Engineering Education Review

RESEARCH

The Double-Edged Sword of AI in Engineering Education: Process Acceleration, Mentoring-Chain Disruption, and a Structural Response from Chinese Industry–University Partnerships

Shuangxi Zhao[1,2,*]

[1]Inspur Haiyue Cloud Technology (Shenzhen) Co., Ltd., Shenzhen 518057, China
[2]Faculty of Business Administration, University of Macau, Macau SAR, China

ABSTRACT

A growing concern in engineering education is that generative artificial intelligence (AI) may automate the entry-level tasks through which junior engineers develop judgment, weakening the mentoring pathway on which long-term expertise depends. This paper examines an institutional response grounded in Chinese practice. Using a document-based comparative case analysis of three industry–university partnerships at different degrees of institutionalization, informed by the author's practitioner knowledge, it reinterprets three established institutional forms — Order Classes, Micro-Majors, and Industry-Education Integration Bases — as a three-tier additive framework. The mechanisms are separable and combinable, addressing problem framing, cross-disciplinary translation, and the continuity of mentoring and organizational memory. The most developed case documents a delivered cohort and supervised delivery center alongside a six-course Micro-Major specified in a later cooperation text; the least has installed dual badges, a documented AI-and-case training plan, and a June 2 practicum attendance sheet, without verified AI-course content or full-program delivery. The cases are read as a pattern contrast, not a causal test: they illustrate possible complementarities without measuring learning effects. The contribution is to connect existing partnership arrangements to the preservation of guided learning opportunities under AI-assisted task substitution, and to formulate institutional design propositions for further testing.

Keywords: AI in engineering education; generative artificial intelligence; mentoring chain disruption; situated learning; work-integrated learning; industry–university collaboration; engineering talent pipeline

INTRODUCTION

A Concern That Has Now Been Named

In the first months of 2026, two senior industry voices — Mark Russinovich, Chief Technology Officer of Microsoft Azure, and Scott Hanselman, Vice President of Developer Community at Microsoft — published an article in *Communications of the ACM* titled "Redefining the Software Engineering Profession for AI" (Russinovich & Hanselman, 2026). Their central warning is that, absent deliberate intervention, the early-in-career training pathway of the software engineering profession faces collapse: as AI assistants take over the entry-level tasks that historically formed the apprenticeship phase, the mechanisms by which juniors become seniors are silently dismantled. Empirical work has begun to substantiate the concern. Brynjolfsson, Chandar, and Chen (2025), in a widely-circulated Stanford Digital Economy

***Corresponding Author:**
Shuangxi Zhao, Inspur Haiyue Cloud Technology (Shenzhen) Co., Ltd., Shenzhen 518057, China; Faculty of Business Administration, University of Macau, Macau SAR, China. Email: YC47086@um.edu.mo; https://orcid.org/0009-0006-5006-1962
Received: 17 May 2026; Revised: 21 October 2026; Accepted: 30 October 2026
https://doi.org/10.67229/eer.26100004

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License, which allows others to copy and redistribute the material in any medium or format non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

Lab paper, documented an approximately 16 percent relative decline in employment among workers aged 22–25 in the most AI-exposed occupations since the widespread adoption of generative AI, even after controlling for firm-level economic shocks.

The employment signal concerns access to early-career work; it does not directly measure learning or establish that AI has disrupted mentoring. The present paper treats that disruption as a developmental risk to be examined through theory and institutional arrangements.

The concern is not limited to software. As Brynjolfsson, Li, and Raymond (2025) showed in a generative-AI deployment at a large call center, generative AI codifies and disseminates expert practices and disproportionately assists novices. That finding raises a separate institutional question: when an assistant supplies an expert move directly, are the tasks and mentoring interactions through which novices build their own judgment retained? Dell'Acqua et al. (2026) found that AI assistance improved performance on tasks inside its competence boundary but could reduce performance outside that boundary. Learning to recognize such boundaries is therefore a relevant educational objective; the studies do not establish how that capacity develops over a career.

The Problem in Engineering Education Terms

For engineering education, the question concerns the development of capability as well as the production of deliverables. The Conceive–Design–Implement–Operate (CDIO) framework, the Accreditation Board for Engineering and Technology (ABET) accreditation criteria, and the National Academy of Engineering's *Grand Challenges* articulate the knowledge, practice, and professional judgment expected of future engineers (ABET, 2025; Crawley et al., 2014; National Academy of Engineering, 2008). These commitments remain relevant when AI performs parts of the practice through which students are expected to develop that judgment.

The mechanism by which the developmental arc breaks is, in this reading, less about students themselves than about the *organizational incentives that surround students*. A senior engineer who used to delegate routine work to a junior — and in the delegation, by necessity, taught the junior — now asks an AI assistant for a working implementation in thirty seconds. The senior saves time. The junior gets the immediate problem unblocked. The organization, however, has lost a mentoring interaction. Iterated across an engineering organization at scale, the disappearance of these interactions hollows out the mentoring chain. In one Chinese engineering-software firm familiar to the present study, the front-line consequence is stated by managers in the simplest possible terms: *they no longer want to take on new hires*, because the routine work that new hires used to do has been absorbed by AI, and taking on a new hire is now perceived as unrewarded organizational friction. This is a practitioner illustration obtained through factual clarification, offered to motivate the mechanism rather than as prevalence evidence.

What This Paper Contributes

The problem so stated is now sufficiently well-known that the contribution of this paper is not its identification. The contribution is the institutional response. Drawing on three industry–university partnerships in China at different degrees of institutionalization, the paper reinterprets three established Chinese institutional forms — Order Classes, Micro-Majors, and Industry-Education Integration Bases — as a three-tier *additive* mechanism framework, and argues that these mechanisms are separable and combinable, each addressing a different developmental function through which the mentoring chain can be institutionally protected.

The framework is grounded in three observed cases:

- *Partner University C × Industry Partner A (2026)* — cooperation agreement text dated January 2026, dual-badge bases established, a June AI-and-case training plan recorded, and one June 2 practicum session documented by an attendance sheet; full-program delivery remains unverified;
- *Partner University B × Industry Partner A (2025–2028)* — three-year agreement, first cohort opened June 2025 with fifteen learners and thirteen retained, a second cohort of thirty now in the program, and first-cohort interns mentoring the second;
- *Partner University A × Industry Partner B (from 2024)* — first-cohort implementation plan, a later cooperation text specifying a six-course *Cloud-Native Smart Finance Micro-Major*, a joint delivery center staffed by the cohort under three enterprise mentors, and a standing cross-cohort mentoring arrangement.

Structure of the Paper

Section **"RELATED WORK"** reviews the relevant literatures: engineering education frameworks, generative AI in higher and engineering education, AI productivity boundary research, situated learning and communities-of-practice theory, and Chinese institutional context. Section **"MENTORING CHAIN DISRUPTION IN THE ENGINEERING TALENT PIPELINE"** articulates the *mentoring chain disruption* mechanism with greater precision, drawing on the situated-learning tradition. Section **"THE THREE-TIER ADDITIVE INDUSTRY-UNIVERSITY-RESEARCH FRAMEWORK"** lays out the three-tier additive framework. Section **"METHODS AND COMPARATIVE CASE ANALYSIS"** sets out the study's methods and presents the three cases as a comparative analysis across imple-

mentation states. Section "**DISCUSSION**" discusses theoretical implications, practical implications, limitations, and directions for further research. Section "**CONCLUSION**" summarises the key outcomes.

RELATED WORK

The discussion of artificial intelligence and engineering talent development now sits at the intersection of six bodies of work.

Engineering Education Frameworks

The first body of work concerns the structural design of engineering curricula. The CDIO initiative (Crawley et al., 2014) reframed engineering education around the full lifecycle of engineered systems, integrating personal, interpersonal, and professional capabilities with disciplinary knowledge. The ABET (2025) criteria operationalize this orientation through seven student outcomes spanning problem identification, design under constraint, communication, ethics, teamwork, experimentation, and lifelong learning. The National Academy of Engineering (2008) projected fourteen *Grand Challenges for Engineering* as anchors for curricular reform. Felder and Silverman (1988), in the foundational engineering-education text on learning styles, mapped the discipline-specific cognitive habits of engineering students. Boyer's (1990) *Scholarship Reconsidered* enlarged the definition of academic scholarship to include the scholarship of teaching alongside discovery, integration, and application — a move that anticipates the cross-institutional teaching that the present framework requires.

