Performance study of knowledge integration in marketing-oriented small and medium enterprises

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ABSTRACT

Purpose: This study aims to examine the impact of the knowledge fermentation field on the knowledge integration performance of marketing-oriented SMEs. This research will help develop more useful market policies for company management.

Design/Methodology/Approach: This research focuses on marketing-oriented SMEs, conducting a survey among 700 employees from 421 such enterprises. The collected data were analyzed to understand the influence of the knowledge fermentation field on the knowledge integration performance of these enterprises.

Findings: Knowledge management plays a crucial role in marketing-oriented SMEs especially in terms of knowledge integration. Effective knowledge management strategies significantly enhance the market adaptability and innovation capabilities of these enterprises.

Conclusion: The knowledge fermentation field in marketing-oriented SMEs positively impacts the enterprise's knowledge integration performance. The relationship between the field of knowledge fermentation and the performance of knowledge integration in marketing-oriented SMEs is moderated by the knowledge spiral fermentation system.

Research Limitations and Implications: The study primarily targets marketing-oriented SMEs in a specific region and may not be entirely applicable to other regions or different types of enterprises. The influence of temporal variations on business knowledge integration performance may not have been properly taken into account during data collection.

Practical Implications: This study provides businesses with an effective tool for developing and comprehending knowledge creation and innovation in the spiral fermentation system model of the knowledge ecosystem in small and medium-sized marketing companies. It fosters a healthier development path for the knowledge ecosystem in these enterprises.

Contribution to the Literature: This study proposes a new theoretical framework in the field of knowledge management for marketing-oriented SMEs. It offers new perspectives and theoretical support for understanding and enhancing knowledge management practices in SMEs by integrating the concepts of the knowledge ecosystem and knowledge integration performance.

Keywords: *Knowledge integration, Marketing-Oriented SMEs, Performance.*

1. INTRODUCTION

1.1. Research Background

Businesses are increasingly advocating for effective knowledge management in the knowledge economy era. Companies can only sustain their inaccessible position and increase their competitive advantage by skillfully managing their resources especially their internal and external knowledge resources. Marketing-oriented small

and medium enterprises (SMEs) face many challenges and opportunities in the fiercely competitive market environment. These enterprises need to rapidly adapt to market changes, meet customer demands and maintain a competitive edge over their rivals. An in-depth analysis and study of the knowledge integration in the knowledge ecosystem of marketing-oriented SMEs from the perspective of knowledge management are essential to derive insights beneficial for their knowledge management practices.

1.2. Research Objective

Theoretically, knowledge management is a vast and valuable field of study encompassing a range of significant themes related to knowledge management construction, platforms, tools and knowledge conversion. However, there is a lack of established theoretical frameworks and research on the knowledge ecosystem of marketing-oriented SMEs which is the focus of corporate knowledge management. Therefore, it is very important to research how marketing-oriented SMEs integrate their information into their knowledge environment.

Practically, the primary form of labor has shifted from being physically dependent to being intellectually dependent. The knowledge economy calls for knowledge management and modern knowledge management has emerged as a new management theory and method in this context. Knowledge management may give marketing-focused SMEs market insights that help them comprehend the demands of their target audience and their competitors. This helps these enterprises develop more targeted marketing strategies. Understanding customers' preferences and needs and considering their feedback in product design and promotional activities are crucial. Businesses can offer products and services that align more closely with customer expectations through knowledge management.

1.3. Research Questions

The ability of marketing-focused small and medium-sized firms (SMEs) to maintain a competitive edge in the modern information economy is largely dependent on the effectiveness of knowledge integration. Today, marketing-oriented SMEs play a significant role in the rapidly changing business environment due to their unique attributes and characteristics and widespread research interest. This paper aims to delve into the impact of the knowledge fermentation field of marketing-oriented SMEs on the performance of enterprise knowledge integration. Additionally, it investigates the knowledge spiral fermentation system as a moderating variable in this context (Xin, Li, & Wu, 2022).

1. The knowledge spiral fermentation system, the knowledge fermentation field and the knowledge integration performance of SMEs are focused on marketing. The following study questions are based on the logical relationships between the factors listed above: The relationship between the knowledge fermentation field of marketing-oriented SMEs and their knowledge integration performance.

Whether the knowledge spiral fermentation system in marketing-oriented SMEs plays a moderating role between the spiral fermentation field and knowledge integration performance.

2. LITERATURE REVIEW

2.1. Knowledge Management

Knowledge management has gradually developed as a major field in academic study and corporate practice since the end of the 20th century with the development of the knowledge economy. Businesses increasingly rely on knowledge management to enhance their adaptability, innovation and competitiveness. This includes continual adjustments to knowledge management strategies to adapt to the rapidly changing market and technological environments. Knowledge management has evolved from being a theoretical study issue to an essential component of business practice, supporting the growth of businesses and the overall socioeconomic environment.

2.1.1. Emergence of Knowledge Management Research

Knowledge management practices date back to ancient times with evidence found in the region of Ebla in Syria where archives written in cuneiform script dating back over 4,000 years have been discovered. Knowledge management has always taken the form of organizational knowledge management. This includes two aspects: the organization of knowledge literature and media, the management and application of knowledge which is gradually

evolving into a new management strategy and tool. This new approach encompasses the accumulation and transmission of knowledge as well as innovation, application and protection of knowledge.

