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SECI Model in Technical Education and Entrepreneurship: A Systematic Review of Knowledge Creation Enablers

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ABSTRACT

This paper is a systematic literature review of the SECI model in technical education, entrepreneurship and organizational settings. Although the SECI model has been widely applied to explain knowledge creation, prior studies have predominantly emphasized its structural, procedural, and technological extensions, while giving less attention to the relational and motivational factors that shape knowledge-sharing processes. Using PRISMA guidelines, Scopus-indexed empirical studies published between 2016 and 2025 were systematically identified, screened, and selected based on their explicit application of SECI and their relevance to innovation, learning or performance outcomes. A total of 21 studies were synthesized into four themes: (1) the role of SECI in competency development in technical education, (2) the application of SECI in entrepreneurial and product innovation contexts, (3) relational, psychological, and cultural enablers of knowledge creation, and (4) the adaptation and evolution of the SECI model. The findings indicate that SECI supports competency development, innovation processes, and organizational performance. Furthermore, its effectiveness is strongly influenced by relational and motivational factors such as trust, intrinsic motivation, and interpersonal interaction. This review offers an integrative conceptual understanding of SECI that foregrounds relational and motivational factors as foundational conditions for effective knowledge creation in technical education and entrepreneurial ecosystems.

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1. INTRODUCTION

The knowledge-based economy and the pace of technological transformation not only demand that universities, especially those in the engineering and technology sector, graduate professionals with technical expertise but also with innovation, collaboration and entrepreneurial skills (Dobrovolska et al., 2023; Proença, 2025). Learning is no longer seen in this context as a linear dissemination of

information, but rather as an interactive process with reflection and a transformation of knowledge at different levels. Universities should lead in generating an environment conducive to students for developing ideas, teamwork and translating knowledge into creative solutions relevant to industry needs and the entrepreneurial ecosystem (Herlina & Wahira, 2024; Lv et al., 2022).

As these expectations change, definitions of theories of how knowledge is generated, transmitted, and applied become more relevant. Of these, the SECI model of knowledge creation has proved one of the most popular approaches for modelling the interaction between tacit and explicit knowledge. In the SECI model, invented by Ikujiro Nonaka and Hirotaka Takeuchi in the Japanese context, knowledge is denoted as a flowing, continuous process consisting of 4 phases: Socialization, Externalization Combination, and Internalization (Nonaka & Takeuchi, 1995). In this way, the experiential and tacit knowledge of individual members is shared, explicated into codified forms, synthesised systematically with previous knowledge, and finally re-internalised through usage.

The SECI model has been applied across disciplines such as higher education, product innovation, and entrepreneurship (Asbari & Asbari, 2025; Laptev & Shaytan, 2023; Palaniswamy et al., 2025). The model is becoming more relevant in technical education that emphasizes project-based, teamwork and real-world problem-solving curriculum as the skill acquisition (Songkram & Chootongchai, 2020; Takahashi & Kiyosumi, 2021). SECI offers a strong theoretical framework in the development of team-based and real-world project-based learning that can be tailored so that it is not simply content delivery, but rather an educational process where learning naturally becomes knowledge creation and innovation.

In an entrepreneurial and innovative sense, the SECI model offers a basis to explain ways by which knowledge is translated, leading to ideas, products and economic value (Chang et al., 2025; Leal et al., 2023). Knowledge creation among entrepreneurial teams, startups and innovative organizations results in creative solutions, new product development and sustainable competitive advantage (Hameed et al., 2024; Rattanawichai et al., 2023; Sepúlveda-Rojas et al., 2024). This shows that the SECI model is applicable not only in education but also within entrepreneurial ecosystems where joining efforts, constant learning and adapting to technological change are required.

As research on literature has progressed, the use of the SECI model has expanded beyond its initial image as a knowledge creation spiral model. The SECI model is now recognised as a mechanism for value creation and innovation rather than just for knowledge management (Nonaka & Yamaguchi, 2022). This model has been modified and improved in many research studies, which have combined it with quality management systems, decision-making, and digital technologies (Cerchione et al., 2024b; Jghamou et al., 2022; Liu, 2024a; Tyagi, 2016). These refinements illustrate that SECI is becoming increasingly articulated as a flexible and context-dependent model, relevant in multiple educational settings, institutions, and entrepreneurial ecologies.

Most SECI model developments still focus on the structural, procedural, and technological aspects that support the knowledge creation process. Many SECI adaptations emphasize curriculum design, digital infrastructure, and the physical/virtual context (Albishri et al., 2025; Palaniswamy et al., 2025; Żatuchin, 2025). The application of SECI in these studies places greater emphasis on the structure of activities and technology as process enablers. Meanwhile, relational and motivational factors that influence individuals' willingness to share, externalize, and internalize knowledge have not been a primary focus in model development. In fact, the knowledge creation and transfer process fundamentally depends on interpersonal interactions, trust, intrinsic motivation, and reciprocal relationships between individuals in learning environments and organizations (Bello et al., 2025; Guzik et al., 2025; Leal et al., 2023). In the absence of these social and psychological conditions, the process is likely to be ineffective, even if supported by fancy systems or technology. This state of affairs suggests it is time to revisit the utility of the SECI model by explicitly accounting for the interpersonal and motivational aspects embedded in knowledge-sharing actions. Knowledge about these social and psychological aspects is central, as engineering and entrepreneurship education builds on learning and innovation processes that largely depend upon collaboration, idea exchange, and people's active participation in their own knowledge generation.