Recent competency research makes the practical dimension explicit. Hu and Song (2025) identify a relative neglect of practical abilities in Chinese competency standards and locate reform across institutional, organizational, pedagogical, technological, and evaluative levels. Liu et al. (2025) compare engineering undergraduates' views of core competencies in China and the United States, highlighting differences in the value placed on knowledge application, communication, leadership, and multidisciplinary teamwork. These studies concern competency frameworks and student perceptions; they help define the educational objectives, rather than demonstrating the effects of AI or of the partnerships examined here.

Generative AI in Higher and Engineering Education

A second body of work examines generative AI in higher education. Liang et al. (2025) review its early implications for curriculum, instruction, and assessment, including personalization opportunities and assessment-integrity risks. Honig et al. (2025) apply a unified theory of acceptance and use of technology (UTAUT) framework to engineering instructors' acceptance and use of generative pre-trained transformer (GPT) teaching tools. Adoption and immediate task performance, however, do not by themselves establish durable learning.

Evidence on learning makes this distinction consequential. In a high-school mathematics field experiment, Bastani et al. (2025) found that unguarded AI assistance improved practice performance but could impair subsequent unaided performance; tutoring safeguards largely mitigated the harm. In a university scientific-inquiry task, Stadler et al. (2024) found lower mental effort alongside less depth in students' reasoning with a large language model (LLM)-based tool. The science, technology, engineering, and mathematics (STEM) review and meta-analysis by Boolzen et al. (2026) reports substantial heterogeneity and publication-bias sensitivity, and distinguishes AI that augments students' cognitive activity from AI that substitutes for it. These findings warrant attention to instructional design, while their settings and outcome measures preclude a direct inference about long-term engineering expertise.

The educational question also requires a bounded view of AI capability. Zhang's (2024) review cautions against treating advances in language generation as the resolution of broader challenges in artificial intelligence. In a commentary on AI development, teaching, and governance, Gong (2024a) emphasizes foundational knowledge, independent learning, and practical engagement with intelligent tools. At the educator level, Xu (2025b) proposes an integrated model combining technical, pedagogical, and professional and ethical competencies. These contributions support attention to what teachers and mentors must help learners understand and evaluate; they are not evidence that the present cases have achieved those competencies.

AI and the Entry-Level Pipeline

A third, rapidly-emerging body of work treats generative AI as a structural intervention in the labor pipeline. Russinovich and Hanselman (2026), writing as senior practitioners in *Communications of the ACM*, warn that without deliberate redesign of early-in-career training, the software engineering profession's talent pipeline faces collapse. Brynjolfsson, Chandar, and Chen (2025), in *Canaries in the Coal Mine?*, present six empirical facts about the recent employment effects of artificial intelligence; their headline finding is that employment of workers in their early twenties has fallen sharply in AI-exposed occupations. The International Labour Organization (2025) has issued an update on generative AI and jobs that echoes the concern. Brynjolfsson, Li, and Raymond (2025) had earlier shown that the productivity benefit of generative AI is disproportionately captured by novices, and Dell'Acqua et al. (2026) had documented

the *jagged technological frontier* on which AI degrades work outside its competence boundary. Autor (2015), writing before the generative-AI moment, had argued historically that automation reorganizes rather than eliminates work; the present moment tests how that historical pattern applies when the automation reaches the apprenticeship layer.

Concurrent with the present submission, practitioner-side commentary outside the academic literature has begun to converge on the same diagnosis under the label *Apprenticeship Severance* (Green, 2026), proposing firm-level design shifts. The present paper differs in proposing an education-system structural response with multi-tier institutional pathways, complementary rather than overlapping.

This body of work sharpens the pipeline concern, but employment and productivity findings do not resolve the educational design question. The present study asks how existing partnership arrangements might preserve guided practice when AI substitutes for parts of novice work.

Situated Learning, Communities of Practice, and Informal Workplace Learning

A fourth, older body of work explains *why* the disappearance of apprenticeship matters developmentally. Lave and Wenger (1991), in *Situated Learning: Legitimate Peripheral Participation*, argued that genuine learning occurs through a learner's gradual movement from the periphery of a community of practice toward its center, by participating in the community's real work. Wenger (1998), in *Communities of Practice*, formalized the institutional conditions under which such learning is sustained. Eraut (2004) documented that the bulk of professional capability is built through informal learning in the workplace rather than through formal training. Kram (1985), in *Mentoring at Work*, articulated the developmental functions of organizational mentoring relationships across an employee's career.

Billett (2001) further explains workplace learning through the interdependence of opportunities to participate and individuals' engagement, making the allocation of tasks and guidance an educational design issue. The multidisciplinary meta-analysis by Eby et al. (2008) finds generally favorable but context-dependent associations with mentoring across youth, academic, and workplace settings. Neither source establishes that any designated mentor or placement automatically produces a learning benefit.

Read together with the AI-pipeline literature of Section "*AI and the Entry-Level Pipeline*", these accounts suggest that routine tasks can have developmental value when they provide entry into consequential work with guidance. Their automation can yield an efficiency gain while also removing learning opportunities if the work is not redesigned. Dewey and Kolb locate learning in concrete experience and reflection; the question is therefore whether AI use leaves learners with experiences to interpret and judgments to revise (Dewey, 1938; Kolb, 1984).

Evidence from outside engineering sharpens the mechanism. Beane (2019), studying how surgical residents build robotic-surgery skill, found that when an automation-mediated training path stops transmitting expertise, learners fall back on unofficial *shadow learning* — premature specialization, abstract rehearsal, and undersupervised struggle — to acquire judgment the standard pathway no longer delivers. The lesson generalizes: when a technology absorbs the legitimate peripheral work, skill formation does not stop so much as migrate into improvised and less reliable channels.

Industry-University-Research Integration and Emerging Apprenticeship Responses

A fifth body of work concerns cooperation between industry and universities. Hwang et al. (2026) review work-integrated learning in undergraduate engineering, including internships, cooperative education, and project-based industry engagement. The systematic review by Shah and Gillen (2024) maps university–industry partnerships within engineering education, providing a basis for comparing the purposes and forms of collaboration. Borah et al. (2021) examine teaching-focused collaborations and graduates' employability competencies in Indian higher education. These studies establish an existing institutional literature to build on, while their findings cannot be treated as evidence of an AI-specific buffering effect.

Chinese initiatives also have a substantial institutional history. Lin et al. (2015) describe the Plan for Educating and Training Outstanding Engineers (PETOE) as a multi-sector mechanism involving industry guidance, joint university–industry training, and government support. The *Emerging Engineering* initiative extends the reform agenda toward new industrial and technological demands (Lin, 2017). Wang and Yang (2025) argue for stronger long-term collaboration, joint training bases, and dual-teacher teams. Li et al. (2026) describe Beijing Institute of Technology's "6+1" system, including collaborative mentorship and coordination across the training cycle. These are institutional antecedents and comparators. The present paper reinterprets existing arrangements through the specific problem of preserving guided learning under AI-assisted task substitution.

Chinese Institutional Context

A sixth body of work addresses the institutional spe-

cificity of Chinese engineering education. Tsui (2006) provides the methodological foundation for contextualized management research in China and reminds international readers that mechanisms developed in the Chinese context cannot be assumed to translate directly elsewhere — but also that their value lies in extending the international repertoire of available responses.

Gong (2024b) places engineering education within the dual transformation of sustainable development and digitization, linking technological change with educational responsibilities toward society. This broad framing helps locate the present question: institutional responses to AI should be assessed against the capabilities they sustain, alongside the efficiency they enable.

The Gap This Paper Addresses

Across these six literatures, established curricula, workplace-learning theory, and partnership studies already supply resources for institutional design. The narrower gap addressed here is how three established Chinese partnership forms can be interpreted as separable and combinable means of preserving problem framing, cross-disciplinary translation, and mentored correction when AI compresses novice tasks. The research question is: what developmental functions are specified or observable in these arrangements, and what propositions about their possible complementarity can a bounded document-based comparison support? The analysis distinguishes documented provisions and activity from effects that remain to be tested.