2.1.2. The Essence of Knowledge Management
Literally, knowledge management refers to the study of managing individual or organizational knowledge. However, the definition of knowledge itself is subject to various viewpoints. Gartner Group (1999) views knowledge management as a process primarily focused on collecting and sharing intellectual assets to achieve breakthroughs in productivity and innovation. It involves innovation, extraction and the combination of knowledge to produce smarter, more competitive organizations.

2.1.3. Knowledge Management Models in Marketing-Oriented SMEs
Research in knowledge management should be built on different theoretical foundations and broadly categorized into micro and macro perspectives. The most emphasized concept in the flow of knowledge is Nonaka's (1994) perspective on the knowledge creation process. This type of research divides knowledge management activities into different stages: knowledge creation, knowledge storage, knowledge acquisition, knowledge sharing and finally knowledge application. Each stage has its own research focus (Nonaka, 1994; Nonaka & Takeuchi, 1995) and this is the general understanding of knowledge management activities. Argote, McEvily, and Reagans (2003) proposed an integrated framework to organize and classify the existing literature on knowledge management and pointed out potential future research directions in knowledge management. Knowledge maps have become an important tool for marketing-oriented SMEs to manage knowledge assets and core competencies with the development of the knowledge economy and advancements in information technology. The main function of a knowledge map is to describe and present the status of an enterprise's knowledge resources including the classification, strength and hierarchy of knowledge. Davenport and Prusak (1998) viewed the knowledge map as an inventory catalogue of an organization's knowledge. Tiwana (2000) further pointed out that enterprises can use knowledge maps to determine their strategic positioning in the industry and assess the basic, advanced and innovative knowledge capabilities of the company and its competitors.

2.1.4. Emergence and Maturity of Knowledge Management
The growth of knowledge management in China particularly in marketing-oriented SMEs has experienced considerable changes since 1998 when the Chinese academic community named it the "Year of the Knowledge Economy." Marketing-focused SMEs are competing increasingly as a result of the economy's rapid expansion and the rise of globalization. Marketing-focused SMEs must establish a knowledge ecosystem and integrate knowledge effectively to achieve sustainable development and competitive advantage. As the knowledge economy era continues to deepen, knowledge management will play an increasingly important role for marketing-oriented SMEs in China and globally.

2.2. Ecology of Marketing-Oriented SMEs
2.2.1. Origin and Development of Ecology
The field of ecology was initially defined by the German scientist Ernst Haeckel in his 1866 publication "General Ecology of Beings." The work focused on the mutualistic or antagonistic relationships that exist between humans, animals and plants. The term "ecosystem" was first introduced by Tansley in 1935. Ecology offers many useful concepts and theories to explain the interactions between biological populations and how changes in the external environment affect the ecosystem. To further optimize corporate knowledge organization models and enhance the efficiency of knowledge innovation and creation, thereby accelerating the process of knowledge ecologization. Liu, Zhang, and Chen (2018) proposed building the physical structure of the model from the two levels of demand analysis and logical modeling using mathematical analysis and evaluation methods to analyze the internal connection between model assembly modes and the knowledge ecologization process providing a theoretical basis and operational procedures for corporate knowledge innovation and creation at the system level. Zhao, Le, and Zhou (2021) combined the TPB (TPB stands for the Theory of Planned Behavior). It is a psychological theory developed by Icek Ajzen in the late 1980s and is used to predict and understand human behavior in specific contexts. This theory analyses the influencing aspects of knowledge creation contribution

behaviour using structural equation modelling and combines it with the ecosystem theory viewpoint to provide an in-depth comprehension of the driving factors of enterprise knowledge creation contribution behaviour.

2.2.2. Basic Characteristics of Ecology and Its Application in Marketing-Oriented SMEs
The study of ecology related to organizational ecology in marketing-oriented SMEs mainly involves the relationship between these SMEs and their social, natural and economic environments. Yang (2003) summarized the basic concepts of business ecology to include: (1) growth of business populations; (2) inter-business relationships such as competition, parasitism, symbiosis and predation; (3) business food chains and networks; (4) business adaptability; (5) business evolution; (6) business self-adaptation and self-organization and (7) niche theory. Qi, Wu, and Zhuang (2021) used ecological theory to categorize marketing-oriented businesses within the entrepreneurial ecosystem into symbiotic and competitive types. They subsequently developed a knowledge transfer model between heterogeneous businesses derived a general expression for the knowledge reproduction number through model derivation and confirmed the existence and stability of the knowledge transfer equilibrium point of the business.