Based on this background, the present study will conduct a systematic literature review to investigate the extent to which and how the SECI model has been implemented, modified, and extended across educational, entrepreneurial, and organisational settings. In this study, we synthesised research findings to establish major trends in competency formation, the innovation process, social relations, and the theoretical development of the SECI model. In this context, the present study discusses how the SECI model is used from the perspective of technical education and entrepreneurship. Suiting to these objectives, the present study is aimed at answering the following research questions: (1) How is the SECI model applied in the context of technical education for competency development? (2) How is the SECI model used in the context of entrepreneurship and product innovation? (3) What relational, psychological, and cultural factors influence the effectiveness of the knowledge creation process in the SECI model? (4) How is the SECI model adapted and developed in response to technological and organisational change? This review focuses on empirical and conceptual studies published from 2016 to 2025 that explicitly use or expand the SECI framework in engineering education institutions, entrepreneurial teams, start-ups, or innovation-oriented organisations.

2. METHOD

This review was carried out in a systematic, rigorous manner to maximize the quality of the identification, screening and synthesis of included studies. The paper revisits the SECI model and critically examines how cases have been applied to this analysis during the period from 2016 to 2025. The search process was performed in compliance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.

3.1 Search Strategy

A literature search was performed through Scopus with the objective of identifying high-impact-factor journals (i.e., we included Q1, Q2, Q3 and Q4 journals) to ensure that relevant scientific peer-reviewed empirical studies were included in our investigation (Sauer & Seuring, 2023). Scopus was chosen because it provides extensive coverage of academic articles, particularly in the areas of management, business and social science (Chadegani et al., 2013). This database also includes a number of high-yield journals that frequently publish articles on research related to the SECI model and its application across varying domains, which is why it was included in this systematic review.

The search was performed using a combination of keywords related to the main topics of the SECI model and knowledge management. Keywords include: “knowledge conversion”, “knowledge transformation model”, “SECI model”, “Nonaka model”, “SECI studies”, “SECI application”, “SECI entrepreneur”, “SECI enterprise”, “innovative startup”, “entrepreneur knowledge management”, and “tacit knowledge”. The literature review is limited to the period 2016-2025, aiming to reflect the growing importance attributed to the SECI model in relation to technological and pedagogical developments affecting knowledge management (Gubbins & Dooley, 2021; Żatuchin, 2024).

3.2 Inclusion and Exclusion Criteria

Very strict inclusion and exclusion criteria were established to maintain a focused review. Transparent criteria support strategies for selecting sources in the interest of empirical relevance and conceptual coherence of the review. The following were the inclusion criteria employed by the authors: (1) Empirical studies where SECI model was applied, this being crucial for understanding of its usefulness and applicability; (2) Studies linking SECI to innovation, learning or performance because research that associates the SECI model with measures of innovative success or learning in organisations can help explain how innovations are created within organisations; and also there is evidence-based findings arguing for strong claims; (3) English language articles as availability of widely understandable language facilitates both even application on popularity and closer comprehensive understanding; and(4) peer-reviewed articles, selecting only peer-reviewed articles maintains the scientific rigour and credibility of the findings (Perkmann et al., 2021).

On the contrary, exclusion criteria excluded papers for the following: (1) pure concept papers i.e. research works that do not have any empirical evidence and hence does not fit into the empirical focus of our systematic review; (2) other knowledge management sources, as we need to exclude articles that are not directly connected with SECI to keep validity; (3) non-peer reviewed work, the reason is pretty much obvious, such studies add a bias in their own way and bring down overall quality of survey study thus they should have been removed.

3.3 Screening and Selection Process

The literature's screening and selection process were based on four stages: (1) Identification (Searching): A comprehensive search in the Scopus database generated a high amount of records about SECI model, claims as definitions of knowledge creation; (2) Screening: Removing duplicated results followed after abstracts' review to early exclusion of non-relevant papers; (3) Eligibility Retrieval: Full-text reading to selected papers, aiming to check if they met inclusion criteria or not; And lastly (4) Inclusion report: Works that showed relevancy with research question and also empirical accuracy were included. A PRISMA flow diagram (Figure 1) shows that many records were identified, screened, excluded, and included in the review.