MENTORING CHAIN DISRUPTION IN THE ENGINEERING TALENT PIPELINE

What Generative AI Compresses

Generative AI can compress parts of routine engineering work, such as drafting, coding, and documentation. The magnitude and reliability of that gain depend on the task and its position relative to the tool's competence boundary (Brynjolfsson, Li, & Raymond, 2025; Dell'Acqua et al., 2026). The educational concern arises when the delegated activity was also an occasion for the learner to formulate a problem, test an explanation, or revise a decision. The risk is therefore not task acceleration itself, but substitution without a corresponding redesign of learning opportunities.

Why the Compression Breaks the Mentoring Chain

The proposed mechanism is most clearly understood through situated learning. Lave and Wenger (1991) describe movement toward fuller participation through real work at a community's periphery, with access to more experienced members. If AI absorbs that work and no alternative participation is arranged, a route into practice can narrow. This is a conditional mechanism, rather than a claim that peripheral work or mentoring disappears wherever AI is introduced. Chi and Wylie's (2014) Interactive, Constructive, Active, Passive (ICAP) framework provides a complementary cognitive lens: generating explanations and engaging in substantive interaction differ from receiving information passively. Applied here as a design principle, it directs attention to whether the learner still constructs, explains, and revises a judgment while using AI.

The mechanism, however, operates not only through the learner. It operates also through the *senior members of the community*, whose own incentives have changed. The senior engineer who, in a pre-AI condition, was professionally rewarded for distributing routine work to juniors — both because the work needed to be done and because the seniors' organizational identity included the training function — now finds that the routine work can be completed in thirty seconds by an AI assistant. The senior's incentive to take on a junior, to delegate, to review, to correct, is no longer matched by an organizational structure that demands the delegation. The frontline consequence, as observed in the engineering-software firm referenced in Section "*The Problem in Engineering Education Terms*", is straightforward: managers report that they no longer wish to take on new hires.

Why Engineering Is Structurally Exposed

Three features make engineering education distinctively exposed to the mentoring chain disruption.

First, engineering practice is high-complexity and long-apprenticeship. The mark of a senior engineer is judgment under uncertainty, and judgment is built through years of consequential decisions — many initially incorrect, many subsequently corrected. The judgment-building cycle depends on the existence of consequential decisions that the junior is permitted, and required, to make.

Second, engineering technology iteration cycles are themselves shortening. The faster the technology underneath an engineer changes, the more decisive the judgment foundation becomes — and judgment is built through the apprenticeship cycle.

Third, contemporary engineering practice increasingly requires *compound* capability — engineers who can navigate technical and managerial domains together (Hu & Song, 2025; Liu et al., 2025). The proposition advanced here is that repeated cross-domain encounters help learners develop compound capability; if AI use reduces those encounters without replacement, it may narrow opportunities to practice such integration.

Empirical Signals

Early employment evidence and practitioner accounts motivate the proposed mechanism, without directly measuring changes in mentoring or learning. Brynjolfsson, Chandar, and Chen (2025) document a sharp decline in early-career employment in AI-exposed occupations. Russinovich and Hanselman (2026) articulate, from the practitioner side, the possible risk to the long-run software engineering talent pipeline. Taken together, employment findings and practitioner concerns motivate examining institutional responses, while the extent and developmental consequences of mentoring-chain disruption remain open empirical questions. When AI absorbs routine tasks, learners may also lose occasions to frame ambiguous problems, translate between technical and domain vocabularies, and receive correction through supervised practice. Section **"THE THREE-TIER ADDITIVE INDUSTRY-UNIVERSITY-RESEARCH FRAMEWORK"** examines whether established partnership arrangements can buffer these developmental losses while using AI to accelerate routine work.

THE THREE-TIER ADDITIVE INDUSTRY-UNIVERSITY-RESEARCH FRAMEWORK

Framework Overview

The three institutional forms are not introduced here as new inventions. They are established instruments in Chinese industry–university collaboration; this paper reinterprets them as complementary mechanisms for rebuilding developmental exposure under AI compression, and specifies their additive logic for empirical testing. A partnership may use any subset: an Order Class connects a cohort to partner-defined problems, a Micro-Major structures cross-domain learning, and an Integration Base sustains mentoring and organizational memory across cohorts. These functions can reinforce one another without forming a required sequence. The framework is intended to pair AI-assisted routine work with protected opportunities for problem framing, cross-domain translation, and mentored correction.

- *Mechanism 1: Order Classes (订单班)* — demand-led, employment-anchored arrangement in which an industry partner specifies a workforce need and the university recruits and jointly trains a dedicated cohort against it. The arrangement creates a pathway toward employment with the partner or its ecosystem, subject to program completion and mutual selection; it does not guarantee a position for every participant. What defines an Order Class is the workforce demand that anchors it: the cohort is organized backward from a named need, not forward from a course catalogue.
- *Mechanism 2: Micro-Major Curricula (微专业)* — short, modular, interdisciplinary credentials that aggregate, from across the university and from industry partners, the components of a compound capability (for instance, financial-digital intelligence, or human-capital-management implementation consulting).
- *Mechanism 3: Industry-Education Integration Bases (产教融合基地)* — permanent, jointly-governed institu-tional entities — typically with reciprocal dual-badge designation, faculty mobility in both directions, and shared physical and curricular infrastructure — between a university and one or more industry partners.

A note on terminology: the framework presented here is a refinement of an earlier three-stage articulation presented in the author's 2025 keynote (Zhao, 2025). The original sequence — *Order Classes* → *Micro-Majors* → *Industry Colleges* — has been recast here from a sequential progression into an additive stack, in light of the observation that partnerships do not pass through the three mechanisms in a fixed order but accumulate them as the partnership develops.

What Each Mechanism Does

The three mechanisms address different parts of the developmental terrain that generative AI has compressed.

Order Classes can put students in front of partner problems before those problems have been fully specified for instruction. Their proposed buffer against accepting an AI-generated solution too early is a requirement to clarify stakeholder needs and justify the problem definition before evaluating a proposed solution. The account of an engineering practice center by Lu et al. (2025) provides a related precedent for combining industry challenges, interdisciplinary mentorship, and process-oriented evaluation. The Order-Class proposition is that such requirements preserve problem-framing work; it is not that a workforce-linked cohort necessarily provides them.

Micro-Majors can hold disciplinary knowledge and application knowledge together across a sequence of modules. Xu's (2025a) synthesis of interdisciplinary models identifies project-based learning and the organizational balance between disciplinary depth and integration as recurring design issues. In the present framework, an AI-generated explanation that sounds plausible in both finance and software would still need to be checked against domain rules and implementation constraints. Requiring learners to explain and reconcile that mismatch is the proposed buffer against fluent but unexamined cross-domain answers; the cases do not establish a measured gain in this capability.

Industry-Education Integration Bases can give continuity to the channels through which organizational memory

travels: returning practitioners, rotating faculty, enterprise instructors, and supervised delivery teams (Kram, 1985; Wenger, 1998). Cognitive apprenticeship supplies a relevant instructional model through expert demonstration, coaching, scaffolding, and reflection that make otherwise hidden reasoning visible (Collins et al., 1991). Where AI reduces the need to delegate routine work, scheduled review and correction could preserve contact between novice decisions and expert judgment. This buffer depends on actual mentor participation and responsibility for feedback, rather than on the Base designation alone.

Why an Additive Stack and Not a Single Mechanism

The mechanisms emphasize different developmental functions, and their coverage may overlap. Order Classes can give students real problems but may not, on their own, sustain translation between two disciplinary vocabularies; without an Integration Base, a partnership may struggle to carry mentoring and organizational memory across cohorts. Conversely, an Integration Base without an underlying Order Class can produce institutional continuity without the talent-specification clarity that the AI-era engineering economy now demands.

Combining the mechanisms is proposed to broaden coverage of the three developmental functions; useful partial configurations remain possible. Stated as testable propositions: an Order Class is expected to preserve problem-framing exposure; a Micro-Major, cross-disciplinary translation; and an Integration Base, institutionalized mentoring and organizational memory. The three cases in the next section show different degrees of planning and implementation and help specify conditions for applying the mechanisms; they do not measure the propositions' effects, which the concluding section flags for longitudinal test.