2.3. Knowledge Spiral Fermentation System
2.3.1. Concept of Knowledge Spiral Fermentation System
The knowledge spiral fermentation system is a key concept in knowledge management research particularly within the knowledge ecosystem describing the process of knowledge creation and transformation between individuals and marketing-oriented SMEs. The study of knowledge spiral systems is relatively scarce. Nonaka and Takeuchi (1995) described the knowledge spiral as a cyclical process that transforms tacit knowledge into explicit knowledge and integrates it into practice continually driving the creation and evolution of knowledge. Nonaka and Nishiguchi (2001) developed the theory of organizational knowledge creation and explored the dynamic process of knowledge creation. Levy-Strohman (2003) mentioned that the knowledge spiral includes four stages: experience, abstraction, conceptualization and practice. Huang and Newell (2003) investigated the impact of different types of knowledge-seeking behaviors on the knowledge creation process through field research and case analysis of knowledge-intensive businesses. Zhu et al. (2022) defined the knowledge fermentation system as a cyclical process that externalizes, integrates, disseminates and re-internalizes individual tacit knowledge, transforming it into shared and learning resources within the organization through interaction and collaboration. Liu, Han, and Zhao (2016) described the knowledge fermentation system as a dynamic system that externalizes, integrates and applies tacit knowledge to the innovation process through individual interaction and collaboration. Han and Zhang (2018) noted that the knowledge fermentation system is a knowledge creation and transformation process that converts tacit knowledge into explicit forms through individual communication and cooperation and integrates and applies it. Cheng and Liu (2022) studied how businesses build a quintuple helix innovation ecosystem, improve the knowledge capital system and promote corporate knowledge innovation, offering references and insights.
Marketing-oriented SMEs directly or indirectly depend on other knowledge entities or organizations for their existence forming a regulated combination like living organisms. The system that forms from the mutual influence and interaction between the knowledge entities of marketing-oriented SMEs and the enterprise's knowledge ecological environment is called the knowledge ecosystem of marketing-oriented SMEs. This system can be analyzed from two dimensions: knowledge sharing and knowledge innovation, i.e., the process of "quantity" accumulation in knowledge sharing and "quality" improvement in knowledge innovation. The knowledge synergy between various departments in the knowledge ecosystem of marketing-oriented SMEs achieves a spiral rise based on the original knowledge sharing.

2.3.2. Knowledge Fermentation Field in the Knowledge Ecosystem of Marketing-Oriented SMEs
The "knowledge fermentation" of marketing-oriented SMEs refers to the central component of their knowledge ecosystem that resembles the principles of biological fermentation. A knowledge fermentation model is developed by comparing their similarities in order to provide insight into the internal functioning of the knowledge activities inside the marketing-focused SMEs' knowledge ecosystem. In knowledge management, all processes of knowledge fermentation are considered to occur within an environment called the "knowledge fermentation field." The PESS process which stands for "Performing, externalizing, systemizing and sublimating" is the

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abbreviation for the four steps of a knowledge fermentation field for the knowledge ecosystem of marketing-oriented SMEs that has been developed using Nonaka's SECI model.

2.3.3. Knowledge Spiral Fermentation System in Marketing-Oriented SMEs
SMEs focused on marketing need constant accumulation and updating of information inside their knowledge ecosystem. A single occurrence of knowledge fermentation within the fermentation field is insufficient. It is necessary to continuously increase the stock of marketing-oriented SME knowledge in the enterprise. This is carried out by developing a knowledge spiral fermentation system. The knowledge spiral fermentation system of marketing-oriented SMEs includes two parts: knowledge sharing and knowledge innovation with the core link being knowledge innovation.

3. RESEARCH METHODOLOGY
3.1. Research Methods
The primary objective of this thesis is to study the integration of knowledge in business knowledge ecosystems using scientific methods from knowledge management, ecology, biology and systems science and to apply these findings to the management and practice of knowledge ecosystems in marketing-oriented SMEs. The study uses methods including quantitative analysis, inductive analysis of pertinent research and literature evaluation to accomplish this research purpose.

3.2. Research Framework
Knowledge is currently the most important asset for competitive advantage in businesses. Effectively using knowledge management mechanisms to properly integrate an organization's knowledge assets and master knowledge management performance is the source of competitiveness for marketing-oriented SMEs. Lee and Choi (2003) argue that the main goal of organizational knowledge integration performance is to enhance organizational creativity. They base their analysis on Nonaka's SECI model of knowledge creation to examine the impact of each step in the knowledge creation process on organizational creativity and indirectly on related financial performance. Becerra-Fernandez and Sabherwal (2001) also focus on the SECI which is a knowledge management model representing four stages: Socialization, externalization, combination and internalization. This model was proposed in 1995 by Japanese scholars Nonaka and Takeuchi (1995) to explain how knowledge within organizations transforms from tacit to explicit and how this process facilitates knowledge creation and sharing. The SECI model emphasizes the dynamic process of knowledge conversion and is an important theoretical framework in the fields of knowledge management and organizational learning. This research considers the knowledge integration performance of marketing-oriented SMEs as the outcome variable of the knowledge fermentation field to understand the advantages of studying the knowledge ecosystem of marketing-oriented SMEs from the perspectives of knowledge sharing and innovation. The study explores the impact of different dimensions of the knowledge fermentation field on the knowledge integration performance of marketing-oriented SMEs as shown in Figure 1.
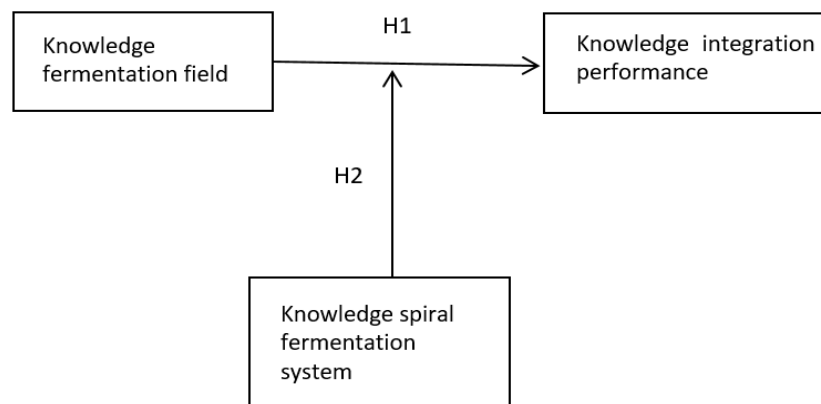

Figure 1. Research framework.

