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REVIEW ARTICLE

A knowledge conversion perspective on case repository building in engineering education: The "321" model

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ABSTRACT

Case-based teaching is widely recognized as an effective approach to bridging the theory-practice gap in engineering education and cultivating the non-technical competencies of outstanding engineers. However, systematically building a high-quality case repository remains an organizational challenge that has received limited scholarly attention. Drawing on the SECI (Socialization-Externalization-Combination-Internalization) model from knowledge management theory, this study examines the "321" case repository development model implemented at China University of Petroleum (Beijing) over more than a decade. The findings reveal three key mechanisms: (1) the three-tier platform (school-university-national) constitutes an integrated "Ba" for knowledge conversion, facilitating the transformation of enterprises' tacit experience into systematic explicit cases; (2) the two-dimensional driving mechanism—institutional coordination between university and school, and faculty-student co-creation embedded in enterprise partnerships—provides institutional safeguards and core momentum, with the latter effectively activating externalization and achieving value co-creation; and (3) the singular core objective of serving talent cultivation and enterprise management innovation drives knowledge through a complete conversion spiral, internalizing it as students' practical competencies while feeding back into industry. The model has been successfully transferred to engineering professional degree education, supporting multiple engineering schools in securing Ministry of Education themed case projects. This study elevates case repository building from experiential practice to theoretical awareness, offering a systematic solution for industry-education integration and outstanding engineer cultivation.

Keywords: knowledge conversion, SECI model, case repository development, engineering education

INTRODUCTION

In September 2022, at the inaugural International Symposium on Case Development in China, Minister of Education Huai Jinpeng stated that "cases embody a teaching philosophy, educational vision, and talent cultivation perspective centered on the unity of knowledge and action, playing a vital role in transforming educational thinking and cultivating innovative talent." In the same year, the Action Plan for High-Quality Development of Philosophy and Social Sciences in Higher Education Institutions Towards 2035 explicitly called for "advancing case development with Chinese characteristics" (Huang et al., 2022). Against this backdrop, case development has been integrated into the national strategy for cultivating high-level practice-oriented innovative talent.

Engineering education has long confronted a core con-

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tradiction: the systematic theoretical knowledge delivered in classrooms is profoundly disconnected from the complex, context-dependent challenges encountered in engineering practice. International engineering education accreditation systems have established non-technical competencies—including "solving complex engineering problems," "engineering and society," "project management," and "teamwork"—as essential graduate attributes (International Engineering Alliance, 2021; China Engineering Education Accreditation Association, 2022). Yet how to effectively cultivate these hard-to-quantify, highly context-dependent competencies remains a shared challenge. As Yang (2025) observes, the cultivation of outstanding engineers currently faces bottlenecks in training models and curriculum innovation, with an insufficient supply of engineering cases and practical projects constraining students' innovative and practical abilities.

Case-based teaching, with its distinctive strengths of using authentic situations as anchor points and problem-solving as the orienting focus, is widely recognized as an effective means of bridging this gap (Wang et al., 2017). However, the effectiveness of case-based teaching depends critically on the quality and relevance of the cases themselves. In other words, high-quality case-based teaching presupposes a repository of excellent cases rooted in local practice, reflecting real challenges, and possessing pedagogical value—along with a mechanism capable of producing such cases on an ongoing basis. This constitutes a pressing yet under-researched "organizational challenge" in engineering education: how can a high-quality engineering case repository be developed systematically and sustainably?

While existing research has contributed substantially to case teaching methods and individual case development (Su & Cui, 2011; Wang & Hu, 2014), few studies have adopted an organizational perspective to explore sustainable mechanisms for systematic case development. Existing studies on case repository building—including the "trinity" case teaching system (Chen & Cheng, 2021), the "5W" cultivation model (Hu et al., 2024), and the "dual-element integration" model (Hu et al., 2022)—have yet to provide an integrative, theoretically grounded analytical framework.

This study responds to this gap. Since 2010, the School of Economics and Management at China University of Petroleum (Beijing) has systematically explored case repository development, taking its three professional degree programs (MBA, MPAcc, MFin) as pilot initiatives and forming the "321" model. When the university was approved to establish a National School of Excellence in Engineering, this model was transferred to multiple engineering professional degree programs, forming a cross-disciplinary radiation pattern of "management taking the lead, engineering applying the outcomes." As Yang (2025) notes, Schools of Excellence in Engineering currently face challenges of resource coordination and governance innovation; the "321" model, as a mature methodology and "infrastructure," offers a viable pathway for addressing these challenges.

