

Organizational digital literacy and enterprise digital transformation: Evidence from Chinese listed companies

Li Zhao, Qile He, Lei Guo, David Sarpong

Abstract — The importance of organizational digital literacy has come to dominate discourse on enterprise digital transformation. Drawing on Organizational Affordance Theory, we explored the relationship between three levels of organizational digital literacy — employee, senior executive and organization — and enterprise digital transformation. Utilizing a big data analytical tool, we first probed the employee digital literacy of Chinese listed companies, then analysed this with senior executive digital literacy and organizational hard/soft digital literacy data to generate a configuration of organizational digital literacy conditions linked with higher-level digital transformation. Our findings show that attributes of organizational digital literacy (i.e., employee, senior executive and hard/soft organizational) serve as important conditions for digital transformation, but higher-level digital transformations are driven by a combination of these conditions through seven types of configurations. Extending the understanding of the role of organizational digital literacy during enterprise digital transformation, our study offers insight into strategic capability requirements for embarking on successful digital transformation.

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Li Zhao is with Shanghai Lixin University of Accounting and Finance, Shanghai, China (e-mail: zhao-sfu@hotmail.com).

Qile He is with the University of Derby, Derby, UK (e-mail: Q.He@derby.ac.uk).

Lei Guo is with Shanghai Lixin University of Accounting and Finance, Shanghai, China (e-mail: guolei@lixin.edu.cn).

David Sarpong is with Aston University, Birmingham, UK (e-mail: d.sarpong1@aston.ac.uk).

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Index terms — Enterprise digital transformation, digital literacy, big data, machine learning, recruitment, fsQCA

Note to practitioners — This paper provides a heuristic framework which managers can utilise to improve their understanding of the key capabilities required to deliver successful digital transformation. In doing this study, we delineate how the configuration of six digital literacy conditions can facilitate the digital transformation of companies. Digital transformation, we argue, is a radical institutional change. With this in mind, we invite managers to view enterprise digital transformation as a process that not only depends on the cognitive development of individuals, but also on the context, leadership, infrastructure and routines of the organisation. We hope that, in doing this, firms will be encouraged, to focus on developing their leadership's digital literacy skills as part of their leadership competence programs, which should support their digital transformation efforts.

I . INTRODUCTION

Many organizations have committed to digital transformation strategies which involve a systematic transformation of their strategic objectives, governance structure and internal management. Previous research has revealed that this strategic response by organizations, which has come to be known as enterprise digital transformation, is mainly driven by frequent disruptions to technological trajectories which are created by digital technologies [1]. The new direction has led to a race in buying the most recent technologies. However, digital transformation is not just about digital technology adoption. It involves the development of specific competences and capabilities in staff to enable the delivery of requisite organizational changes [2]. Thus, the biggest challenge for many organizations involved in digital transformation is getting their employees and managers to participate in and drive the technology change [3].

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Unsurprisingly, some scholars have called for a shift in attention from technology attributes to the *affordance* of technology [4] [5], and have emphasized the strategic role of employees in the successful adoption of digital technology [2] [6]. By affordance, we mean the “active interpretation” of a technology by users/employees so it can lead to the emergence of its use in ways that are socially and culturally determined [4]. Hence, organizational affordance reflects the likelihood of an organization taking meaningful individual and collective action due to the emergence of digital technology in the social and cultural context [2].

Cetindamar Kozanoglu and Abedin [2] focused on the meso level of conceptualizing organizational affordance into two rubrics: employees’ digital literacy as the organizational *information affordance*, and organizational digital literacy as the organizational *articulation affordance*. Employee digital literacy mainly involves their cognitive abilities related to digital technology; whereas organizational digital literacy relates to the technology and interpretive conditions and has the potential to shape affordances of employees’ digital literacy in an organization [2].

