent constructs answers the call for more robust and theoretically consistent measures of collaboration performance. Treating job quality, employer satisfaction, and commercialization as separate dependent variables can encourage "outcome fragmentation" and increase model complexity. The latent construct approach provides a concise representation while preserving multidimensional information.

Our findings also address institutional explanations for reform effectiveness. Instructional and institutional tools are often evaluated based on adoption (whether an institution "implements PBL" or "has a credit bank"). However, our findings suggest that adoption alone is an insufficient indicator. What matters is whether the tools are deeply embedded in governance and operational collaboration, increasing the depth of integration. This helps explain why reforms can sometimes result in symbolic compliance without accompanying performance improvements. From a boundary-spanning perspective, depth of integration can be interpreted as the extent to which university and industry partners establish shared boundary objects and routines (e.g., project outlines, assessment rubrics, and instructional protocols). These shared artifacts reduce interpretational ambiguity and allow student work to circulate between academic and workplace settings. PBL and credit mechanisms can help institutionalize such boundary objects.

First, this study advances the mechanism-focused perspective by identifying depth of integration as a key process linking innovation measures and collaboration outcomes. Second, it integrates project-based learning and credit mechanisms into a unified framework, highlighting their complementary roles in promoting deeper integration. Furthermore, by

modeling collaboration outcomes as latent constructs, it provides a more comprehensive assessment of collaboration outcomes.

5.3 Practical Implications

This study suggests that for industry partners, collaborations that incorporate ongoing engagement and educational aspects are likely to increase the profitability of collaborations. Companies may benefit from a focus on long-term collaboration portfolios (e.g., a series of projects, supervision of multiple cohorts) rather than one-off engagements that do not build deep integration.

For policymakers and system leaders, these results highlight the value of conditions that support enduring partnerships, such as stable funding for joint supervision, incentives for industry mentors, and quality assurance frameworks that consider not only outcome metrics but also the integration process. Governance synergies are important for aligning incentives and reducing transaction costs for deep integration.

For universities, a practical implication is to redesign project-based learning based on shared responsibility rather than external participation. This includes involving industry partners in project scoping, adopting common evaluation criteria, and establishing co-mentoring mechanisms that continue beyond a single course. Similarly, access to credit banks should be linked to jointly defined competency standards and evidence requirements. This ensures that workplace learning is recognised through transparent and trustworthy processes.

For universities, our findings suggest that expanding project-based learning or introducing credit banks is unlikely to be enough without deeper institutional integration such as joint curriculum design, joint supervision and sustained partnership structures.For industry partners, continuous involvement in the educational process may be beneficial in translating collaboration into shared outcomes.At the policy level, governance structures may be most effective if they reduce coordination costs and stabilise long-term collaborations.

5.4 Limitations and Future Research

Future research could also explore heterogeneity across disciplines and types of partnerships. Collaborations in creative and digital fields often involve project-based workflows and rapid iteration, making depth of integration more pronounced through course and project structures. It remains important to examine whether similar mediating mechanisms hold for more research-intensive collaborations or more regulated professional fields.

A further limitation concerns the granularity of measurement. While depth of integration was operationalized as a multidimensional construct, some aspects of collaboration quality (e.g., trust, informal coordination, relationship embeddedness) are difficult to capture using survey or control indicators alone. Future mixed-methods research could combine SEM with qualitative process tracking to examine how integration routines are built, maintained, or disrupted.

This study is limited by its cross-sectional and single-country design. Future research could use longitudinal or comparative designs to examine the applicability of the mechanism of depth of integration across higher education systems. Furthermore, our analysis cannot completely eliminate endogeneity concerns, such as self-selection into more intensive project-based learning environments or differential access to credit union services across institutions. While incorporating institutional records and employer evaluations mitigates the risk of common-source bias, future research could strengthen causal claims by utilizing quasi-experimental designs (e.g., phased-in implementation of credit transfer policies), instrumental variable approaches, or panel data that track cohorts over time. Finally, the generalizability of the proposed mechanism would be improved by comparisons, especially between higher education systems where workplace learning is already strongly institutionalized and those where university-industry collaboration is still in its infancy.

Appendix A. Additional Information

6. Conclusion

From a broader perspective, this study emphasizes that collaboration outcomes should not be measured solely by the number of partnerships and activities, but rather by the extent to which collaboration is structurally embedded in curriculum, assessment, instruction, and accountability. This shift from counting the number of activities to assessing integration provides a clearer foundation for

both research and management in applied higher education.

This study examined how educational and institutional tools connect to the outcomes of industry-academia collaborations in applied higher education, focusing on the depth of integration as a central mediating mechanism. Across the analyzed institutions, the intensity of project-based learning and access to credit banks were both positively correlated with the depth of integration, which strongly predicted collaboration outcomes modeled as latent constructs represented by employment quality, employer satisfaction, and project commercialization. When the depth of integration was taken into account, the direct impact of the two reform measures on outcomes significantly diminished. This suggests that the primary contribution of these reform measures lies in enabling deeper structural integration, rather than bringing about immediate performance improvements on their own.

These findings highlight important implications for contemporary collaboration reform. Expanding the scale of collaboration activities is not synonymous with improving collaboration effectiveness. Universities may introduce project-based courses and credit-based systems without achieving the organizational embeddedness necessary for these tools to function as a collaborative infrastructure. In contrast, deep integration reflects a qualitatively different state in which universities and industry partners co-create educational processes, share oversight responsibilities, and align assessment and competency standards. This deeper embeddedness is likely a prerequisite for collaboration tools to generate coherent and transferable impact.