3.3. Variable Definition and Measurement
The research framework defines three primary variables: the knowledge spiral fermentation system that includes the four dimensions of the PESS model (i.e., tacit-to-explicit field, explicit-to-explicit field and explicit-to-tacit field), the knowledge fermentation field and the knowledge integration performance in marketing-oriented SMEs.

3.3.1. Tacit-to-Tacit Field
3.3.1.1. Dimensions and Operational Definition of the Knowledge Fermentation Field
The knowledge of subjects can only be employed in the knowledge system of marketing-focused SMEs after being converted and incorporated into the knowledge subjects' knowledge system. This process is a tacit- to- tacit learning process. It includes two dimensions: knowledge intensity and knowledge diversity. This study mainly refers to the two dimensions proposed by Nonaka, Umemoto, and Senoo (1996): knowledge intensity and knowledge diversity.

3.3.1.2. Scale Source for Tacit-to-Tacit Field
In terms of the tacit-to- tacit field dimension, this study uses a scale from Porter (1985) with 10 items. Knowledge diversity refers to the differences in knowledge base and perspectives brought by business partners between organizations.

3.3.2. Tacit-to- Explicit Field
3.3.2.1. Dimensions and Operational Definition of the Tacit-to-Explicit Field
Tacit-to-explicit refers to the interaction of knowledge groups within the knowledge fermentation field divided into internal knowledge learning and cooperation with others. This study mainly refers to the two dimensions proposed by Nonaka et al. (1996): internal knowledge learning and cooperation with others.

3.3.2.2. Scale Source for Tacit-to-Explicit Field
In the tacit-to-explicit field dimension, this study uses scales for internal knowledge learning from Davenport and Prusak (1998) and Chase (1997) with 5 items, and scales for cooperation with others from Cohen and Levinthal (1990); Darr, Argote, and Epple (1995) and Zollo and Winter (2002) with 5 items. According to the definition, the tacit-to-explicit field is divided into two dimensions totaling ten items.

3.3.3. Explicit-to-Explicit Field
(1) Dimensions and Operational Definition of Explicit-to-Explicit Field
Explicit knowledge from the externalization field is acquired, integrated and systematized in SMEs focused on marketing. This process involves a culture of willingness to cooperate and a culture of conflict communication. In terms of the culture of cooperation willingness, Lee and Choi (2003) and Gold, Malhotra, and Segars (2001) have studied the impact of an internal cooperative culture on promoting knowledge integration. In terms of conflict communication culture, it mainly measures the behavior of knowledge groups in conflict situations where they conflict with opponents for their own interests without considering the benefits of the conflicting parties.

(2) Scale Source for Explicit-to-Explicit Field
The scale for the willingness to cooperate culture under the explicit –to-explicit field is derived from Lee and Choi (2003) and Gold et al. (2001) with 5 items. The scale for conflict communication culture comes from Orlikowski (1992); Burgelman (1991); Hannan and Freeman (1989) and Carroll (1988) with 5 items. According to the definition, the explicit-to-explicit field is divided into two dimensions totaling ten items.

3.3.4. Explicit-to-Tacit Field
(1) Dimensions and Operational Definition of the Explicit-to-Tacit Field
The explicit-to-tacit field involves transforming systematized explicit knowledge into higher-level tacit knowledge. The knowledge mutation dimension mainly measures the internal evolutionary forces of knowledge (knowledge mutation) and external evolutionary forces (knowledge evolution) prompting continuous variations and evolution of knowledge in marketing-oriented SMEs.

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(3) Scale Source for Explicit-to-Tacit Field

The scale for knowledge mutation in the explicit-to-tacit field comes from Bieber et al. (2002) and Menon and Pfeffer (2003) with 6 items. The scale for knowledge evolution is derived from Zollo and Winter (2002) and Van den Bosch, Volberda, and De Boer (1999) with 6 items. According to the definition, the explicit-to-tacit field is divided into two dimensions totaling twelve items.

3.3.5. Knowledge Spiral Fermentation System

(1) Dimensions and Operational Definition of the Knowledge Spiral Fermentation System

The knowledge spiral fermentation system describes the process of knowledge creation and transformation between individuals and organizations. Individual tacit information is converted into explicit knowledge through the four steps of socialization, externalization, combination and internalization. This process integrates and applies knowledge in practice, continuously promoting the production and evolution of new knowledge (Nonaka & Takeuchi, 1995).

(2) Scale Source for Knowledge Spiral Fermentation System

This study develops questionnaires for the knowledge spiral fermentation system based on the dimensions put forth by Nonaka and Takeuchi (1995) distributing the items of the knowledge spiral fermentation system to 5 dimensions totaling 10 items.

3.3.6. Operational Definition and Scale for Knowledge Integration Performance in Marketing-Oriented SMEs

(1) Dimensions and Operational Definition of Knowledge Integration Performance

This study primarily aims to measure the performance of marketing-oriented SMEs directly enhanced by knowledge integration. The study adopts 14 items proposed by Gold et al. (2001) for measuring knowledge management performance.