Combining mechanisms also creates coordination demands. The review by Vuoriainen et al. (2025) proposes six conditions for higher education–industry collaboration: clarity, communication, commonality, commitment, continuity, and confidence. These conditions help specify what an additive arrangement would require, such as agreed mentor responsibilities and continuity across cohorts; neither that review nor the present cases validate the effectiveness of the proposed stack.

METHODS AND COMPARATIVE CASE ANALYSIS

Methods: Case Selection, Evidence, and Comparative Analysis

This study uses a document-based comparative case analysis, informed by the author's practitioner knowledge, to examine three industry–university partnerships. The structured comparison matrix reported below was assembled during the revision of this paper as a retrospective organization of existing materials; material collection and factual clarification took place during the paper's preparation and revision. No coding scheme was applied while the programs ran, and the account makes no claim to a research protocol executed during program delivery.

Design and unit of analysis. The unit of analysis is an industry–university partnership and its institutional configuration, not the individual student. Each case is bounded by its partnership materials and program cycle: Partner University A by the May 2024 first-cohort plan, a later framework-agreement text, its first delivery cohort, and employment status verified through 2026 — earlier alumnae figure as background evidence for the mentoring mechanism rather than as cohort outcomes; Partner University B by the 2025 three-year cooperation agreement and its first two cohorts through July 2026; and Partner University C by the January 2026 school-enterprise agreement, dual-badge installation, a contemporaneous training plan, and a June 2 practicum attendance sheet. The three are compared as institutional arrangements at different degrees of implementation, not as points on a single developmental scale.

Case selection. The three cases are the full set of partnerships the author directly led or sustained access to during 2024–2026; they are not a sample selected for favorable outcomes. Their differing documented arrangements — one with a delivered cohort and supervised center operations plus a proposed Micro-Major, one with two mechanisms and a self-replicating mentoring chain beginning to emerge, and one with an installed partnership arrangement and a planned course — enable a structured contrast across implementation states. No claim of national representativeness is made.

Evidence corpus. Across the cases, the corpus comprises cooperation texts, recruitment and training plans, program-review materials, and roster or project-management records, with their dates where available. The materials differ by case: for Partner University C, the available evidence is the agreement text, a university-published account of the signing and badge ceremony, a contemporaneous message recording a training plan, and a dated attendance sheet for a June 2 practicum session in human resources (HR) services that the author identifies as part of this partnership. The sheet itself does not identify the enterprise instructor or describe the teaching content; no complete attendance or delivery record for the planned program is available. During the paper's preparation and revision the author solicited and cross-checked factual clarifications from partner leads, instructors, and students by telephone and messaging;

Table 1: Evidence Base for the Case Claims

Case	Claim used in manuscript	Source type and record	Coverage and period	Verification and interpretive limit
Partner University A	Intake funnel: 30 completed training → 20 entered the center → 15 completed the internship → ~15 employed	Management records + phone/message factual clarification	First cohort; recruited 2024, employment status verified through 2026	Reported as a funnel, not a placement rate; denominator is the training-qualified group
Partner University A	Joint delivery center staffed by the first cohort under three enterprise mentors	2024 center program-management record	First cohort + 3 enterprise mentors; 2024 management record, not a full-year student placement	Site of live delivery practice, not an educational outcome or a mechanism effect
Partner University A	Mentor demonstration, review, and correction across stages; standing cross-cohort succession	Practitioner knowledge + phone/message factual clarification; project records corroborate the task stages	Across project stages	Central mechanism fact; observable arrangement, not causal proof
Partner University B	15 → 13 retained; 9 remote maintenance + 4 on-site implementation	Program roster; deployment records	First cohort; opened June 2025	Deployment structure, not a measured learning gain
Partner University B	AI in real use (system-problem diagnosis, meeting minutes, documentation, knowledge-base retrieval)	Second-cohort course records and skill-download, learning-report, and token-consumption logs; specific use scenarios from phone/message factual clarification	Second cohort; from July 2026	Logs establish use, not the specific scenarios or a capability gain
Partner University B	Remote-to-on-site progression; first-to-second-cohort mentoring	Role structure from management records; progression and mentoring from factual clarification + practitioner knowledge	2025–2026	Records establish role structure only; progression and mentoring are clarified, not measured
Partner University C	Agreement signing and dual-badge ceremony; proposed AI, cases, and exercises for HR students; one HR-services practicum session documented	University-published January 2026 account for signing and badges; agreement text for instructional roles; contemporaneous project-progress message for training plan; author-identified June 2 attendance sheet for one practicum session	January 2026 ceremony; June 2, 2026, practicum session; no complete attendance or delivery record for the planned program	Attendance sheet does not name the enterprise instructor or specify AI content; no observed learning, workplace deployment, or outcome

these were used to verify project-level facts against the existing records, not as an independent interview data stream. The author's operating role supplies contextual knowledge and access to these materials rather than a separate stream of systematically collected observational data.

Evidence extraction. For this revision the author organized the record into a structured matrix whose fields are: the case, the mechanism, the AI-exposed novice task, the mentoring function at risk, the documented institutional response (planned or implemented), the documentary evidence, and the inference boundary. The matrix is an analytical device built during revision to compare the cases on common terms; it is not a coding scheme applied to primary data while the programs ran.

Bowen's (2009) discussion of document analysis informs the attention to record provenance, purpose, and incompleteness. Here, administrative records are evidence of specified arrangements or recorded activity within their coverage; their existence does not establish learning quality. The comparison therefore retains the distinction between a contractual provision, a training plan, a delivered activity, and an educational outcome.

Comparative analysis. The cases were first verified individually and then compared field by field, as a pattern contrast rather than a statistical test. Alternative explanations for the observed differences — the age of each partnership, the type of industry partner, the disciplinary field, and the collinearity between the number of mechanisms a partnership instantiates and how long it has run — are examined explicitly and constrain the inferences drawn.

Validity and limitations. Four limits set the level of inference: the account has a single practitioner-analyst author; it relies on management records not designed as research instruments; it has no independent second analyst; and it identifies no causal effect. Following Yin (2018), the analysis holds to three principles that these materials can support — bounded cases, a traceable chain of evidence from record to matrix to claim, and a structured cross-case comparison — while making analytic rather than statistical generalizations. These limits mean the cases yield descriptive findings and a theoretical mechanism contribution, not measured effects.

Flyvbjerg's (2006) discussion of case-study research supports the value of context-dependent analysis without making statistical representativeness its sole criterion. In this study, that value lies in specifying possible mechanisms and their documentary limits; the small accessible case set and the author's operating role remain constraints, not grounds for a stronger claim.

The quantitative claims retained in the case analysis, together with the central mechanism facts, are set out in Table 1, which records for each the type of source, the coverage and period, and the interpretive limit. Three source types are distinguished: contemporaneous documents or management records, factual clarifications obtained by telephone or message during preparation and revision, and the author's practitioner knowledge.

The three partnerships are presented below in reverse order of partnership age, beginning with the most institutionalized, to make the cross-case contr ast legible.

Partner University A / Industry Partner B

Partner University A — a public teaching-oriented university in central China, College of Accountancy — planned its first cohort with a major Chinese enterprise resource planning (ERP) software company (Industry Partner B) in May 2024. That implementation plan already specified recruitment, six weeks of training, and a six-to-twelve-month internship. A later strategic framework-agreement text set out the proposed *Cloud-Native Smart Finance Micro-Major* and an *Industry-Education Integration Base for Online Delivery*. The cohort plan, the later institutional provisions, and their subsequent implementation are distinguished below.

Mechanism 1 — Order Class. The Recruitment Implementation Plan for the first cohort (dated May 2024) specifies a six-week training program followed by a six-to-twelve-month on-site internship, addressed to third-year undergraduates in the financial disciplines. Students who complete the program may, subject to mutual selection at the conclusion of the internship, take up full-time positions at Industry Partner B's central-China online delivery center or at the partner's branch offices and ecosystem partners. Of the first cohort, thirty completed the six-week training, twenty entered the delivery center, fifteen completed the internship, and approximately fifteen received and accepted employment offers — a funnel reported here in place of a placement rate, since its denominator is the training-qualified group rather than an open applicant pool.