However, digital transformation, we argue, also represents an important institutional change as it encompasses systems, practices and routines [7]. In this regard, successful digital transformation is almost impossible without the requisite leadership to drive coordinated action among stakeholders, including employees [7]. This means that employees’ digital literacy is not only affected by the organizational articulation affordance, but also by leadership conditions. Therefore, this study proposes a new aspect of organizational affordance during the process of enterprise digital transformation — senior executives’ digital literacy — as the *leadership affordance*. We argue that organizational affordance is a three-dimensional concept. Hence senior executive digital literacy, together with

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employee digital literacy and organizational digital literacy will promote enterprise digital transformation.

Extensive review of the existing literature suggests there is a lack of comprehensive perspective about organizational affordance in previous studies of enterprise digital transformation. For this reason, this research attempts to fill the gap and to develop a multi-dimensional perspective of organizational affordance.

This paper contributes to existing literature in three ways. Firstly, we respond to the clarion call for research on the socio-technical dimension of digital literacy by examining employees' and senior executives' digital literacy, as well as organizational hard/soft digital literacy in the organizational context. Secondly, in drawing on organizational affordance theory [2] as a focus, we provide some salient insight into the relationship between different attributes of organizational digital literacy and the enterprise digital transformation. Thirdly, in developing a big data analytic tool based on data mining and text analysis, we extend our understanding of employees' digital literacy, while our adopted Fuzzy-set Qualitative Comparative Analysis (fsQCA) method serves as an analytical tool to examine the effects of different attributes of organizational digital literacy on enterprise digital transformation.

The rest of this article is structured as follows. The next section reviews key concepts and introduces the conceptual framework and research propositions. The third section introduces the research methods, as well as data collection and analysis. This is followed by the discussion of different modes of enterprise digital transformation emerging from the data and the related configurations of conditions. The final section summarizes the theoretical and practical implications as well as limitation and further research directions.

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II. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

A. Enterprise Digital Transformation and Organizational Digital Literacy

Digital transformation is defined as the ‘process of improving an entity by triggering significant changes to its properties through combinations of information, computing, communication and connectivity technologies’ [3] (p.2). Previous studies suggest that an enterprise’s digital transformation is a strategic response from an organization to the disruptions created by digital technologies [1]. Digital technologies allow enterprises to change their paths of value creation to maintain competitiveness. To that end, they must implement organizational changes to overcome obstacles that may hinder the change [1].

Previous scholars have proposed a plethora of organizational factors that may facilitate (or impede) effective digital transformation. Significant factors are technology adoption, perceptions and attitudes toward technological change, skills and training, workplace resilience and adaptability and work-related wellbeing [9]. Similarly, by emphasizing the importance of human-centered digitalization and intrapreneurial competency in digital transformation, previous researchers put forward six categories of capabilities: management insight, proactiveness, idea generation, opportunity evaluation, interpersonal mobilization and market foresight [10] as giving form and shape to enterprise transformation in practice. However, the organizational factors proposed by previous studies appear to be fragmented. At worst, there is a lack of a coherent theoretical thread running through or linking them together. This largely limits further development of related research.

Recently, a major advance within the scope of literature has seen researchers beginning to examine the relationship between organizational digital literacy as an integrated organizational concept

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and the digital transformation of organizations [2] [11] [12] [13]. By digital literacy, we refer to ‘the abilities a person or social group draw upon when interacting with digital technologies to derive or produce meaning, and the social, learning and work-related practices that these abilities are applied to’ [14] (p.475). In the previous literature, although there are multiple concepts linked with digital literacy, such as digital skills [15] [16] [17] [18] [19], digital human capital [21], digital readiness [22], and digital competence [23], digital literacy is generally viewed as a concept with both cognitive (i.e., awareness and ability of individuals) and social practice dimensions (i.e., the social, cultural, political and economic context of which an individual is a part) [14] [20].