(2) Scale Source for Knowledge Integration Performance

This study uses the 14 items proposed by Gold et al. (2001) for the knowledge management dimension to measure the performance of marketing-oriented SMEs directly improved by knowledge integration.

3.4. Research Subjects

A questionnaire survey approach is used to more effectively collect data and get insights on unknown circumstances or occurrences in order to collect new knowledge. The survey subjects in this study which focuses on marketing-oriented SMEs are the general managers or individuals in control of these businesses. According to Thompson's (2000) recommendations, there should be around a 1:10–1:15 ratio between each item and the number of samples.

3.5. Data Analysis Methods

After the formal questionnaires are collected and invalid questionnaires are excluded, the valid questionnaires will be compiled and entered into a computer database. This study will use SPSS version 25 statistical software as the analysis tool to conduct descriptive statistical analysis, reliability analysis, validity analysis, correlation analysis, regression analysis and moderation effect analysis tests. This approach will enable a comprehensive examination of the relationships and effects among the various variables studied providing a robust statistical foundation for the research findings.

4. EMPIRICAL RESEARCH ANALYSIS

We will discuss the findings of this study's statistical analysis in this chapter. This includes the results of data collection, primarily encompassing descriptive statistical data and the reliability and validity analysis of the questionnaire. Additionally, we will test the research framework and hypotheses proposed in this study.

4.1. Data Collection Results

The survey for this study was conducted in May 2023. A total of 1000 questionnaires were distributed with 798 being returned yielding a response rate of 79.8%. After excluding 98 incomplete or otherwise invalid questionnaires, the final number of valid questionnaires was 700 resulting in a valid response rate of 70%. The characteristics of the valid questionnaire samples are detailed below in Table 1.

Table 1. Basic information table (N=700).

Variables	Categories	Frequencies	Percentages（%）
Company industry category	Manufacturing	246	35.1
	Service industry	229	32.7
	Others	225	32.1
Educational background	Associate degree	158	22.6
	Bachelor's degree	268	38.3
	Master's degree	159	22.7
	Doctorate	115	16.4
Work experience	Employed for 90-180 days	234	33.4
	Employed for more than 181 days	466	66.6
Does the marketing-oriented SME employ dedicated personnel for knowledge management work?	Yes	354	50.6
	No	346	49.4

Table 1 provides the following information about the respondents who were marketing-focused SMEs: Industry category: The distribution across industries is fairly balanced. Manufacturing accounts for 246 respondents (35.1%) followed closely by the service industry with 229 respondents (32.7%) and other industries with 225 respondents (32.1%).

Educational background: The majority of respondents hold a bachelor's degree with 268 individuals (38.3%). This is followed by master's degrees (159 respondents 22.7%) and associate degrees (158 respondents, 22.6%). The least represented educational level is a doctorate with 115 individuals (16.4%).

Work experience: There is a notable difference in the distribution of work experience. The number of people who worked for more than 181 days is about double that of people employed for 90−180 days. 234 respondents have been employed for 90-180 days (33.4%) while 466 have been employed for more than 181 days (66.6%).

Dedicated personnel for knowledge management: The presence of dedicated knowledge management personnel is nearly evenly split among the surveyed SMEs. 354 respondents (50.6%) indicated that their marketing-oriented SME employs dedicated personnel for knowledge management whereas 346 respondents (49.4%) reported the absence of such personnel.

4.2. Descriptive Statistical Analysis

The following table makes it clear that the values for knowledge fermentation field, knowledge spiral fermentation system, knowledge integration performance, tacit-to-tacit field, tacit-to-explicit field and explicit-to-tacit field are 1 and 5. In terms of mean values ranked from highest to lowest, they are as follows: Knowledge integration performance, explicit-to-tacit field, tacit-to-tacit field, knowledge fermentation field, knowledge spiral fermentation system, tacit-to-explicit field, and explicit-to-explicit field with mean scores of 3.33, 3.32, 3.28, 3.21, 3.11 3.10, and 3.10 respectively.

The explicit-to-explicit field shows the largest standard deviation of 0.776 indicating the greatest dispersion of data whereas the knowledge fermentation field shows the least dispersion with a standard deviation of 0.569. The kurtosis values for tacit-to-tacit field, tacit-to-explicit field, explicit-to-tacit field, Knowledge fermentation field knowledge spiral fermentation field and knowledge integration performance are all greater than 0 indicating a more peaked distribution. The skewness values for tacit-to-tacit field, tacit-to-explicit field explicit-to-tacit field, knowledge fermentation field, knowledge spiral fermentation field and knowledge integration performance are slightly greater than 0 suggesting a slight right skew in their frequency distributions. Meanwhile, the skewness

values for tacit-to-tacit field, tacit-to-explicit field and explicit-to-tacit field are slightly less than 0 indicating a slight left skew in their frequency distributions (see Table 2).

Table 2. Descriptive statistical analysis of variables.