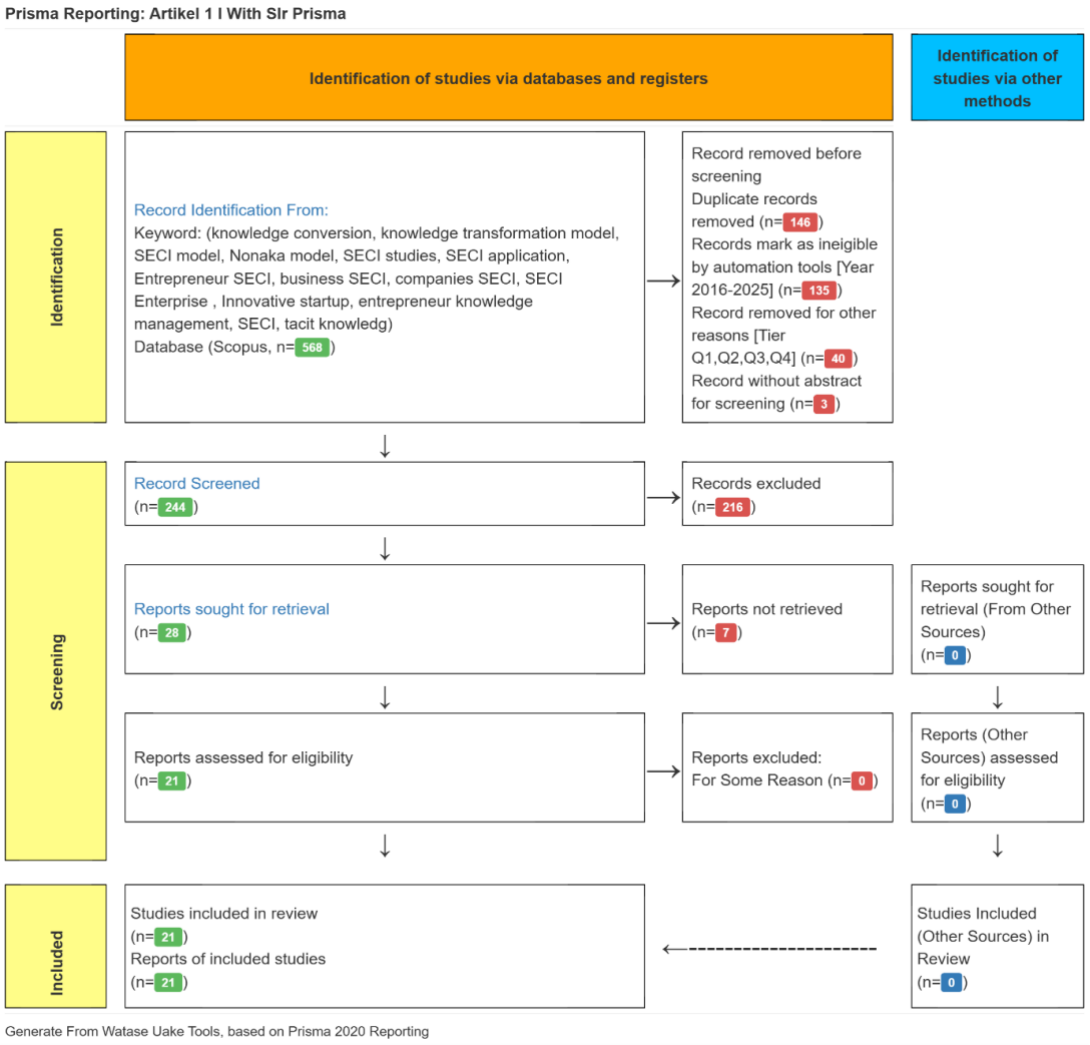

Figure 1. PRISMA flow diagram

3. FINDINGS AND DISCUSSION

Consistent with the literature screening and synthesis, 21 empirical articles were critically examined. For ease of navigating the structure of synthesis identification and to facilitate transparency in terms of how the study findings were synthesised, articles were mapped into four over-arching themes representing the predominant direction of enquiry around immersion and evolution in using ('applying') or extending ('developing') the SECI model they were: (1) SECI for competency development in technical education, (2) The use applied SECI in entrepreneurship and product innovation, (3) Relational, psychological, and cultural drivers advancing knowledge creation; as well as (4) Adaptation and evolution SECI in response to technological and organizational changes. This mapping also intends to present the contributions of each study on a given theme and demonstrate how research interests are distributed in the literature under review. Table 1 provides the mapping of the 21 papers within these four themes and is used to provide a thematic discussion in subsequent sub-titles.