Research on the cognitive dimension of digital literacy mainly focuses on the digital ability of individuals, such as information and data literacy, communication and collaboration, digital content creation, safety awareness and problem solving. Since the seminal paper of Stordy [14], which suggested a socio-technological perspective to understand digital literacy, researchers have begun to shift their attention from the cognitive dimension to the social practice dimension of digital literacy [24] [25]. For example, Cetindamar et al. [25] explored the meaning of employees’ AI literacy and emphasized four groups of abilities related to AI literacy, namely, technology-related, work-related, human-machine-related and learning-related capabilities. Similarly, Shao et al. [19] found that data-driven culture, data analysis affordance and individual absorptive capacity were positively related to employees’ data analysis skills, thus having a positive impact on their tasks and innovation performance. Another study shows that industry digital maturity has a positive and indirect impact on the development of proactive skills through employees’ interpretation of digitalization as controllable and viewing it as an opportunity for their organization [18].

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Nevertheless, due to the lack of consistent understanding of organizational digital literacy, the structure and forms of digital literacy in the organizational context are still unknown. Moreover, the relationship between organizational digital literacy and enterprise digital transformation is still in the conceptual stage and more empirical tests are needed [2].

B. Organizational Affordance and Digital Transformation

In recent times, Organizational Affordance Theory has become important in understanding the changes brought to enterprises by digital technology [5]. According to Affordance Theory, what technology can provide is not the technology itself, or its properties, rather, its value lies in the relationship between users' capabilities and the environment [5]. The affordance of a type of technology is therefore determined by both technological characteristics and user characteristics.

Exploring organizational affordance in practice, Vyas et al. [4] introduce three levels of understanding — individual, organizational and societal users. According to Vyas et al. [4], there are three factors that determine the interpretive flexibility of technology, namely, the material characteristics of technology, the characteristics of human beings (such as knowledge, motivation and experience), and the environment in which the technology is used. In the process of user technology interaction, the “active interpretation” of users/employees leads to the emergence of affordance that is socially and culturally determined. In this vein, organizational conditions (technological, interpretative, hierarchical and cultural) affect the way technology is implemented in a specific organizational context, and therefore its affordance [4].

From the perspective of Organizational Affordance Theory, organizational digital literacy should be regarded as a concept closely related to organizational affordance, which has been operationalized

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as a multi-dimensional construct consisting of both individual and organizational levels [2]. Digital literacy at the individual level (i.e., information affordance) is defined as the skills, knowledge and capabilities used by individuals when interacting with digital technology [14]; while digital literacy at the organizational level (i.e., articulation affordances) is mainly related to ‘the range of digitally relevant practices and processes in an organization’s daily operations as well as their inter-relationships both internally and externally’ [2] (p.1662).

However, what is largely missing in the extant literature drawing on affordance theory is the perceived underemphasis of the role of leadership in enabling affordance in practice. Representing an interesting shift in scholarship, there has been growing evidence suggesting that digital leadership is important in the digital transformation of enterprises [7] [26] [27] [28] [29]. Leaders are presented as key players in developing a digital culture for organizations. They need to build relationships with multiple stakeholders, focus on achieving collaborative processes in complex environments and focus on pressing ethical issues [30]. Thus, it is emphasized that successful digital transformation is almost impossible without effective leadership to drive coordinated action among various stakeholders [7]. Effective leaders can help enterprises succeed in digital transformation through “(1) following the trends of emergent technologies; (2) determining the direction of the digital change and investment strategy; and (3) leading the team to change swiftly and precisely” [7] (p.638). In addition, digital leadership can impact on employees’ cognition, emotion and behavior in the process of digital transformation [28]. For example, a previous study shows that digital leadership has a positive impact on employee creativity through job crafting [31]. Digital leadership is also related to employees’ cognitive trust of the leader [28], and moderates the negative effects of uncertainty on employees’

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appraisal of digital transformation, self-efficacy, and job performance [8]. In this sense, digital leadership is the affordance coming from the top management team, which is also an integral part of the organizational affordance in the context of digital transformation. Therefore, in this study we attempt to extend the Affordance Theory to include digital leadership as an important dimension of organizational technology affordance — leadership affordance.