In research on higher education collaboration, this study offers a process-oriented perspective that complements activity-based evaluation. By holistically considering outcomes and modeling integration as a mediating mechanism, this study demonstrates that innovations can be evaluated not simply by their existence but also by their ability to transform how collaborations are organized and governed. Future research is expected to strengthen causal inference through longitudinal and quasi-experimental research designs and further examine how different partnership configurations, sector contexts, and labor market dynamics affect the formation and

effectiveness of integration depth.

Overall, the evidence suggests that the most effective path from reform to outcomes is through integration. Leadership and institutional innovations are important for reshaping the relational structure of collaboration and making deeper collaboration feasible and sustainable. Policy and institutional efforts that prioritize this depth dimension (e.g., stable partnership governance, joint oversight mechanisms, and standardized standards for workplace learning) are likely to be more effective than efforts that focus primarily on expanding the quantity of collaboration.

A1. Platform-Related Measure (not Included in the Main Model)

Construct	Description	Cronbach's alpha
Platformization (Plat)	Information platforms; physical platforms; data interoperability between credit bank and university/industry systems	0.84

A2. Indicators of Collaboration Outcomes

Indicator	Data source
Employment quality	Graduate tracking (6 months)
Employer satisfaction	Employer survey
Project commercialization	Institutional outcome records

6. Conclusion

This study examined how institutional tools in applied higher education contribute to university-industry collaboration outcomes. By focusing on integration depth as a mediating mechanism, our analysis shows that project-based learning intensity and access to credit banks contribute to collaboration outcomes primarily by deepening substantive collaboration between university and industry partners. Governance synergies further strengthen the performance effects of integration depth, highlighting the importance of a supportive organizational environment.

The findings suggest that universities and policymakers should shift from implementation-focused reform strategies to integration-focused implementation. The value of collaboration-focused tools lies not in increasing the number of projects or credit transactions, but in building common structures, routines, and accountabilities to materialize collaboration outcomes.

References

[1] Barachino, H., Timmermans, A., Venhorst, VA, & van Dijk, J. (2025). Operationalizing Graduate Employment Support in Higher Education: A Systematic Review. Education + Training, 67(10), 89–110. https://doi.org/10.1108/ET-10-2024-0463

[2] Baumgartner, H., & Weijters, B. (2021). Addressing Common Method Variance in International Marketing Research. Journal of International Marketing, 29(3), 7–22. https://doi.org/10.1177/0022242921995871

[3] Cohen, M., Fernandes, G., & Godinho, P. (2025). Measuring the Impact of University-Industry R&D Collaboration: A Systematic Literature Review. The Journal of Technology Transfer, 50, 345–374. https://doi.org/10.1007/s10961-024-10114-5

[4] Council of the European Union (2022). Council Recommendation of 16 June 2022 on a European approach to microcredentials for lifelong learning and employability (2022/C 243/02). Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj:JOC_2022_243_R_0002

[5] Eimer, A., Mahlberg, J., & Wöhrer, V. (2023). Employability models in higher education: a systematic literature review. Journal of Applied Research in Higher Education, 15(6), 1330–1347. https://doi.org/10.1108/JARHE-11-2022-0377

[6] Etzkowitz, H., Leydesdorff, L. (2000). The Dynamics of Innovation: From National Systems and "Mode 2" to the Triple Helix of University-Industry-Government Relations. Research Policy, 29(2), 109–123. https://doi.org/10.1016/S0048-7333(99)00055-4

[7] Fornell, C., Larcker, DF (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. Journal of Marketing Research, 18(1), 39–50. https://doi.org/10.1177/002224378101800104

[8] Hair, JF, Black, WC, Babin, BJ, & Anderson, RE (2019). Multivariate Data Analysis (8th ed.). Cengage.

[9] Kline, RB (2016). Principles and Practice of Structural Equation Modeling (4th ed.). Guilford Press.

[10] Kolb, DA (1984). Experiential Learning: Experience as a Source of Learning and Development. Prentice-Hall.

[11] Naseer, F., Tariq, R., Alshahrani, HM, Alruwais, N., & Al-Wesabi, FN (2025). A Project-Based Learning Framework Integrating Industry Collaboration to Enhance Student Future Readiness in Higher Education. Scientific Reports, 15, 24985. https://doi.org/10.1038/s41598-025-10385-4

[12] OECD (2023). Microcredentials for Lifelong Learning and Employment: Uses and Potential (OECD Education Policy Perspectives No. 66). OECD Publishing. https://doi.org/10.1787/9c4b7b68-en

[13] Podsakoff, PM, MacKenzie, SB, Lee, J.-Y., & Podsakoff, NP (2003). Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Countermeasures. Journal of Applied Psychology, 88(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

[14] Ramírez de Dampierre, M., Rodríguez, J., & Pérez, A. (2024). Evaluation of the Implementation of CDIO-Based Project-Based Learning Programs: A Systematic Review. Education Sciences, 14(10), 1107. https://doi.org/10.3390/educsci14101107

[15] Varadarajan, S., Koh, JHL, & Daniel, BK (2023). A systematic review of the opportunities and challenges of microcredentials for various stakeholders (learners, employers, higher education institutions, and governments). International Journal of Educational Technology in Higher Education, 20, 13. https://doi.org/10.1186/s41239-023-00381-x

[16] Zhang, T., & Li, C. (2023). Relationships and Pathways: The Behavioral Logic of Industry-Academia Collaboration in Developing Excellent Engineers. China Research on Higher Education, (5), 48–54. https://doi.org/10.16298/j.cnki.1004-3667.2023.05.08