Mechanism 2 — Micro-Major. The later framework-agreement text specifies the joint development of a *Cloud-Native Smart Finance Micro-Major* curriculum, planned around six courses spanning enterprise information systems and databases; the partner's flagship platform construction and management practice; enterprise digital-intelligent operations and strategy; smart project management and methodology; cloud-native business-finance integration; and the practitioner path of the financial-digitalization consultant. The proposed curriculum would combine accounting-discipline knowledge, enterprise-resource-planning technical knowledge, and consulting-practice knowledge. The available materials establish this curricular plan, not that the Micro-Major credential was delivered.

Mechanism 3 — Industry-Education Integration Base. The framework-agreement text proposes a jointly developed Base on the university campus, with partner consultants and project leaders contributing to instruction. Separate program-management material describes an on-campus delivery center in which the first cohort practiced on delivery projects routed from the partner's branch offices nationally.

The online delivery center — staffed by members of the first cohort and guided by three enterprise mentors — provided a site of supervised delivery practice during the cohort's internship. What this establishes is the site of practice and the mentoring arrangement, not revenue created by the students and not a causal effect of the training mechanisms. Its provenance and inference boundary are recorded in Table 1.

Read against the mentoring-chain mechanism, the case shows what the Base is for. In routine delivery work an AI assistant can now handle much of the data preparation, meeting minutes, documentation, system setup, code generation, and testing that once formed a junior consultant's first tasks. What it does not supply is the judgment those tasks used to carry alongside them: reading a client's emotional state in a tense implementation, deciding whether a request falls inside or outside the agreed project scope, and applying the differentiated financial logic that distinguishes one industry from another. In this case those judgments are transmitted through mentors who demonstrate, review, and correct across the successive stages of a real project — requirements investigation, solution design, system configuration, and user training — and through a standing arrangement in which each cohort mentors the next. The supervised center and mentor arrangement provide a channel through which this experience can travel; the available materials do not show that the proposed Base itself created that channel or produced a particular outcome.

The mentoring chain reported in this partnership predates the later framework text. Alumnae who entered the partner's branches several years before the 2024 first-cohort plan have progressed, across successive positions, into project-manager and internally recognized "best mentor" roles, and now return to address incoming cohorts. In keeping with individual-privacy considerations these trajectories are described only in the aggregate: no individual is named or numbered, and they concern employees of several years' standing rather than members of the current intern cohort. The proposed Base could provide standing infrastructure for this con-

nection between established practitioners and incoming students — a *legitimate peripheral participation* pathway in Lave and Wenger's (1991) terms — but the available material does not establish that the Base itself formalized it.

The Partner University A case documents a delivered cohort and supervised delivery-center practice, while the later framework text specifies a Micro-Major and a proposed jointly developed Base. The cross-cohort mentoring arrangement is described separately, and the earlier alumnae pathway predates these arrangements. The case therefore illustrates a configuration at different stages of specification and implementation, not a measured effect on employment or individual capability.

Partner University B / Industry Partner A

Partner University B — a polytechnic university in southern China — entered into a three-year *Industry-Education Cooperation Agreement* with Industry Partner A in September 2025 (v2.0 of the agreement, which formalized an earlier cooperation agreement, signed after legal and academic review). The first cohort opened in June 2025 and, as of mid-2026, has completed one program cycle. Two of the three mechanism layers are explicitly instantiated, delivery participation is observable, and the mentoring chain has begun to self-replicate.

Mechanism 1 — Order Class with a three-stage progressive training architecture. The agreement specifies that the university will, each year, directionally cultivate and channel not fewer than ten outstanding students to the partner. The first cohort opened in June 2025 and comprised fifteen learners, thirteen of whom were retained through the program. The training is delivered in three progressive stages:

- *Induction stage (June)* — class formation, team building, alignment of expectations, and code-of-conduct briefing.
- *Systematic training stage (August)* — a "homeroom-teacher" stage of structured classroom instruction covering the partner's core human-capital-management platform modules together with several platform-as-a-service configuration capabilities, structured around group-competition and bonus-question incentive mechanisms.
- *On-post deployment stage (from October)* — a "mentor" stage replacing the homeroom-teacher model, in which learners begin in remote operations-and-maintenance work and, as they become more proficient, may move into on-site implementation according to their technical readiness, communication ability, and willingness to travel. Of the thirteen retained learners, nine work in remote maintenance — handling client calls, ticket logging, system-problem diagnosis, testing, and client replies — and four in on-site implementation, covering system testing, feature design, and configuration.

Mechanism 3 — Industry-Education Integration Base (partial, in dual-badge form). The agreement establishes reciprocal dual-badge designations: an Off-Campus Practical Training Internship Base at the partner's site, and a Talent Training Base at the university. The dual badges constitute the institutional skeleton of a future full Integration Base; the partnership has not yet reached the level of micro-major curricular co-design specified in Partner University A's framework text.

Deployment and AI use. The retained learners are deployed across the partner's ecosystem project portfolio, spanning a range of major state-owned-enterprise and listed-company clients in heavy industry, agriculture and food, transportation infrastructure, healthcare, and municipal conglomerates. Within this work an AI assistant is in real use — for system-problem diagnosis, meeting minutes, documentation, and knowledge-base retrieval — the second cohort's course records and its skill-download, learning-report, and token-consumption logs establish that the course was delivered and the assistant is in use, while the specific use scenarios are drawn from factual clarification with partner leads and instructors. Neither source, on its own, measures a gain in capability or in problem-solving quality.

Read against the mechanism, the double-edged pattern is visible here. Remote maintenance work — logging tickets, diagnosing recurring problems, replying to clients — is exactly the layer an AI assistant most readily absorbs, and with it the ladder by which a novice once accumulated judgment from small problems. The partnership's response is not to withdraw the AI but to rebuild the ladder institutionally: a staged progression from remote maintenance into on-site implementation that restores graduated client contact and design responsibility, together with the cross-cohort arrangement described below. The operations-and-maintenance knowledge base the learners work with functions, in community-of-practice terms, as a *shared repertoire* (Wenger, 1998)*;* it and the AI-use records document that the mechanisms are operating, not that learning outcomes have been measured.

Emergence of the self-replicating mentoring chain. A second cohort of thirty learners began in 2026, accompanied by a deliberate institutional move: first-cohort interns, having completed the first program cycle and entered ongoing delivery work, now serve as mentors to the second cohort — offering system-setup guidance, workplace-communication modeling, and a lower-threshold channel of peer support for the everyday questions a newcomer might hesitate to put to a senior mentor or manager. The mentoring chain has begun to self-replicate.

What is observable is that the arrangement has been implemented; the second cohort's learning outcomes are not yet measured.

The case as theoretical evidence. The middle-case configuration illustrates Lave and Wenger's (1991) *legitimate peripheral participation*: the staged progression from remote maintenance into on-site implementation moves learners from more peripheral toward more central delivery work as their judgment develops — the centripetal movement the theory describes. The operations-and-maintenance knowledge base functions, in the same conceptual register, as the *shared repertoire* (Wenger, 1998) of a community of practice. These are theoretical correspondences drawn from the situated-learning tradition, not measured effects.

Partner University C / Industry Partner A

A *School-Enterprise Cooperation Agreement* text dated January 2026 sets out the proposed collaboration between Partner University C's Business School and Industry Partner A. The Business School's public account reports that the agreement was signed and a dual-badge ceremony held on January 19, 2026; it also reports that the parties defined five cooperation objectives for that year. A contemporaneous project-progress message proposed June training for HR students using AI, cases, and exercises, including solution and informatization work. A dated attendance sheet records an HR-services practicum class on June 2, 2026; the author identifies it as part of the partnership. This sheet documents one class session but does not identify the enterprise instructor, show what was taught, or verify delivery of the planned AI-and-case program as a whole. The case remains a limited curriculum-and-partnership boundary rather than evidence of a measured training outcome.