C. Conceptual Framework and Propositions

Based on Organizational Affordance Theory, this study proposes a framework that consists of four attributes of organizational digital literacy: employee digital literacy, senior executive digital literacy, organizational hard digital literacy and organizational soft digital literacy.

1) *Employee Digital Literacy*: Organizational Affordance Theory suggests that when evaluating organizational digital literacy, the characteristics of employees' digital literacy should also be assessed [2]. Some previous studies show that if enterprises want to benefit from technology investment, they need to equip employees with digital skills to achieve organizational goals [32]. Similarly, several scholars suggest that employee's digital competency and skills [2] [10] [23] [32], involvement [33] and behaviours [34] are important facilitators in the process of digital transformation.

As Fernandez-Vidal et al. [32] pointed out, human capital plays a fundamental role in the digital transformation of enterprises. Similarly, extant research has found that there exists a significant positive correlation between employees' digital literacy and the company's use of cloud technology [3]. Therefore, we propose that,

Proposition 1: Employees' digital literacy significantly affects enterprise digital transformation.

2) *Senior Executive Digital Literacy*: Strategic and organizational changes triggered by digital

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transformation are boundless and could result in the re-organization of an entire business model. In this regard, we surmise that effective digital leadership and strategic human resource management will play a fundamental role in the process [35]. For instance, Singh, and Hess [36] observe that there are some capabilities related to talent management that senior managers must have in the digital era. These, they argue, may include organizational agility and technical know-how, as well as emotional intelligence.

Recent literature has referred to the role of senior executives' functional background or experience as the technical know-how in the digital transformation of enterprises [37] [38]. For example, Zhang, and Chen [37] show that the greater the number of the senior management team with technical background and technical work experience, the more likely they are to engage in digitally related technology mergers and acquisitions due to the imprinting of skills and experiences. Mao et al. [38] also suggest that the multi-functional background and heterogeneity of senior management teams would significantly contribute to the level of enterprise digital transformation. Heterogeneity provides diversified knowledge, decision-making styles and professional perspectives, which help to overcome the inertia of change, identify strategic problems and develop strategic choices of enterprises [39]. Hence, researchers call for attention to the combined effect of senior executives' background and other organizational factors (e.g., hierarchical power) and external environmental factor during the enterprise strategic change [40]. Based on the above discussion, we propose that,

Proposition 2: Senior executive digital literacy significantly affects enterprise digital transformation.

3) *Organizational Hard Digital Literacy*: There is a consensus that ICT (information and

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communication technology) infrastructure is an important technological foundation for enhancing readiness for digital transformation [41]. For example, the World Economic Forum (WEF) takes ICT infrastructure as a measure of the readiness for innovation in the digital economy². Previous researchers show that ICT infrastructure construction will contribute to an enterprise's digital transformation [42] [43]. For example, IT infrastructure capabilities have a significant impact on the strategic agility of IT-dependent enterprises [43]. It was also found that digital infrastructure has significantly improved the technological innovation of manufacturing firms [44]. Hence, we define *organizational hard digital literacy* as the state of an organization's ICT infrastructure as well as infrastructure that matters for ICT development (e.g., Internet bandwidth, cyber security and electricity production), and propose that,

Proposition 3: Organizational hard digital literacy significantly affects enterprise digital transformation.

4) *Organizational Soft Digital Literacy*: The extant literature believes that the ability of organizations to use ICT is as important as the ICT infrastructure. The Organizational Affordance Theory emphasizes that organizational level digital literacy is 'articulation affordances accumulated over time through employees' interactions with each other through digitally relevant practices and processes imposed on them' [2] (p.1663). Such articulation affordances can be in the form of firm-level digital technology absorption, innovation capacity, or the capacity for new technologies [2]. In this study we use the framework of Cetindamar et al. [2] which regards organizational soft digital

² The Global Information Technology Report 2016 Innovating in the Digital Economy, World Economic Forum, Switzerland, available at: http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf.