Table 1. Mapping of Reviewed Studies Across the Four Themes

No	Author(s) & Year	Tema				Key Finding
		1	2	3	4	
1	Astorga-Vargas et al. (2017)	✓				Interaction among SECI modes significantly improves learning outcomes in software engineering education.
2	Ibidunni et al. (2021)	✓		✓		Teacher–student knowledge exchange and professional respect significantly enhance workplace preparedness through SECI processes.
3	Songkram & Chootongchai (2020)	✓				Pedagogical design and IT integration foster knowledge sharing and innovation via SECI-based learning models.
4	Chootongchai & Songkram (2018)	✓				SECI-based online learning systems significantly improve higher-order thinking and innovation skills.
5	Palaniswamy et al. (2025)	✓				Integration of SECI and Ba in instructional design enhances learners' work-related skills and knowledge transfer.
6	Anshari & Hamdan (2022)	✓				SECI supports workforce upskilling and knowledge transformation in Industry 4.0 environments.
7	Bandera et al. (2017)		✓			Entrepreneurial activities inherently embed SECI processes, supporting startup learning and growth.
8	Canonico et al. (2020)		✓			Collaborative practices in lean product development enable SECI-based knowledge creation across teams.
9	Leal et al. (2023)		✓	✓		Externalization, combination, and internalization positively influence innovative behavior in startups.
10	Laptev & Shaytan (2023)		✓	✓		Knowledge-sharing barriers and team dynamics shape SECI processes in early-stage product design.
11	Prabhakar & Savinkina (2018)		✓	✓		Knowledge conversion processes positively affect operational excellence, product leadership, and financial performance.
12	Jghamou et al. (2022)		✓		✓	Integration of SECI with ISO 9001 creates a structured knowledge management framework for manufacturing operations.
13	Liu (2024)		✓	✓		SECI-mediated knowledge innovation links AI adoption to product innovation efficiency, moderated by user perceptions.
14	Sepúlveda-Rojas et al. (2024)		✓			Integration of SECI with AHP improves knowledge retention and operational efficiency in remanufacturing.

No	Author(s) & Year	Tema				Key Finding
		1	2	3	4	
15	Baldé et al. (2018)			✓		Team trust and intrinsic motivation enhance creativity through SECI-mediated knowledge creation.
16	Zahedi (2024)			✓	✓	Organizational culture, leadership, and institutional context significantly shape SECI-based knowledge processes.
17	Chin et al. (2021)			✓	✓	Cross-cultural interactions and cognitive differences reshape knowledge creation beyond traditional SECI logic.
18	Farnese et al. (2019)				✓	The validated SECI measurement model links the knowledge conversion dimensions to performance, innovativeness, and collective efficacy.
19	Arantes et al. (2021)				✓	Knowledge management maturity varies across organizations, demonstrating the structural role of SECI-based knowledge processes.
20	Tyagi (2016)				✓	Integration of SECI with fuzzy-AHP improves the evaluation of conceptual product design processes.
21	Cerchione et al. (2024)				✓	The WISED model extends SECI to address knowledge creation in digital transformation contexts.
		6	**8**	**8**	**7**	

3.1. SECI for competency development in technical education

The SECI model presents a theoretical framework for higher education to optimize students' potential. A review of literature reveals that the use of the SECI model has beneficial effects on enhancing students' technical competencies, critical thinking and job readiness. In the face of the challenges brought by Industry Revolution 4.0, this model is more urgent than ever to support students in meeting on an innovative job market.

The value of the SECI dimension in building technical knowledge has been shown by research findings. The transformation of tacit-explicit knowledge through the SECI model and within industry-like environments will prepare the students as intellectual capital with a culture of sharing knowledge (Astorga-Vargas et al., 2017). Active interactions between these teams in knowledge creation and transfer can enhance understanding and the application of knowledge in real-life settings. Such a process establishes a setting in which the learned knowledge is not merely theoretical, but it also takes effect on the real commission of practical assignments.

In addition to technical competencies, competencies that can be developed within the SECI model structure are wide and varied, such as critical thinking, functional abilities, communication skills, and innovative problem-solving. Applications of e-learning systems like Moodle, which are also developed based on SECI steps, have, in fact, been found to increase the level of students' critical thinking and innovation abilities (Chootongchai & Songkram, 2018). This pedagogical approach supports externalization, so that students share ideas and solutions in forums and contribute to the development of their critical thinking. However, it is to be kept in mind that technology itself is not enough, a process of pedagogy takes part actively that supports the phases of the SECI model (Songkram & Chootongchai, 2020). These results support the claim that the process of student innovation is contingent on effective integration between pedagogy and technology in facilitating knowledge sharing/transfer from tacit to explicit.

A cross-study comparison also results in similar conclusions regarding the efficacy of the SECI model for student work-ready development. Of particular significance are the Socialization and Externalization factors, which have been identified to play a critical role in preparing students for the world of work. These insights indicate that an informal knowledge-sharing environment can enhance collaborative culture (Ibidunni et al., 2021). Socialisation is the key to developing bonds that support

knowledge sharing. Likewise, the process of externalization allows students a means for expressing their tacit knowledge in a tangible format, which is essential to creating new ideas. Also, a well-functioning knowledge management cycle is the vehicle to prepare the workforce for changing industry requirements (Anshari & Hamdan, 2022). Here, the SECI model contributes to reframing the learning dynamic to develop new skills required by the new work context.