Mechanism 1 — Order Class (foundation only). The agreement specifies the standard order-cultivation language: directional cultivation of students based on partner workforce requirements, with the partner permitted to recommend technical staff and project leaders as curriculum advisors and instructional contributors. The project-progress message describes a planned training cohort, but the available materials do not verify that the training occurred as planned.

Mechanism 3 — dual-badge installation. As in the middle case, dual-badge designations are established: an Off-Campus Practical Training Internship Base at the partner, and a Talent Training Base at the Business School.

The June training plan proposed combining AI, cases, and exercises for HR students, including solution and informatization work; the agreement text also permits enterprise technical staff and project leads to contribute to curriculum advice and teaching. Together, these planned elements are adjacent to enterprise-software implementation education, although this is a conceptual connection rather than an observed course feature. The message does not identify particular HR scenarios; the June 2 sheet documents a practicum session but not its AI content or the full planned course delivery. Partner University C is therefore a limited boundary example; it cannot establish observed AI-assisted learning, an engineering talent pipeline, workplace mentoring, or post-training capability gains.

Reading the Three Cases Together

The three partnerships differ in their documented arrangements and observed program activity. Partner University C has an Order-Class provision and dual badges, with a training plan and one dated practicum attendance sheet but no verified full-program delivery; Partner University B has an operating cohort and dual badges, with cross-cohort mentoring beginning to emerge; Partner University A has a delivered cohort and supervised delivery-center practice, while its later framework text specifies a Micro-Major and Integration Base. Table 2 sets the three side by side along five analytical dimensions.

Read together, the cases present a pattern contrast, not a causal test. They illustrate how three separable mechanisms could be combined to address different developmental functions compressed by generative AI: Order Classes provide exposure to unstructured problems, Micro-Majors specify cross-disciplinary learning, and Integration Bases provide channels for mentoring and organizational memory. Partner University A's framework text specifies all three, but the available materials do not establish that its proposed Micro-Major credential was delivered. The cases also differ in partnership age, industry partner, and disciplinary field; these differences cannot be separated with three cross-sectional cases. The supported claim is conceptual — that the mechanisms address complementary functions and can be combined in institutional design — rather than a comparison of effect size across configurations.

DISCUSSION

Theoretical Implications

The contribution to engineering education is to connect the distinction between AI-assisted task performance and learning to the organizational design of partnerships. Existing work on collaboration and Chinese joint-training mechanisms already supplies institutional responses to the separation of classroom and workplace learning (Li et al., 2026; Lin et al., 2015; Shah & Gillen, 2024; Wang & Yang, 2025). This paper adds an AI-specific interpretation of three established forms, distinguishing the developmental function each might protect and the

Table 2: Cross-Case Comparison Across Five Analytical Dimensions

Case	AI-exposed novice work	Mentoring function at risk	Documented response (planned or implemented)	Observable status	Inference boundary
Partner University A	Data preparation, meeting minutes, documentation, system setup, code generation, testing	Client-emotion reading, scope judgment, sector-specific financial logic	Mentor demonstration, review, and correction across project stages; standing cross-cohort succession	Standing cross-cohort mentoring arrangement documented	Co-present with the institution, not a causal effect
Partner University B	System-problem diagnosis, meeting minutes, knowledge-base lookup	Judgment accumulated from small problems; graduated client contact	Remote-to-on-site progression; first-to-second-cohort peer mentoring	Deployment, AI use (second cohort), and cohort-to-cohort mentoring implemented	Use and deployment; no measured capability gain
Partner University C	AI, cases, and exercises proposed for HR students; specific tasks unrecorded	Mentored problem framing as a possible design aim, not an observed activity	Dual badges installed; AI, cases, and exercises planned	Signing and badge ceremony publicly reported; one June 2 practicum session documented by attendance sheet, with AI content and full-program delivery unverified	Limited boundary only; no observed AI learning, engineering pipeline, or outcomes

conditions under which they might complement one another. It proposes a mechanism framework supported by a descriptive comparison, not evidence of its effectiveness.

Read through situated learning, the question concerns access both to consequential novice tasks and to experienced people who guide them. Generative AI may compress either when it substitutes for practice and reduces delegation. The three mechanisms are intended to preserve problem-framing exposure, cross-disciplinary translation, and mentored correction and memory transfer. Their educational effect depends on how tasks, guidance, and assessment are organized, and has not been demonstrated by the present cases.

The paper also dialogues with the productivity-boundary literature. Where Dell'Acqua et al. (2026) identify a jagged frontier of AI competence and conclude that workers must learn to perceive the frontier, the present paper extends the argument by asking how future engineers will develop frontier-perception in the first place. A testable proposition is that frontier-perception develops through the iterative apprenticeship cycles the framework's three mechanisms are intended to protect.

Practical Implications

For engineering deans, the framework suggests an audit. Of the trial-and-error mechanisms historically embedded in our curricula, which have been substantively compressed by AI, and which of Order Classes, Micro-Majors, and Industry-Education Integration Bases should we develop in response? For industry leaders, the framework suggests a re-specification of the corporate-university partnership: the partnership should target the reconstruction of specific developmental experiences, not merely the maintenance of a recruitment pipeline. For accreditation, professional, and governance bodies and networks — including ABET, the World Federation of Engineering Organizations, and the Global Engineering Deans Council — the framework suggests an additional dimension of program evaluation: how does the program protect the developmental pathway under conditions of AI substitution? For policy-makers concerned with national engineering capacity, the framework offers a concrete institutional design vocabulary at a moment when the entry-level employment data (Brynjolfsson, Chandar, & Chen, 2025) suggest that the implicit assumption of automatic talent regeneration can no longer be relied upon.

An immediate design implication is to assess a student's reasoning separately from the quality of an AI-assisted deliverable. Learners could document an initial problem definition, explain why an AI suggestion fits or fails domain constraints, and revise a decision after mentor feedback. These are proposed assessment practices informed by the learning and cognitive-apprenticeship literature, not activities verified across the three cases (Bastani et al., 2025; Chi & Wylie, 2014; Collins et al., 1991).

The Chinese Contribution

A specific contribution of the cases presented here lies in the Chinese industry–university partnership configuration, supported by national policy infrastructure, that enables the framework's operationalization. The Partner University A case rests on a partnership between an engineering-financial software firm (Industry Partner B), a teaching-oriented public university, and — through the wider *Industry-Education Integration Base* designation system — the national policy infrastructure that legitimates such configurations. The Partner University B case rests on the comparable configuration between a human-capital-management software firm (Industry Partner A) and a polytechnic-oriented university. The Partner University C case repeats the partnership pattern with a business-school-oriented partner; its agreement permits technical contributors in teaching, its training plan includes AI, cases, exercises, and informatization work, and a June 2

practicum attendance sheet documents one class session. It remains a limited boundary example at the edge of enterprise-software implementation education and adjacent sociotechnical coursework, not evidence that the planned AI training or engineering training took place. The configuration — large-scale industry partner, teaching-strong university, supportive policy infrastructure — is recognizable across the Chinese engineering-education system and provides a context-specific institutional template for further testing.

Tsui (2006) reminds international readers that mechanisms developed in the Chinese context cannot be assumed to translate directly elsewhere. The author concurs with the caution. The translation of the three-tier framework into other national contexts will require local adaptation: substitution of comparable industry partners, alignment with local accreditation frameworks, adjustment to local employment-law treatment of student interns, and so on. The proposition offered for other contexts is that, where generative AI compresses routine engineering work, curricular design and institutional support should be coordinated to preserve guided developmental opportunities; the three mechanisms provide a vocabulary for examining that coordination.

Limitations

The paper has four principal limitations. *First*, the case material is descriptive and document-based rather than experimental; the longer-run effectiveness of each mechanism in producing senior engineers can be evaluated only over the multi-year horizon on which engineering expertise develops, and that longer evaluation lies beyond the scope of the present paper. *Second*, the three cases are drawn from a single national context; cross-national replication is necessary before the framework's generalizability can be confidently asserted. *Third*, generative AI technology is itself evolving rapidly; the substitution boundary that the present paper diagnoses will shift as foundation-model capabilities expand, and the framework's structural mechanisms will need re-calibration as the technology shifts. *Fourth*, the author's multi-vantage position — industry, engineering-education governance, and academic research — supplies access to the cases but also introduces a constellation of conflicts of interest that the author has sought to declare in full (see Conflict of Interest below).