This paper introduces the SECI model to systematically deconstruct the mechanisms of the "321" case repository development model, with particular attention to how university-enterprise collaborative case development drives knowledge conversion and value co-creation. Our central argument is that the essence of case repository building is a knowledge conversion spiral that transforms enterprise tacit knowledge into systematic explicit knowledge, which is then converted into students' internalized competencies. The theoretical awareness and institutional design of this spiral constitute the foundation for the model's success and transferability.

THEORETICAL FOUNDATIONS AND ANALYTICAL FRAMEWORK

The SECI model

The SECI model, proposed by Nonaka and Takeuchi, is one of the most influential theories in knowledge management. Its core proposition is that sustained organizational innovation arises from the continuous dynamic conversion between tacit knowledge and explicit knowledge (Nonaka & Takeuchi, 1995). This upward spiral consists of four phases:

- **Socialization:** Tacit knowledge is shared through joint practice, observation, and imitation (e.g., mentoring, on-site shadowing).
- **Externalization:** Tacit knowledge is articulated as explicit concepts through dialogue, modeling, and writing—the most critical step in knowledge creation.
- **Combination:** Dispersed explicit knowledge is sorted, categorized, and recombined into a more systematic knowledge system.
- **Internalization:** Through "learning by doing," explicit knowledge is internalized as personal practical wisdom.
- Nonaka emphasizes that these phases require a shared **"Ba"** (context)—a space that may be physical, virtual, or institutionalized as an interactive platform. Only when an organization consciously creates appropriate "Ba" for each phase can the knowledge spiral operate continuously.

Case repository building through the SECI lens

When case repository building is examined through the SECI lens, its essence becomes clear: it is precisely about

managing the complete chain of knowledge transformation from enterprise contexts to educational texts to student competencies. Zhang and Hou (2020) also identify "knowledge conversion" as the core mechanism of case teaching, arguing that it achieves the integration of knowledge and action through four stages: creation of practical situations, activation of theoretical knowledge, externalization of tacit knowledge, and internalization and transfer of knowledge. Accordingly, this study systematically examines how the "321" model provides institutional support for each phase of SECI knowledge conversion, constructing appropriate "Ba" to drive the continuous operation of the knowledge spiral.

METHODOLOGY

This study adopts a qualitative case study approach (Eisenhardt, 1989), taking the case repository development practices at China University of Petroleum (Beijing) as its analytical object. The case spans over a decade and serves a radiation function of "management taking the lead, engineering applying the outcomes," providing a window for cross-disciplinary academic observation.

Data sources include: (1) archival materials consisting of annual work reports of the Professional Degree Education Center from 2010 to 2024, training program documents, incentive policy documents, case competition records, and case award lists; (2) participant observation by the authors, who have served as administrators and instructors in the case development process for over ten years, accumulating extensive materials during case writing workshops, case competition preparation, and enterprise interviews; and (3) in-depth interviews. A total of 10 semi-structured interviews were conducted between 2020 and 2024, including three administrators directly overseeing case development, five faculty members who had successfully published cases in national repositories, two enterprise supervisors involved in university–enterprise case co-creation, and five professional degree postgraduates at different stages of their programs. Each interview lasted between 40 and 70 minutes.

Data analysis followed a theory-driven thematic analysis approach. Open coding was first conducted on all transcripts and archival excerpts to generate descriptive codes. These codes were then mapped onto the four phases of the SECI model (socialization, externalization, combination, internalization), with disagreements resolved through discussion to produce a final coding scheme. To strengthen the trustworthiness of the findings, data triangulation was employed: patterns identified in interview accounts were cross-checked against archival documents and the authors' own observational notes. Only themes consistently supported by at least two data sources were retained in the final analysis.

KNOWLEDGE CONVERSION MECHANISMS OF THE "321" MODEL

The "321" model progressively developed over more than a decade. Viewed through the SECI lens, its core components constitute an organically coordinated institutional ecology for knowledge conversion.

The "three"-tier platform: Constructing the "Ba" for knowledge conversion

The "3" refers to the three-tier case development platform system—school, university, and national levels. In SECI theory, these platforms constitute the institutionalized "Ba" required for knowledge conversion.

- **School-level platform:** Composed of the Case Research and Development Center and the annual School-Level Case Competition, this platform serves as the primary arena for knowledge externalization, providing seed funding, organizing faculty-student teams, and hosting writing workshops that scaffold case writing.
- **University-level platform:** High-quality case outcomes are incorporated into faculty promotion criteria and postgraduate award systems (Cheng & Qin, 2021), and case competitions are integrated into compulsory practical teaching. This elevates case development from a school-level initiative to an institutionalized standard practice.
- **National-level platform:** This includes case competitions organized by national professional degree education steering committees, the National Top 100 Excellent Management Cases, and the China Professional Degree Case Center. Submitting cases to this level entails more rigorous peer review and broader societal impact.