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literacy as an organizational level digital integration capability. Hence, *organizational soft digital literacy* is defined as the ‘range of digitally relevant practices and processes in an organization’s daily operation as well as their inter-relationships, both internally and externally’ [2] (p.1662).

Previous studies found that organizational soft digital literacy is closely related to strategic agility [45] [46], technological innovation [47] [48] and business model change [49] [50]. For example, absorptive capacity is found to be a boundary condition for traditional organizations to carry out digital transformation in strategic alliances [51]. Empirical results show that firms need to develop their potential absorptive capacity and realized absorptive capacity in order to improve strategic flexibility and further innovate their business models [50]. Similarly, dynamic digital capabilities are also found to be able to contribute to firms’ capability to build digital platforms by changing, expanding or adjusting the firms’ existing resources, processes and value creation [52]. Therefore, we develop the following proposition:

Proposition 4: Organizational soft digital literacy significantly affects enterprise digital transformation.

Despite the importance of the digital literacy of employees, senior executives and organization, it is worth noting that it is necessary to broaden the treatment of affordance by transcending the one-to-one relationship in order to understand the potential interaction between these attributes [4]. Based on Structural Theory, previous scholars put forward the notion of ‘technology-in-practice’, to refer to ‘people’s enactment vis-à-vis a system or a technology leading to the emergence of social structures’ [53] (p.2). Vyas et al. [4] further developed the concept of technology-in-practice and suggest that affordance should be conceptualized as ‘a notion that emerges in people’s situated practices and is

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affected by the social and cultural issues that surround it' (p.2). They also emphasize the important role of hierarchical power conditions as one of the main factors that may affect the emergence of affordance of technology in organizations [4]. Hence, when understanding the digital transformation of enterprises from the perspective of affordance, the role of senior executives as designers of organizational systems should not be ignored.

In fact, Shao et al. [19] show that, although higher levels of employee skills can lead to higher levels of digital transformation, they may not necessarily contribute to the financial performance of firms. One possible reason is that employees' digital skills can only make a positive contribution where digital core values are embedded in firms' entire scope and business models, especially in small enterprises [19]. This also means that successful digital transformation needs to rely on senior executives to initiate an institutional change related to the values of digital transformation.

Moreover, in organizational soft digital literacy research, researchers pointed out that various internal and external factors from the environment need to be taken into account while considering how the organization's capabilities can play a role [54]. Organizations are best understood as 'clusters of interconnected structures and practices, rather than as modular or loosely coupled entities whose components can be understood in isolation' [55](p.1180).

Based on the above analysis, we propose that enterprise digital transformation does not rely on any single attribute of organizational digital literacy (i.e., employee, senior executive, or organization hard/soft digital literacy), but on specific configurations of these attributes. Therefore,

Proposition 5: Attributes of organizational digital literacy of firms have a combined effect on enterprise digital transformation, such that a higher level of enterprise digital transformation will be

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DCFC framework, but the scale is more suitable for questionnaire purposes. Among the few other studies that investigated the digital skills required for a particular industry [25] or a position [24], only potential categories of indicators were presented. Hence, to fill the gap in the assessment tools of employee digital literacy, we developed a big data analysis tool based on the DCFC framework.

First, we adopted the classification provided by the DCFC framework, namely digital knowledge, digital skills and digital attitudes, where digital knowledge is defined as ‘the outcome of the assimilation of information through learning’; digital skills are ‘the ability to apply knowledge and use know-how to complete tasks and solve problems’; digital attitudes are ‘conceived as the motivators of performance, the basis for continued competent performance, and include values, aspirations and priorities’⁴ (p.4).