Directions for Further Research

Two directions invite further work. The first is longitudinal tracking of engineering cohorts who pass through Order-Class / Micro-Major / Integration-Base programs versus comparable cohorts who do not, to test the framework's predictions about senior-engineer pipeline preservation over the multi-year horizon on which engineering expertise develops. The second is comparative institutional study of multi-stakeholder partnerships — the German *Fraunhofer* model and the Chinese Industry-Education Integration Base — to help separate the framework's universal logic from its national-context-specific implementations.

CONCLUSION

The possibility that generative AI will weaken the engineering mentoring chain has been articulated by senior practitioners (Russinovich & Hanselman, 2026). Early employment findings heighten concern about entry into professional work, while learning research shows why AI-assisted performance should not be equated with independent capability (Bastani et al., 2025; Boolzen et al., 2026; Brynjolfsson, Chandar, & Chen, 2025). The institutional question is how to preserve guided developmental opportunities while using AI productively.

This paper has argued that a structural, multi-mechanism response grounded in partnership practice merits testing as an institutional answer. The three-tier additive framework — reinterpreting three established Chinese institutional forms: Order Classes, Micro-Majors, and Industry-Education Integration Bases — supplies a structural vocabulary. The three Chinese cases illustrate different combinations of institutional provisions and observed activity, from Partner University C's limited curricular boundary case with one documented practicum session to Partner University A's delivered cohort, supervised center, and proposed Micro-Major.

The framework is offered, from a multi-vantage industry–education–research position, not as a finished product but as a working vocabulary for the institutional design work that the engineering education community now confronts globally. The work of building the three mechanisms at scale, across many universities and many industries simultaneously, lies ahead. This paper contributes to that work by translating one strand of Chinese engineering-education practice into an internationally legible analytical form.

DECLARATIONS

Acknowledgments

The author thanks Dr. Hans J. Hoyer (Co-Editor-in-Chief, *Engineering Education Review*; Secretary General, International Federation of Engineering Education Societies; Executive Director, Global Engineering Deans Council), and Dr. Shen Ye (Director, EER Editorial Office; UNESCO ICEE Future Technology Education Base) for the editorial conversations in 2025 that shaped the analytical orientation of the paper. The author also thanks colleagues at the two industry partner firms and at the three partner universities for the field access on

which the cases of Section "**METHODS AND COMPARATIVE CASE ANALYSIS**" rest.

The author additionally thanks the three anonymous reviewers for comments across the first and second review rounds that materially improved the manuscript's methods, evidence boundaries, and explanation of the proposed framework.

Funding

The author received no external funding for the preparation of this manuscript.

About the Author

Shuangxi Zhao is General Manager of Inspur Haiyue Cloud Technology (Shenzhen) Co., Ltd. He holds an MBA from Xi'an Jiaotong University and is pursuing a Doctor of Business Administration at the University of Macau. His research interests include generative AI, industry-university collaboration, and the development of professional capabilities. Email: YC47086@um.edu.mo

Author Contributions

As the sole author, all authorship roles in this manuscript were undertaken by the author under the Contributor Roles Taxonomy (CRediT): conceptualization; methodology; investigation; formal analysis; data curation (with respect to institutional records and factual clarifications); writing — original draft; writing — review and editing; visualization; supervision; and project administration. The manuscript was prepared without co-author contributions; the author bears full responsibility for the content.

Ethics Approval and Consent to Participate

This study draws on institutional records — cooperation agreements, recruitment and program-launch materials, program-management records, and a dated course attendance sheet — together with factual clarifications obtained from partner leads, instructors, and students. No experiment was conducted; the clarifications were operational checks rather than a formal interview protocol. The manuscript does not name or quote the people contacted, reproduce student names or numbers from the attendance sheet, or report individual-level outcome figures. The partners discussed joint academic development, but the author has not identified a written authorization specific to publication of this article. At the time of each telephone or WeChat factual clarification, the author told the person contacted that the information would be used in a paper intended for publication. The author's dual role as manager and analyst is a limitation of the study. After the study had commenced, the author consulted the institutional research ethics office, which advised in writing that ethics approval or exemption must be obtained before commencement and data collection and cannot be granted retroactively. No prospective approval, exemption, or written determination that review was unnecessary is available for this study. The author makes no claim of ethics approval, exemption, or informed consent.

Data Availability Statement

The paper draws on descriptive, document-based case material from three industry–university partnerships and on published empirical and policy information. Primary case materials — including cooperation texts, recruitment plans, and program materials — are held by the contracting parties and are not openly redistributable. The author does not hold authority to release those underlying records for external verification, and they are therefore not offered on request; their provenance, denominators, periods, and interpretive limits are instead recorded in Table 1. Published empirical and policy works are cited in the References. A university-published news account corroborates the anonymized signing and badge ceremony in Partner University C; the identifying citation can be provided confidentially to the editor. No new survey or experimental data set was created.

Conflict of Interest

The author is a senior executive of one of the industry partner firms referenced in Sections "*Partner University B / Industry Partner A*" and Sections "*Partner University C / Industry Partner A*" of this paper, and has prior professional involvement, during an earlier career stage, with the industry partner referenced in Section "*Partner University A / Industry Partner B*". Case material is drawn from cooperation agreements, recruitment plans, program-launch materials, internal program-management records, and factual clarifications obtained from partner leads, instructors, and students. The author holds a current managerial interest in the partner firm of the Sections "*Partner University B / Industry Partner A*" and Sections "*Partner University C / Industry Partner A*" cases and held prior managerial responsibility at the partner firm of the Section "*Partner University A / Industry Partner B*" case; he therefore does not claim that these interests have left the analysis unaffected. The safeguards adopted are to report quantitative material only in aggregate or as ranges, to attribute no individually identifiable value, and to remove enterprise operating figures that describe business scale rather than an educational outcome.

AI-Generated Content Declaration

In the preparation and revision of this manuscript, the author used AI assistants — Claude (Anthropic) and Codex (OpenAI), used for drafting, revision, and independent critique during 2026 — in a structured, author-directed workflow. They supported literature search (including Crossref queries and identification of relevant

reviews and practitioner commentary), structural organization, drafting of expository passages, iterative review and consistency checking, and citation and formatting conversion. These tools did not determine the paper's claims: the author personally formulated the research questions, theoretical claims, and three-tier framework; led or participated in the underlying partnerships and conducted factual clarifications; selected the case material; and bears responsibility for checking all quantitative claims, citations, and edits and approving the final manuscript before submission. No AI tool produced the methodological, analytical, or empirical content autonomously.

REFERENCES

ABET. (2025). *Criteria for accrediting engineering programs, 2025–2026*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2025-2026/

Autor, D. H. (2015). Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspectives*, *29*(3), 3–30. https://doi.org/10.1257/jep.29.3.3

Bastani, H., Bastani, O., Sungu, A., Ge, H., Kabakcı, Ö., & Mariman, R. (2025). Generative AI without guardrails can harm learning: Evidence from high school mathematics. *Proceedings of the National Academy of Sciences*, *122*(26), Article e2422633122. https://doi.org/10.1073/pnas.2422633122

Beane, M. (2019). Shadow learning: Building robotic surgical skill when approved means fail. *Administrative Science Quarterly*, *64*(1), 87–123. https://doi.org/10.1177/0001839217751692

Billett, S. (2001). Learning throughout working life: Interdependencies at work. *Studies in Continuing Education*, *23*(1), 19–35. https://doi.org/10.1080/01580370120043222

Boolzen, C., Kuhn, J., Flegr, S., Rott, E. M., Stausberg, N., & Küchemann, S. (2026). Evidence of impact and interpretational limits of generative AI in STEM education: A systematic review and meta-analysis on cognitive learning outcomes. *Artificial Intelligence Review*, *59*(10), Article 223. https://doi.org/10.1007/s10462-026-11665-9

Borah, D., Malik, K., & Massini, S. (2021). Teaching-focused university–industry collaborations: Determinants and impact on graduates' employability competencies. *Research Policy*, *50*(3), Article 104172. https://doi.org/10.1016/j.respol.2020.104172

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27–40. https://doi.org/10.3316/QRJ0902027

Boyer, E. L. (1990). *Scholarship reconsidered: Priorities of the professoriate*. Carnegie Foundation for the Advancement of Teaching.