The three tiers progress step by step, forming a complete chain of "Ba" for knowledge conversion. This explains the school's sustained high productivity in case development: not merely the enthusiasm of a few faculty members, but the institutionalized platform that ensures externalization activities have space, safeguards, and progression pathways.

The "two"-dimensional driving mechanism: The "twin engines" of knowledge conversion

The "2" refers to two bidirectional interactive dimensions: vertical "university-school" management coordination and horizontal "faculty-student" co-creation. Together, they constitute the "twin engines" of case repository development.

The vertical dimension: The institutional engine

The university level provides policy direction and project support, while the school level establishes a dedicated Case Center responsible for organization, training, selection, and external liaison. This ensures sustained institutional resource infusion and administrative support for each phase of knowledge conversion.

The horizontal dimension: The collaborative engine of faculty-student co-creation

If university-school coordination provides the institutional safeguard, the bidirectional "faculty-student" interaction—especially faculty-student co-creation embedded with deep enterprise participation—serves as the core driving force for knowledge creation. This process can be deconstructed through the SECI lens.

- **Socialization:** Faculty-student teams conduct in-depth investigations in partner enterprises, which share their actual decision-making processes, management dilemmas, and practical wisdom from specific projects. Enterprise engineers and managers transfer hard-to-articulate "tacit knowledge"—such as intuitive market judgments and engineering risk assessment experience—to the faculty-student team through face-to-face communication and on-site observation. This contextualized knowledge sharing represents the unique value of industry-education integration.
- **Externalization:** After acquiring rich enterprise tacit knowledge, faculty members lead students in theoretical condensation and synthesis. The core task is the analysis, induction, and elevation of fragmented enterprise experience through theoretical frameworks, externalizing it into structured, generalizable explicit knowledge. This process yields dual value:

For the enterprise: This is tantamount to high-level management consulting. A theoretically refined case helps the enterprise systematically organize its tacit management experience, elevating it into transferable management wisdom that supports internal training and, through case publication and repository inclusion, enhances brand image.

For the university: This produces high-quality teaching cases that originate from and transcend real-world practice, containing deep theoretical value and pedagogical dilemmas.

- **Combination:** The initial case drafts undergo rigorous review and revision before entering the three-tier platform, thereby completing combination. This process integrates the case with related cases and theoretical modules, forming a structured curriculum resource system.
- **Internalization:** These cases are applied in classroom teaching and further internalized, through case competitions and case-based degree theses, as students' practical competence in analyzing and solving complex engineering management problems.

The effectiveness of this mechanism is reflected in the accounts of participants. A faculty member who had led several award-winning case development projects remarked in an interview:"*When we first approached the enterprise, the managers were reluctant to open their project files. But after we presented a draft that turned their messy crisis response into a clear decision-making model, they realized this could also help train their own new managers.*"

An enterprise supervisor from a state-owned oilfield services company similarly observed:"*The case they wrote about our shale gas project not only captured what we did but also explained why we made those choices using theories I hadn't thought about. We now use that case in our internal training.*"

Internal policy documents also underscore the institutional weight placed on case development. The university has incorporated outstanding teaching cases into the faculty annual evaluation system and promotion review documents. Case development receives dedicated project funding support, and faculty are encouraged to submit their work to leading domestic and international case repositories. Cases selected for inclusion in such repositories or recognized among the "National Top 100 Outstanding Management Cases" receive substantial rewards. Several interviewees described this policy as "the single most important driver" of sustained faculty engagement.

It is evident that university-enterprise collaboration under the "321" model has transcended the traditional "internship base" model, establishing a win-win mechanism based on knowledge co-creation and value exchange. The enterprise contributes knowledge raw materials and gains condensed management wisdom and brand communication; the university contributes theoretical tools and gains teaching resources, research material, and talent cultivation vehicles. This constitutes the inherent logic by which the model continuously activates the enthusiasm of both partners and achieves deep industry-education integration. As Cai and Liu (2022) argue, the essence of industry-education integration lies in universities and enterprises mutually supporting, interpenetrating, and deeply integrating throughout the entire collaborative talent cultivation process. This study provides a concrete micro-level pathway for such integration.

The "one" core objective: The "spiral destination" of knowledge conversion

The "1" represents the value destination of the model: serving the dual objectives of enhancing talent cultivation quality and synthesizing Chinese enterprise management experience. At the individual level, students com-

plete the entire SECI process—from classroom case-based learning, through participation in case development investigations, to case competitions and case-based degree theses—and internalize these experiences as their own competencies (Hu et al., 2022). At the organizational level, cases archived in national platforms upgrade explicit knowledge accumulated by a single institution into nationally shared educational resources.