Curriculum development, where a spiral method (SECI model) is introduced and used in the learning activity, offers significant advantages. The literature suggests that such a method leads to a higher student engagement compared to the linear one (Palaniswamy et al., 2025). Being an iterative process, which incorporates the SECI model approach, students can continually react to feedback and further develop their soft skills (Anshari & Hamdan, 2022; Ibidunni et al., 2021). This proves the success of the SECI model as a part of a dynamic and adaptive teaching method.

3.2. SECI in entrepreneurial and innovation contexts

The SECI model has been found to be critical for product innovation, predominantly in start-ups and entrepreneurial teams. Four knowledge creation processes of the SECI model have been found to positively impact organizational performance (Prabhakar & Savinkina, 2018). In addition, using this model can foster sustainable innovation in the context of firms (Leal et al., 2023; Sepúlveda-Rojas et al., 2024).

From a startup perspective, the SECI model offers insight into how knowledge is generated and managed successfully. One such study found that three elements of the SECI model, namely externalization, combination, and internalization were positively related with innovative behavior in organizations, including start-ups. We interpret this as a sign that adequate knowledge management provides the context for developing product innovation (Leal et al., 2023). Moreover, another study also found that the knowledge conversion and transferring in entrepreneurial teams at the product design phase depends on socialization and externalization of knowledge sharing and transferring. This is crucial since, in the process of product design, collective action is where novel ideas are sometimes innovated (Laptev & Shaytan, 2023). From the SECI perspective, it not only applies to internal teams but also extends to external networks, where they can have access to new resources and knowledge (Bandera et al., 2017). This external collaboration represents a key means by which startups can reinforce innovation processes and business sustainability (Jghamou et al., 2022; Laptev & Shaytan, 2023). If managed right through the SECI framework, this process can speed up the idea generation and make the product innovation more effective.

At the product development stage, the SECI cycle serves as a mechanism for facilitating knowledge creation and transfer. As socialization provides the opportunity to share tacit knowledge, trainee members get integrated by learning users' needs and actively defining solutions, while the externalization of tacit into explicit knowledge helps develop and validate product concepts (Leal et al., 2023). The use of a collaboration space (Obeya Room) also significantly increased the effectiveness of socialization (team discussions) and combination (data integration) in new product development (Canonico et al., 2020). It is also worth noting that additional studies have noted difficulties encountered in knowledge transfer when barriers to communication and a lack of time for collaboration occurred (Laptev & Shaytan, 2023). This corroborates that the SECI model is not just a reference point for knowledge creation but also places emphasis on the management of interactions and team dynamics in order to enhance innovative results.

The SECI model also leads to innovation performance and organizational competitive edge, especially in startups. Sepúlveda-Rojas et al. (2024) show an example in which this model was used with furniture remanufacturing, and how sustainable knowledge management contributed to a higher percentage of remanufactured products, at the same time that important economic and environmental benefits were achieved by the company (Sepúlveda-Rojas et al., 2024). The use of SECI here enables organisations to innovate and generate sustainable competitive value by increasing the efficiency of operating business processes. Other research outcomes that implemented AI technology in the SECI model suggest that knowledge innovation in the SECI circle directly affects the effectiveness of product innovation, which also improves a company's competitiveness in an ever-increasingly fierce market

(Liu, 2024a). As a result, investment in knowledge management systems that empower the SECI cycle could become a source of strategic advantage for the start-ups to create more breakthrough innovation and long-term market performance.

3.3. Relational, Psychological, and Cultural Enablers of SECI

The reviewed studies consistently demonstrate that the SECI model's effectiveness is heavily influenced by relational, psychological, and cultural factors. Institutions such as communities, businesses, organisations or even schools are shaped by non-technical factors that affect the creation, sharing and absorption of knowledge. Instead of a strict structure or technical system, SECI appears in the literature to be a socially embedded process where end results are at least partly dependent on the quality of social exchanges, motivational driving forces and systems context (Baldé et al., 2018; Ibidunni et al., 2021; Zahedi, 2024). Knowledge of these elements is important for deepening our understanding of such phenomena and for fine-tuning the application of the SECI framework across different situations.

Interpersonal relationships are crucial to facilitate or constrain the process of knowledge creation as an underlying theme of the reviewed studies. The transfer of knowledge between agents, such as teachers and students, team members, or organisational partners, is most often used as an applied part of the SECI process, supported by empirical evidence. Professional respect and knowledge transfer within the teacher-student relationships are strong predictors of the success of socialization and externalization processes, which in turn determine work readiness (Ibidunni et al., 2021).

In the same vein, in team and organisational studies, trust within the team enhances interpersonal relationships, which results in enabling knowledge exchange. The trust and intrinsic motivation of the team are also viewed as a crucial factor for knowledge circulation in order to increase creativity and, more broadly, outcomes related to knowledge management (Baldé et al., 2018; Leal et al., 2023). Such implications may be a strong support for the doubt that SECI processes would be self-forming but rather trust-dependent on the existence and openness of communication as well as understanding.