Brynjolfsson, E., Chandar, B., & Chen, R. (2025). *Canaries in the coal mine? Six facts about the recent employment effects of artificial intelligence* [Working paper]. Stanford Digital Economy Lab, Stanford University. https://digitaleconomy.stanford.edu/publication/canaries-in-the-coal-mine-six-facts-about-the-recent-employment-effects-of-artificial-intelligence/

Brynjolfsson, E., Li, D., & Raymond, L. R. (2025). Generative AI at work. *The Quarterly Journal of Economics*, *140*(2), 889–942. https://doi.org/10.1093/qje/qjae044

Chi, M. T. H., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, *49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

Collins, A., Brown, J. S., & Holum, A. (1991, Winter). Cognitive apprenticeship: Making thinking visible. *American Educator*. https://www.aft.org/ae/winter1991/collins_brown_holum

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking engineering education: The CDIO approach* (2nd ed.). Springer. https://doi.org/10.1007/978-3-319-05561-9

Dell'Acqua, F., McFowland, E., III, Mollick, E., Lifshitz, H., Kellogg, K. C., Rajendran, S., Krayer, L., Candelon, F., & Lakhani, K. R. (2026). Navigating the jagged technological frontier: Field experimental evidence of the effects of artificial intelligence on knowledge worker productivity and quality. *Organization Science*, *37*(2), 403–423. https://doi.org/10.1287/orsc.2025.21838

Dewey, J. (1938). *Experience and education*. Kappa Delta Pi.

Eby, L. T., Allen, T. D., Evans, S. C., Ng, T., & DuBois, D. L. (2008). Does mentoring matter? A multidisciplinary meta-analysis comparing mentored and non-mentored individuals. *Journal of Vocational Behavior*, *72*(2), 254–267. https://doi.org/10.1016/j.jvb.2007.04.005

Eraut, M. (2004). Informal learning in the workplace. *Studies in Continuing Education*, *26*(2), 247–273. https://doi.org/10.1080/15803704200022524 5

Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education*, *78*(7), 674–681.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245. https://doi.org/10.1177/1077800405284363

Gong, K. (2024a). On artificial intelligence and how to develop, teach and govern it. *Cultures of Science*, *7*(2_suppl), 82–86. https://doi.org/10.1177/20966083251315257

Gong, K. (2024b). Sustainable development and digitization: A further discussion on the dual transformation of engineering education. *Engineering Education Review*, *2*(1), 1–6. https://doi.org/10.54844/eer.2023.0490

Green, T. (2026, May 8). *The apprenticeship severance: How AI is breaking the expertise pipeline*. SmarterArticles. https://smarterarticles.co.uk/the-apprenticeship-severance-how-ai-is-breaking-the-expertise-pipeline

Honig, C., Rios, S., & Desu, A. (2025). Generative AI in engineering education: Understanding acceptance and use of new GPT teaching tools within a UTAUT framework. *Australasian Journal of Engineering Education*, *30*(1), 80–92. https://doi.org/10.1080/22054952.2025.2467500

Hu, D., & Song, H. (2025). The elements and reform path of core competencies for excellent engineers in China. *Engineering Education Review*, *3*. https://doi.org/10.54844/eer.2025.0854

Hwang, W., Aguinalde, P., Crippen, K. J., Shin, J., & Carroll, B. F. (2026). Systematic review of work-integrated learning in undergraduate engineering education. *Journal of Engineering Education*, *115*(1), Article e70050. https://doi.org/10.1002/jee.70050

International Labour Organization. (2025). *Generative AI and jobs: A 2025 update*. https://www.ilo.org/publications/generative-ai-and-jobs-2025-update

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.

Kram, K. E. (1985). *Mentoring at work: Developmental relationships in organizational life*. Scott, Foresman.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Li, M., Qiu, Y., Liu, X., Wang, J., Xue, W., & Wei, S. (2026). Cultivating outstanding engineers through university-industry collaboration: A case study in Beijing Institute of Technology. *Engineering Education Review*, *4*(1), Article eer26070014. https://doi.org/10.67229/eer.26070014

Liang, J., Stephens, J. M., & Brown, G. T. L. (2025). A systematic review of the early impact of artificial intelligence on higher education curriculum, instruction, and assessment. *Frontiers in Education*, *10*, Article 1522841. https://doi.org/10.3389/feduc.2025.1522841

Lin, J. (2017). Xin gong ke jian she: Qiang shi da zao "Zhuo yue ji hua" sheng ji ban [Construction of emerging engineering: Upgrading the Excellent Engineer Education and Training Program]. *Research in Higher Education of Engineering*, (3), 7–14.

Lin, J., Wang, S., Yu, S., & Qiao, W. (2015). PETOE: A new multi-sector

collaboration mechanism for engineering training in China. *International Journal of Chinese Education*, *4*(2), 234–249. https://doi.org/10.1163/22125868-12340054

Liu, Y., Xiao, Y., & He, X. (2025). What core competencies should a great engineer possess? A comparative study from the perspective of engineering undergraduates in China and the United States. *Engineering Education Review*, *2*(3), 109–119. https://doi.org/10.54844/eer.2024.0818

Lu, D., Kang, L., Guo, L., Ma, Y., & Ke, W. (2025). How to cultivate interdisciplinary and comprehensive practical abilities of engineering students—A case study of innovative design and advanced manufacturing center at South University of Science and Technology. *Engineering Education Review*, *3*(1), Article eer20250902. https://doi.org/10.54844/eer.2025.0902

National Academy of Engineering. (2008). *Grand challenges for engineering*. https://www.engineeringchallenges.org/

Russinovich, M., & Hanselman, S. (2026). Redefining the software engineering profession for AI. *Communications of the ACM*, *69*(4), 41–44. https://doi.org/10.1145/3779312

Shah, R., & Gillen, A. L. (2024). A systematic literature review of university-industry partnerships in engineering education. *European Journal of Engineering Education*, *49*(3), 577–603. https://doi.org/10.1080/03043797.2023.2253741

Stadler, M., Bannert, M., & Sailer, M. (2024). Cognitive ease at a cost: LLMs reduce mental effort but compromise depth in student scientific inquiry. *Computers in Human Behavior*, *160*, Article 108386. https://doi.org/10.1016/j.chb.2024.108386

Tsui, A. S. (2006). Contextualization in Chinese management research. *Management and Organization Review*, *2*(1), 1–13. https://doi.org/10.1111/j.1740-8784.2006.00033.x

Vuoriainen, A., Rikala, P., Heilala, V., Lehesvuori, S., Oz, S., Kettunen, L., & Hämäläinen, R. (2025). The six C's of successful higher education-industry collaboration in engineering education: A systematic literature review. *European Journal of Engineering Education*, *50*(1), 26–50. https://doi.org/10.1080/03043797.2024.2432440

Wang, S., & Yang, J. (2025). Seeking key focus areas for industry-education integration in the current reform of higher engineering education. *Engineering Education Review*, *3*(1), Article eer20250844. https://doi.org/10.54844/eer.2025.0844

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press. https://doi.org/10.1017/CBO9780511803932

Xu, L. (2025a). Innovative interdisciplinary models in engineering education: Transforming practices across global universities. *Engineering Education Review*, *2*(3), 129–144. https://doi.org/10.54844/eer.2024.0846

Xu, L. (2025b). An integrated competency model for engineering teachers: A comparative framework insights. *Engineering Education Review*, *3*(1), Article eer20240816. https://doi.org/10.54844/eer.2024.0816

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage Publications.

Zhang, B. (2024). Venturing into the "uninhabited zone" to explore the path of artificial intelligence. *Engineering Education Review*, *2*(2), 45–65. https://doi.org/10.54844/eer.2024.0628

Zhao, S. (2025, September 22). *Breakthroughs in "technology + management" talent in engineering* [Keynote presentation]. WEEF & GEDC 2025, Engineering Education Review special session, Daegu, South Korea. https://www.hksmp.com/journals/eer/announcement/view/116