Cronbach's α values	Minimum value	Maximum value	Average	Standard deviation	Kurtosis	Skewness
Tacit-to-tacit field	1	5	3.28	0.613	0.114	0.013
Tacit-to-explicit field	1	5	3.10	0.641	0.380	-0.045
Explicit-to- explicit field	1	5	3.10	0.776	0.278	-0.133
Explicit-to-tacit field	1	5	3.32	0.703	2.006	-0.648
Knowledge fermentation field	1	5	3.21	0.569	0.307	0.117
Knowledge spiral fermentation system	1	5	3.11	0.677	0.443	0.137
Knowledge integration performance	1	5	3.33	0.626	0.814	0.089

4.3. Reliability Analysis

Reliability analysis is a fundamental element and step in empirical analysis primarily aimed at determining whether the collected data and results meet the expected standards set by the scale developers. It reflects the degree of congruence between the data and the expected values. This study primarily evaluates the reliability of scales using the Cronbach alpha coefficient, a common measure of internal consistency. When conducting reliability analysis, the Cronbach alpha value is used for testing. An alpha value of at least 0.6 is considered acceptable (Hair, 1998) and an alpha value greater than 0.7 indicates high reliability (Nunnally, 1978).

Table 3 shows that the following is clearly obvious: The Cronbach alpha coefficient for the tacit-to-tacit field is 0.798. The Cronbach alpha coefficient for the tacit-to-explicit field is 0.830. The Cronbach alpha coefficient for the explicit-to-explicit field is 0.889. The Cronbach alpha coefficient for the explicit-to-tacit field is 0.865. The Cronbach alpha coefficient for the knowledge spiral fermentation system is 0.831. The Cronbach alpha coefficient for knowledge integration performance is 0.851. These values indicate good reliability for each dimension.

Table 3. Reliability of each variable.

Cronbach α values	Cronbach α values	Cronbach α value of a variable
Tacit-to-tacit field	0.798	0.955
Tacit-to- explicit field	0.830	
Explicit-to- explicit field	0.889	
Explicit-to- tacit field	0.865	
Knowledge spiral fermentation system	0.831	
Knowledge integration performance	0.851	

4.4. Validity Analysis

Exploratory factor analysis (EFA) is used to classify a large number of observed variables or questionnaire items into a few specific factors based on the magnitude of their correlations. The suitability of the data for factor analysis is indicated by the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. A KMO value between 0.7 and 0.8 suggests moderate data correlation and feasibility for factor analysis while a value between 0.8 and 0.9 indicates good suitability for factor analysis providing valuable results. A KMO value above 0.9 is indicative of excellent suitability offering highly valuable results (Hair, Anderson, Tatham, & Black, 2010).

According to Table 4, the KMO test values for the survey data under knowledge spiral fermentation system, knowledge integration performance, and knowledge fermentation field (including tacit-to-tacit field, tacit-to-explicit field, explicit-to-explicit field and explicit-to-tacit field) are 0.855, 0.883, 0.939, 0.914, 0.884 and 0.897 respectively, all greater than 0.6. This indicates the high validity of the questionnaire at its good effectiveness. The Bartlett's test of sphericity results show approximate Chi-square values of 1577.080, 1793.850, 2680.091, 2643.654, 1795.471 and 2480.917 which are considerably high with a significance probability of 0.000 ($P < 0.05$).

Therefore, the null hypothesis of Bartlett's test is rejected suggesting good structural validity of the variables. This demonstrates that the reliability and validity of the questionnaire meet the standards for the survey.

Table 4. Validity analysis of each variable.

Variable	KMO measure of sampling adequacy	Bartlett's test of sphericity		
		Chi-square	Df	Significance
Tacit-to-tacit field	0.855	1577.080	45	0.000***
Tacit-to-explicit field	0.883	1793.850	45	0.000***
Explicit-to-explicit field	0.939	2680.091	45	0.000***
Explicit-to-tacit field	0.914	2643.654	66	0.000***
Knowledge spiral fermentation system	0.884	1795.471	45	0.000***
Knowledge integration performance	0.897	2480.917	91	0.000***
Overall validity	0.939	20706.77	2145	0.000***

Note: ***$P < 0.001$.

4.5. Correlation Analysis

This study uses Pearson correlation coefficients to explore the degree of association between the knowledge fermentation system (including tacit-to-tacit field, tacit-to-explicit field, explicit-to-explicit field, explicit-to-tacit field), the knowledge spiral fermentation system and knowledge integration performance. According to statistical principles, correlation coefficients (r) are interpreted as follows: $r < 0.2$ indicates negligible correlation; $0.2 < r < 0.4$ indicates low or weak correlation; $0.4 < r < 0.7$ indicates moderate correlation and $r > 0.7$ indicates high or strong correlation.

The particular correlations derived from Table 5 are as follows:

Tacit-to-tacit field has a high positive correlation with tacit-to-explicit field ($r = 0.734$, $p < 0.01$), a moderate positive correlation with explicit-to-explicit field($r = 0.602$, $p < 0.01$), explicit-to-tacit field ($r = 0.579$, $p < 0.01$), knowledge spiral fermentation system ($r = 0.580$, $p < 0.01$) and knowledge integration performance ($r = 0.556$, $p < 0.01$).

The tacit-to-explicit field has a moderate positive correlation with explicit-to-explicit field ($r = 0.629$, $p < 0.01$), explicit-to-tacit field ($r = 0.562$, $p < 0.01$), knowledge spiral fermentation system ($r = 0.655$, $p < 0.01$) and knowledge integration performance ($r = 0.504$, $p < 0.01$).

The explicit-to-explicit field has a moderate positive correlation with explicit-to-tacit field ($r = 0.471$, $p < 0.01$), knowledge spiral fermentation system ($r = 0.693$, $p < 0.01$) and knowledge integration performance ($r = 0.525$, $p < 0.01$).