In addition to social relationships, some research has also examined the influence of individual-level psychological factors on the implementation of SECI. Intrinsic motivation has been recognized as an important motivator of knowledge generation, especially in creativity and innovation environments (Baldé et al., 2018). Highly motivated people are more likely to process knowledge sharing, reflection and experimentation so that the internalisation/externalisation of SECI can be enhanced.

The perceptions and attitudes of individuals towards digital tools in technology-rich situations also impact SECI outcomes. It has indeed been reported that users' perceptions of technology ease can have a moderating effect between knowledge creation processes and innovation efficiency (Liu, 2024a). It means that while behavioral acceptance of technology functions as a mediating path in the structural knowledge system and innovation performance. Moreover, research into innovative behavior at the individual level supports that SECI processes are closely related to behavioral outputs, particularly whenever knowledge is explicitly articulated, combined and exploited (Leal et al., 2023). This, in turn, supports the proposition that SECI serves both as a model of knowledge creation and as a behavior mechanism to affect how people behave towards each other in innovation-based environments.

At an organizational level, culture, leadership and institutional context were also powerful structural triggers for the implementation of SECI. Empirical work indicates that the culture, values and leadership within the organisation influence the mechanisms by which knowledge is created, shared, and applied (Zahedi, 2024). Organizational culture also plays a crucial role in the success of SECI, particularly in the context of cross-border teams where "polychronic" challenges arise. When organizations face cultural differences, adapting to these dynamics is essential to support effective knowledge creation (Chin et al., 2021). A culture that supports innovation and collaboration can mitigate conflicts arising from cultural differences among team members.

The human resource (HR) activities, like training and the interest policy, are also effective for enhancing the effectiveness of all four SECI modes (Prabhakar & Savinkina, 2018). Intervention of

effective training programs can enhance staff competency to share and manage knowledge, as is essential in transitioning between SECI modes. This suggests that support from human resource management not only helps improve skills but also facilitates a collaborative environment that encourages creativity and knowledge sharing. Furthermore, technology is often seen as the solution to knowledge-sharing problems, yet without the right behavioral and cultural support, technology is insufficient to guarantee success (Zahedi, 2024). This implies that creating a knowledge-sharing-friendly culture is even more crucial and core for success than the provision of state-of-the-art technology.

It has much more to do with behavioral barriers than it does with technological. Often, people do not give away knowledge for insecure reasons or because they fear losing their status within the organization. In entrepreneurial teams, breakdowns in communication, misaligned expectations and challenges with knowledge sharing may inhibit the transformation of tacit insights to explicit design knowledge (Laptev & Shaytan, 2023). These obstacles are especially serious when it comes to early-stage innovations and technologies, as the knowledge is incomplete, uncertain and very context-specific. This has the potential to undermine the realisation of the SECI model, as people would rather hang on to their knowledge than share. When managers do not actively provide social and task support, the climate does not support initiatives for knowledge sharing and its potential as a base for knowledge creation is diminished.

3.4. Adaptation and evolution of the SECI model

The studies in this finding as a whole show that the SECI model has been further developed from its original meaning as a knowledge creation spiral into an adaptive, context-aware framework. This section will also explore three major paths taken in the evolution of the SECI model. These are: embedding with outside systems and methodologies, operationalization and measurement, and conceptual repositioning in light of the digital global landscape.

Simultaneously, it is an interesting path to develop SECI by connecting it with other management models and information-analytic approaches. This is due to the structuring of knowledge creation by the organizational system and decision-making. For example, SECI has been integrated into the quality management system to establish a systemic knowledge management procedure. When applying SECI processes with ISO: 9001, knowledge creation was integrated with standard operation, and it combined knowledge with the quality process (Jghamou et al., 2022). This adaptation enables us to move SECI from a theoretical concept toward an organizational function.

Similarly, SECI has also been embedded in quantitative decision-making models. SECI process combined with fuzzy AHP can be employed for estimating the degree of facilitation of Conceptual Product Design Development and how different SECI modes affect at different stages of design (Tyagi, 2016). This method combination brings to the fore the possibilities of SECI as a decision support tool for innovation processes. At the organisational level, modified versions of the SECI model have been developed, contextualising it under such factors as leadership, cultural and institutional inherencies. This revision reveals that the SECI model is not general, but is informed by organisational form and context, which implies that we need to extend it with contextual drivers of knowledge management (Zahedi, 2024). Many of these studies suggest that SECI is being adopted more and more as a skeletal structure in larger systems, not necessarily as an independent model for knowledge creation.