Second, we collected data from three major Chinese recruitment websites: 51job.com, Liepin.com, and zhipin.com, which have highly standardized HTML structures of job positions and account for about 70% of the market share of the entire online recruitment industry of China⁵. From March to June 2022, we used Python to crawl through job information on the recruitment website that contains the keyword “data analyst” in the job title, job description, or job requirements, and finally obtained 65,161 items of recruitment data. The reason we focused solely on the role of “data analyst” is because among the top ten future digital skills released by LinkedIn⁶, data analysts are in the highest demand, and the ‘data analyst’ posts data is the most complete data set. This data set includes recruitment information

⁴ IMD (2018), World Digital Competitiveness Yearbook 2018, IMD, Switzerland, available at: <https://www.imd.org/wcc/world-competitiveness-center-rankings/world-digital-competitivenessrankings-2017/>.

⁵ <https://bg.qianzhan.com/report/detail/300/211110-d1c8b966.html>

⁶ https://reports.hrflag.com/Report/detail?fileid=ac85490dfb1d4cf686824ad9fd3106a1&msg=%E9%A2%86%E8%8B%B1-%E6%9C%AA%E6%9D%A5%E6%8A%80%E8%83%BD%E8%B6%8B%E5%8A%BF%E6%8A%A5%E5%91%8A-%E9%A2%86%E8%8B%B1_HRflag%E4%BC%97%E6%97%97

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ID, company name, recruitment position name, position requirements, salary, workplace, working years, education requirements and information release time.

Third, data cleaning was performed as follows: Step one, delete any duplication in the recruitment data published by the same company at different times; Step two, the Chinese text was processed by Jieba Chinese word segmentation, so that the computer can accurately identify Chinese and English words. After word segmentation, stop words and invalid words (such as “and”, “or”) were removed to eliminate any adverse effects on data analysis; Step three, after word segmentation and deactivation processing for recruitment position names, 50 nouns that appear more than 5 times in the results were selected to form a position name dictionary. Recruitment information that does not include words in the position name dictionary was marked as invalid and eliminated. The top 10 job title words with the largest number of occurrences is shown in Table 1. Step four, repetitive data and invalid data was eliminated through de-duplication and double cleaning. Finally, 4,858 pieces of data was retained for data analysis.

===== Table 1 about here =====

Fourth, based on Feng’s [56] approach of building text indicators, we developed the seed word set based on three categories of digital literacy: digital knowledge, digital skills and digital attitudes. We used Python software and the Jieba thesaurus to analyze the text, to identify 2,790 seed words (1,156 on digital knowledge, 927 on digital skills, and 707 on digital attitudes), and to obtain their frequency. The top 50 seed words by frequency are shown in Table 2.

===== Table 2 about here =====

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Fifth, since multiple words with similar semantics might describe the same concept, it was necessary to expand the seed word set with the similar words as well. Mikolov et al. [57] suggested a Word2Vec machine learning tool. Based on neural network Word Embedding, this tool considers words as multi-dimensional vectors according to the context of semantic information, and then obtains the semantic similarity between words by calculating the similarities between vectors. Hence, following Mikolov et al. [57], we used this machine learning tool to analyze the employee recruitment data. Specifically, we adopted the CBOW (Continuous Bag of Words) model in Word2Vec:

$$\text{Max} \sum_{w \in C} \log p(w | \text{Context}(w))$$

C is the corpus (i.e., employee recruitment text); w is seed word (i.e., 2,790 seed words identified previously); Context(w) is the context of the seed word. After machine training, 21,928 words were formed as the word set for employee digital literacy. We invited 3 experts from industry and academia to verify the word set by comparing the employee recruitment text samples and 3,137 words were finally selected as the word set for employee digital literacy.

B. Configuration Analysis of Enterprise Digital Transformation

We used the big data analysis tool developed above to evaluate employee digital literacy of Chinese listed companies. Configuration analysis of how employee digital literacy, senior executive digital literacy and organizational hard/soft digital literacy affect the enterprise digital transformation was conducted.