The explicit-to-tacit field has a moderate positive correlation with knowledge spiral fermentation system ($r = 0.527$, $p < 0.01$) and knowledge integration performance ($r = 0.571$, $p < 0.01$).

The knowledge spiral fermentation system has a moderate positive correlation with knowledge integration performance ($r = 0.595$, $p < 0.01$).

Table 5. Correlation analysis between variables.

Variable	Tacit-to-tacit field	Tacit-to-explicit field	Explicit-to-explicit field	Explicit-to-tacit field	Knowledge spiral fermentation system	Knowledge integration performance
Tacit-to-tacit field	1					
Tacit-to-explicit field	0.734**	1				
Explicit-to-explicit field	0.602**	0.629**	1			
Explicit-to-tacit field	0.579**	0.562**	0.471**	1		
Knowledge spiral fermentation system	0.580**	0.655**	0.693**	0.527**	1	
Knowledge integration performance	0.556**	0.504**	0.525**	0.571**	0.595**	1

Note: **. Significance at the 0.01 level (2-tailed) indicates a significant correlation.

4.6. Regression Analysis

Regression analysis is a statistical method used to establish and analyze the linear relationship between variables. It is commonly used to predict the relationship between one or more independent variables (also known as predictors or explanatory variables) and a dependent variable (also known as the response or target variable). The goal of linear regression is to find a line (or a hyperplane in multiple linear regression) that best fits the data points, representing the relationship between the independent and dependent variables as accurately as possible. Important aspects of regression analysis include collinearity diagnostics, significance, explanatory power (R^2) and effect size. These aspects are explained as follows:

4.6.1. Collinearity Diagnostics

(1) VIF value : VIF stands for Variance Inflation Factor which is the reciprocal of tolerance (1/tolerance). A VIF value less than 10 indicates no collinearity among the independent variables (Hair et al., 2010). A VIF greater than 10 suggests the presence of collinearity and it may be necessary to consider removing the collinear independent variables.

(2) Tolerance: Tolerance is calculated by regressing one of the independent variables as a dependent variable against the remaining independent variables. The model estimate is R^2 and the larger the R^2, the stronger the relationship between the independent and dependent variables. Tolerance is $1-R^2$ meaning a larger correlation leads to a smaller tolerance and a larger VIF.

4.6.2. Significance

The impact of independent variables on the dependent variable is assessed for significance. If the p-value is less than 0.05 ($p < 0.05$), it indicates that the independent variable significantly affects the dependent variable and the hypothesis is supported. If the p-value is greater than 0.05 ($p > 0.05$), it means the independent variable has no significant impact on the dependent variable, and the hypothesis is not supported.

4.6.3. Model Explanation

R-squared (R^2): R^2 represents the proportion of the variance in the dependent variable that is predictable from the independent variables. According to Chin (1998) the standards for R^2 are:

(1)$R^2 < 0.19$ indicates low explanatory power meaning the independent variables weakly predict the dependent variable.

(2)R^2 between 0.19 and 0.33 indicates moderate-low explanatory power suggesting that while the independent variables have some explanatory power, other potential predictors might have been overlooked.

(3)R^2 between 0.33 and 0.67 indicates moderate-high explanatory power suggesting an acceptable level of explanation. Researchers might consider adding more independent variables to increase the R^2 value of the model.

(4)$R^2 > 0.67$ indicates high explanatory power meaning the selection of independent variables for predicting the dependent variable is highly suitable. Researchers might consider applying the model in other areas to enhance its applicability and scope.

According to Table 6, a linear regression analysis was conducted with the knowledge fermentation field as the independent variable and Knowledge integration performance as the dependent variable. The collinearity VIF value is 1.000 (less than 10) indicating no collinearity issue with the independent variable. The unstandardized coefficient of the knowledge fermentation field is 0.715 suggesting that for each unit increase in the knowledge fermentation field knowledge integration performance increases by 0.715 units. The standardized coefficient is 0.650 implying that for each standard deviation increase in the knowledge fermentation field, knowledge integration performance increases by 0.650 standard deviations. The t-value for the knowledge fermentation field is 10.109 ($p = 0.000 < 0.05$), which is significant indicating that the independent variable, knowledge fermentation field significantly affects the dependent variable, knowledge integration performance. The adjusted R^2 is 0.422 indicating that the knowledge fermentation field explains 42.2% of the variance in knowledge integration performance demonstrating a moderate to high explanatory power. Therefore, the regression equation can be expressed as: Knowledge integration performance = 1.040 + 0.715 (knowledge fermentation field) where the coefficients are unstandardized values.

Table 6. Regression analysis of the knowledge fermentation field on knowledge integration performance.

Model		Unstandardized coefficients		Standardized coefficients	t	Collinearity statistics	Significance
		B	Standard error	Beta		VIF	
Knowledge integration performance	Constant	1.04	0.103		10.109		0
	Knowledge intensity	0.715	0.032	0.65	22.622	1	0
F		511.758					
P		0					
Adjusted R²		0.422					

4.7. Moderation Analysis

Moderation analysis is a method of statistical analysis used to determine whether one or more variables affect the relationship between two other variables. Specifically, a moderating variable can enhance, weaken or reverse the relationship between these two variables. The fundamental components of moderation analysis are: Independent Variable (IV): The variable that predicts or explains.

Dependent Variable (DV): The variable being predicted or explained.