Moreover, some researchers have tried to develop tools and models for empirically measuring the knowledge creation process. For example, one research project designed and tested a psychometric instrument for SECI factors, providing evidence that individual types of knowledge creation are related to different outputs such as performance, innovation and collective efficacy (Farnese et al., 2019). This paper constitutes a major breakthrough in the empirical application of the SECI that now allows for systematic quantitative inquiry. In other studies, the SECI model has been used as a reference in rating knowledge management organzational maturity (Arantes et al., 2021). In fact, their model of fuzzy logic shows that knowledge management maturity stages differ by size and types of organization, showing

that SECI processes operate differently according to institutional characteristics. Such an approach implies that the SECI is used as a diagnostic and evaluation model for measuring knowledge-capabilities. Collectively, these studies indicate a general methodological turn from conceptual treatments of the SECI to inquiries that are focused on measurement and evaluation and thus permit rigorous empirical exploration of knowledge creation activities.

In addition, some researchers have expanded the SECI model at a conceptual level to cope with the situation of digital transformation and global knowledge milieu. These findings indicate that some of the basic tenets of the SECI spiral are questioned with evolving technological and organizational contexts. Against this background of cross-border digital business at a large scale, we see the role played by cultural diversity, as well as cognitive constraints and distributed collaboration in knowledge creation. These contexts cannot be fully explained by linearity or cycles under the normal SECI model and require a more flexible, context-specific approach (Chin et al., 2021).

The digital transformation is also giving rise to new modes of knowledge creation that go beyond the classic SECI spiral. A conceptual decomposition suggests that a new, data-driven conceptual framework integrating data-driven learning, networked knowledge ecologies, and digitally mediated interactions will be applied to adapt Industry 4.0 knowledge-creation processes (Cerchione et al., 2024b). Thus, this generalisation of the concept reflects that we have now entered an age in which it is even more pertinent than ever to reconsider SECI, given that organizations are ubiquitously digitally networked and distributed across the globe.

3.5 Critical Cross-Theme Synthesis of the SECI Framework

According to the review, the SECI model still holds significant relevance for knowledge creation in technical education, entrepreneurship, and organizations as evident from the four themes. However, a cross-theme examination indicates that the contribution of the literature is uneven across the areas. The studies reviewed cumulatively confirm the usefulness of SECI in supporting learning, innovation, and the organizational performance of companies. However, a fractured pattern of development emerges from the reviewed studies. A situation occurs in which educational outcomes, innovation outcomes, relational enablers, and model adaptation are discussed separately. This means that while the current literature shows empirical advancement, it requires stronger conceptual integration (Anshari & Hamdan, 2022; Bandera et al., 2017; Cerchione et al., 2024a; Leal et al., 2023; Palaniswamy et al., 2025). Table 2 gives a critical mapping of studies along the various themes to read the literature in a more analytical framework.

Table 2. Critical Mapping of SECI Research Across the Four Themes

No	Theme	Dominant Focus	Main Strengths in the Literature	Main Limitations in the Literature
1	SECI for competency development in technical education	Knowledge creation in teaching, learning design, work readiness, and skill formation	Strong evidence that SECI supports higher-order thinking, work readiness, collaborative learning, and competency development in higher education	Tends to focus on instructional design and learning outcomes, with limited explanation of the relational and motivational basis of knowledge sharing
2	SECI in entrepreneurship and product innovation contexts	Startup learning, product development, knowledge transfer, innovation efficiency, and organizational performance	Shows strong practical relevance of SECI for innovation processes, entrepreneurial collaboration, and performance outcomes	Gives greater emphasis to innovation outputs than to the social and learning conditions that sustain knowledge creation
3	Relational, psychological,	Trust, intrinsic motivation, professional respect, leadership,	Introduces an important behavioral perspective by showing that SECI	Often treated as supporting factors only, rather than theorized as

No	Theme	Dominant Focus	Main Strengths in the Literature	Main Limitations in the Literature
	and cultural enablers of SECI	organizational culture, and communication dynamics	effectiveness depends on relational and motivational conditions	foundational drivers within an integrated SECI framework
4	Adaptation and evolution of the SECI model	Model extension, measurement, digital transition, integration with external systems, and organizational diagnostics	Demonstrates conceptual flexibility of SECI through integration with ISO 9001, fuzzy-AHP, maturity models, AI, and digitally mediated knowledge creation	Dominated by structural and technological extensions, with relatively limited incorporation of motivational and relational dimensions

The important patterns are revealed by the critical mapping. First, research in technical education provides evidence that the SECI model supports competency development, collaborative learning, and work readiness (Astorga-Vargas et al., 2017; Chootongchai & Songkram, 2018; Ibidunni et al., 2021; Palaniswamy et al., 2025; Songkram & Chootongchai, 2020). However, they rarely explain the motivational and relational conditions that allow students to engage in knowledge creation. Second, studies in entrepreneurship and innovation indicate that SECI helps improve learning, product development, and organizational performance in startups (Bandera et al., 2017; Canonico et al., 2020; Leal et al., 2023; Liu, 2024b; Prabhakar & Savinkina, 2018; Sepúlveda-Rojas et al., 2024). Nevertheless, these studies pay more attention to innovation outcomes than to the social conditions that make knowledge sharing effective. Third, relational and motivational factors such as trust, intrinsic motivation, communication quality, leadership and organizational culture shape the effectiveness of SECI processes, as scholarly work importantly evidences (Baldé et al., 2018; Chin et al., 2021; Ibidunni et al., 2021; Laptev & Shaytan, 2023; Zahedi, 2024). Nonetheless, these factors are still infrequently positioned as a key component in an integrated SECI-based framework. Fourth, research on SECI adaptation shows the conceptual flexibility of the model, yet most developments target structural, procedural, and technological refinements instead of the human basis of knowledge creation (Arantes et al., 2021; Cerchione et al., 2024a; Farnese et al., 2019; Jghamou et al., 2022; Tyagi, 2016).