Over the past decade, this institutionalized system has produced measurable outcomes. Faculty and students have collaboratively developed over 160 cases with independent intellectual property rights, of which 40 have been selected for national-level case repositories, 7 were honored as "National Top 100 Outstanding Management Cases," and 1 was included in the Ivey Business School case library. The annual school-level case competition attracts over 300 participants each year, and the proportion of faculty engaged in case development has more than tripled since the early years of the program. These figures illustrate not merely the volume of output, but the sustained participation that the "321" model has been able to generate.

EXTENSION AND APPLICATION: EMPOWERING THE NATIONAL SCHOOL OF EXCELLENCE IN ENGINEERING

The model's extension to the National School of Excellence in Engineering provides the most compelling test of its generalizability. Following the school's approval, the School of Economics and Management forged a strategic synergy with the School of Excellence in Engineering: the established "321" model was transplanted as a methodology and infrastructure into engineering discipline case repository building.

Implementation measures included: platform sharing through the three-tier system; mechanism replication adapted to engineering disciplines; and cross-disciplinary co-creation, with faculty from management and engineering schools forming joint teams, taking authentic engineering projects as raw materials, with management faculty providing analytical frameworks and engineering faculty ensuring technical accuracy. Multiple engineering schools have adopted this model, collaboratively developing dozens of energy-sector engineering cases and securing multiple Ministry of Education themed case projects. This validates that the "321" model is a transferable case development infrastructure.

However, this transfer was not without challenges. Three obstacles emerged in the initial stage. First, engineering faculty, accustomed to laboratory-based research, were initially skeptical about the academic value of case writing; some viewed it as "soft" work that would not contribute to their promotion prospects. To address this, the university's promotion committee revised its criteria to explicitly recognize high-quality engineering cases as equivalent to teaching and educational research outputs. Second, the highly technical nature of engineering content required a longer co-creation cycle: management faculty needed additional time to understand the engineering context before applying theoretical frameworks, and engineering faculty required training in case-writing methodology. The school has therefore attempted to organize a series of cross-disciplinary case development workshops over two semesters. Third, the incentive structure originally designed for business cases did not fully accommodate the team-based, multi-author nature of engineering case projects, where contributions from several engineers, managers, and faculty members needed to be acknowledged. The school is currently adjusting its reward allocation guidelines to better reflect collaborative authorship. These adjustments, while incremental, were critical in establishing the model's legitimacy in the engineering education context, and they highlight that transferability depends not only on the robustness of the original model but also on the willingness to adapt its operational details to the norms of the target discipline.

CONCLUSIONS AND DISCUSSION

Theoretical contributions

This study provides an integrative analytical framework for case repository building in engineering education through SECI knowledge conversion theory. Its contributions are threefold: (1) It elevates case repository building from experiential practice to theoretical awareness, revealing the micro-mechanisms of university-enterprise collaborative case development and providing a knowledge management explanation for industry-education integration. (2) It proposes the concept of "case development infrastructure," demonstrating that when institutional design follows the laws of knowledge conversion, sustainability and transferability can be simultaneously achieved. (3) It reveals a distinctive pathway through which management disciplines can provide methodological tools for engineering education reform.

Practical implications

Effective case repository development should be systematically designed across three dimensions—incentives, platforms, and objectives—rather than relying on individual faculty efforts. This approach constitutes a concrete implementation of Minister Huai Jinpeng's vision that cases embody the unity of knowledge and action, and an effective response to the strategic deployment of advancing case development with Chinese characteristics.

Limitations and future directions

As a single case study, the generalizability of conclusions must consider differences in institutional type, disciplinary background, and resource conditions. Future research could conduct multi-case comparative studies across different universities. Second, the study relies primarily on the SECI model; future research could incorporate multiple perspectives such as resource dependence theory and the triple helix model. Finally, the measurement of students' internalization effects currently relies on competition awards and employer evaluations; future research could develop more systematic assessment tools.

DECLARATIONS

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Author contributions

Hui Lv analyzed and wrote the manuscript. Chunai Ma proposed an overall framework for the manuscript. Zhuoyi Li revised and proofread the manuscript content. All authors have read and approved the final version of the manuscript.

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Ethics approval

Not applicable.

Informed consent

Not applicable.

Conflict of interest

The authors declare no competing interest.

Use of large language models, AI and machine learning tools

None declared.

Data availability statement

No additional data.

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