Moderating Variable (Moderator): A variable that may affect the strength or direction of the relationship between IV and DV. Moderation analysis typically includes a simple slope test which often involves dividing the moderating variable into groups and conducting separate regression analyses for each group. It is possible to determine if the moderating variable influences the relationship between IV and DV by comparing slopes.

Interaction term regression: In addition to the main effects (the effects of IV and the moderating variable), an interaction term (the product of IV and the moderating variable) is included in the regression model. If the interaction term is significant, it indicates the presence of a moderating effect.

Interpreting results: If the moderating effect is significant, it is found that under certain conditions, the relationship between IV and DV is stronger (or weaker), or the direction of this relationship changes.

In this study, hierarchical regression analysis is used with interaction terms to further explore the existence of moderating effects among the variables in this research as illustrated by a simple regression equation.

$$y = a + bx + cm + e \qquad (1)$$
$$y = a + bx + cm + c'mx + e \qquad (2)$$

The knowledge fermentation field, knowledge integration performance and knowledge spiral fermentation system are the independent, dependent and moderating variables respectively, according to the research paradigm shown in figure 1 of this study. Regression analysis is conducted and the results are presented in Table 7. The regression results show that in the third regression, the change in R² is 0.013, significant at the $p < 0.05$ level indicating the presence of a moderating effect. The regression coefficient for the interaction term " knowledge fermentation field * knowledge spiral fermentation system " is 0.083 significant at the $p < 0.05$ level suggesting a positive moderating effect. Therefore, the presence of the knowledge spiral fermentation system enhances the impact of the knowledge fermentation field on knowledge integration performance.

Ina nutshell, the scores of the moderating variable positively moderate the relationship between the scores of the independent variable and the dependent variable.

Table 7. Moderation analysis of knowledge spiral fermentation system between knowledge fermentation field and knowledge integration performance.

Variable	Regression one	Regression two	Regression three
Knowledge fermentation field	0.650***	0.464***	0.454***
Knowledge spiral fermentation system		0.253***	0.244***
Knowledge fermentation field * knowledge spiral fermentation system			0.083***
F	511.758***	287.639***	201.473***
P	0.000	0.000	0.000
Adjusted R-squared	0.422	0.451	0.462
Change in R-squared	0.423	0.029	0.013

Note: *. Indicates significance at the 0.05 level and ***. Indicates significance at the 0.001 level.

4.8. Summary of Research Hypotheses

The influences of different factors and dimensions have been analysed and the study hypotheses have been tested based on the findings of the empirical analysis. The consolidated findings are as follows:

1. Hypothesis 1 (H1): Analysis from Table 6 indicates that the knowledge fermentation field in marketing-oriented SMEs positively influences the knowledge integration performance of the enterprise. Therefore, hypothesis 1 is confirmed.

2. Hypothesis 2 (H2): Analysis from Table 7 reveals that the knowledge spiral fermentation system in marketing-oriented SMEs moderates the relationship between the knowledge fermentation field and knowledge integration performance . Thus, hypothesis 2 is confirmed.

5. CONCLUSION

5.1. Research Conclusions

This study has found that the Knowledge fermentation field in marketing-oriented SMEs significantly and positively impacts the knowledge integration field. Businesses may efficiently collect and convert team and individual information using the information fermentation field which improves decision-making and creativity. The research further reveals that the knowledge spiral fermentation system has a moderating effect between the knowledge fermentation system and knowledge integration performance. When businesses implement an appropriate knowledge spiral fermentation system, it strengthens the interaction, sharing and innovation of knowledge thereby boosting the efficiency and effectiveness of knowledge integration.

5.2. Limitations and Future Research Directions

This study proposed an organizational knowledge ecology framework, where the Knowledge Fermentation Field, including the tacit-to-tacit field, tacit-to-explicit field, explicit-to-explicit field and explicit-to-tacit field is influenced by internal and external environmental factors in marketing-oriented SMEs. However, the industry environment, technical environment, corporate policy and organizational culture were all taken into consideration but only the organizational knowledge spiral fermentation system was selected as a moderating variable in the study's framework. This was due to limitations in time and focus as the knowledge spiral fermentation system is a key aspect of knowledge management research. However, this design might lead to an underrepresentation of the knowledge ecology as the impact of other external and internal environmental factors on organizational knowledge ecology could be as significant as that of the knowledge spiral fermentation system. Therefore, the influence of other external and internal environmental factors on knowledge ecology is a valuable direction for future research to make the study of organizational knowledge ecology more rigorous and comprehensive.

Additionally, this study used a questionnaire survey method to collect empirical data aiming to validate the knowledge ecology model and research hypotheses with a large sample size. This method allows for objectivity with its large sample. It does not enable an in-depth exploration of the research questions. The knowledge ecology model is an innovative research model still in its early stages of exploration. Future research could combine this model with qualitative research methods, exploring organizational knowledge management activities over a prolonged period from the perspective of knowledge ecology. Analyzing the meanings and interrelationships of different aspects of the DICE model in knowledge ecology would enable more in-depth and comprehensive research in this field.

INSTITUTIONAL REVIEW BOARD STATEMENT
The Ethical Committee of the International College, Krirk University, Thailand has granted approval for this study on 25 March 2023 (Ref. No. 2023-0325).

TRANSPARENCY
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

COMPETING INTERESTS
The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS
Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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