The research results indicate that a main gap in the literature is not the lack of SECI application but rather the absence of conceptual integration across domains. The studies reviewed indicate that SECI fosters the development of organizational competencies, innovations, and adaptability. Without considering the relational and motivational factors, this contribution will remain fragmented in the knowledge creation process. Consequently, this synthesis supports a more integrated view of SECI as a socially embedded, context-specific framework for knowledge creation. The conceptual model proposed in the next section is based on this synthesis of the SECI model.

3.6 Integrative Conceptual Model of SECI in Technical Education and Entrepreneurship

Considering the synthesis across the themes, this review proposes a conceptual model of SECI in technical education and entrepreneurship. The model is based on the 21 articles reviewed and is intended as a conceptual rather than a tested model. Its purpose is to explain the ways in which the four themes identified in this review can be theoretically connected within a theory of knowledge creation.

The proposed conceptual model contains interrelated elements. The basic constructs of the relational and motivational factors are represented as trust, intrinsic motivation, interpersonal interaction, leadership, organizational culture, etc. These serve as enabling knowledge creation (Baldé et al., 2018; Ibidunni et al., 2021; Leal et al., 2023; Zahedi, 2024). The primary mechanism for the transformation of tacit to explicit knowledge is the SECI process via socialization, externalization, combination and internalization. Effective knowledge creation produces competency and innovation outcomes, including work readiness, higher-order thinking, product development, startup learning,

and organizational performance (Astorga-Vargas et al., 2017; Canonico et al., 2020; Liu, 2024b; Palaniswamy et al., 2025; Songkram & Chootongchai, 2020). The repeated application of SECI across various contexts demonstrates its adaptive evolution, for instance, through integration with measurement tools, quality management systems, decision-support approaches, and digital knowledge environments (Arantes et al., 2021; Cerchione et al., 2024a; Jghamou et al., 2022; Tyagi, 2016).

Based on this synthesis, the integrative conceptual model proposed in this review comprises four interrelated aspects. At first, the enabling foundation of knowledge creation refers to the relational and motivational factors. Second, the SECI process is the main mechanism whereby explicit and tacit knowledge interact. Third, depending on the context of application, it affects competency and innovation outcomes. Fourth, the development of these applications leads to the adaptive evolution of the SECI model across various contexts.

Conceptually, the model articulates a directional logic in which relational and motivational factors shape the effectiveness of the SECI process. This process subsequently influences the development of competencies and the innovation outcomes. Furthermore, sustained implementation across diverse contexts provides feedback that supports the framework's adaptation and ongoing evolution. This interpretation repositions SECI as a socially embedded, context-sensitive model of knowledge creation rather than merely as a procedural spiral of tacit-to-explicit knowledge.

This model contributes to the development of SECI by extending the framework beyond structural and technological perspectives and by emphasizing the human mechanisms that sustain knowledge-sharing processes. It also provides a theoretical basis for future research to examine how relational and motivational factors can be more systematically incorporated into SECI-based studies. Future empirical work is needed to test and refine the relationships proposed in this conceptual model.

4. CONCLUSION

This systematic literature review demonstrates that the SECI model remains relevant and adaptable across technical education, entrepreneurship, and organizational contexts. The reviewed studies indicate that SECI supports competency development in educational settings, facilitates innovation and product development in entrepreneurial environments, and strengthens organizational learning and performance. These findings confirm the continuing relevance of the SECI process model in diverse contexts of knowledge creation.

A key theoretical implication of this review is that the SECI model should be interpreted beyond its dominant structural and technological orientations. The synthesis reveals that relational and motivational factors are not merely contextual enablers, but foundational conditions for knowledge creation. Accordingly, this review contributes to the ongoing development of the SECI model by repositioning it as a socially embedded and context-sensitive framework for knowledge creation, rather than treating it primarily as a procedural mechanism of tacit–explicit knowledge interaction.

Future research should examine how relational and motivational factors can be more systematically incorporated into SECI-based studies. Such efforts may provide a clearer explanation of how actors in technical education and entrepreneurial contexts engage in knowledge sharing and contribute to knowledge creation. Further empirical research is needed to test and refine the proposed integrative conceptual model, particularly in contexts where knowledge creation depends not only on formal systems and processes, but also on human interaction.

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