Firstly, the data of enterprises digital transformation, senior executive digital literacy, organizational hard/soft digital literacy from the public data of listed companies in the CSMAR

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database⁷ was collected.

Secondly, we identified the sample listed companies according to the following criteria: 1) companies included have their data analysis job posts advertised in one or more of the three recruitment websites. Any company which publishes multiple recruitment advertisements on these websites will be counted only once. Based on data mining technology and text analysis [58], 2,757 sample companies were obtained; 2) sample companies should be undergoing digital transformation, according to the digital transformation index of listed companies published in the CSMAR database. This resulted in 316 companies. After matching the recruitment data with the CSMAR data, and eliminating companies with missing data, 202 companies were obtained; 3) considering the effect of industry sectors, we finally selected 152 companies in industries with high digital maturity [18], including manufacturing (62.3%), software and information technology services (25.4%), and other industries (12.3%).

Thirdly, we use the fsQCA [59] to test how six conditions of digital transformation (i.e., employees' digital knowledge, employees' digital skills, employees' digital attitudes, senior executive digital literacy, organizational hard digital literacy, and organizational soft digital literacy) jointly affect the level of enterprise digital transformation. Qualitative Comparative Analysis (QCA), of which fsQCA is a type, is a comparative case-oriented research approach and a collection of techniques based on configuration theory and Boolean algebra, and it can be used to explore the "joint effect" of various factors on specific phenomena [59]. The reasons for choosing fsQCA as the method are: 1) the traditional regression analysis method is mainly applicable to exploring a single effect, but fsQCA can

⁷ China Stock Market & Accounting Research Database (CSMAR), <https://cn.gtadata.com/>.

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identify the configuration relationship between multiple factors [60]; 2) although other methods (such as cluster analysis and factor analysis) can also test the configuration relationship, they cannot effectively identify the interdependence, configuration equivalence and causal asymmetry between multiple conditions; 3) because most of the conditions of digital transformation in this study are continuous variables, fsQCA has more advantages than other QCA techniques (such as csQCA and mvQCA) in capturing the subtle effects of changes in antecedent conditions at different levels [61].

C. Measurement and Analysis

1) Condition variables: Employee digital knowledge, digital skills and digital attitudes are calculated following Nan et al. [62] as the proportion of the word frequency of a sample company in the total word frequency of the word set identified before (see section III-A) and then multiplying by 100 to get the index value of employee digital knowledge, digital skills and digital attitudes, respectively. The higher the index value, the higher the employee digital literacy of this company.

In this study, senior executives is defined as ‘the personnel directly involved in business management decision making, including CEOs, chairpersons, vice-chairpersons, general managers, deputy general managers, secretaries of the board, and other managers announced in the annual report’ [63]. Based on the study of He et al. [63], the proportion of senior executives with technical backgrounds (such as experience in R&D, information systems, production and design) in the senior management team is used to measure senior executive digital literacy. A dummy variable was created for the technical background, with 1 meaning the senior executive has the technical background and 0 otherwise.

We used the 2020 Digital Ecology Index released by the National Engineering Laboratory for

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Big Data Analysis and Application to get the infrastructure readiness scores of the province where the company is located⁸, which was used as a proxy to measure organizational hard digital literacy.

The EU provides a proxy that uses firm-level digital technology absorption as the level of application of digital related processes⁹. We followed this approach and used the firm-level digital technology absorption capability to assess the organizational soft digital literacy. Referring to Yang et al. [65], the firm-level digital technology absorption capability was measured using the ratio of annual R&D expenditure and operating income of the sample company [64].

2) *Result variable*: In this study, the result variable was measured by the index of enterprise digital transformation, which is calculated by the word frequency of relevant keywords mentioned in the strategic planning content of the sample companies' annual reports, such as artificial intelligence, blockchain, cloud computing, big data and digital technology application. The higher the value of this index, the higher the level of enterprise digital transformation.

3) *Calibration*: In the process of fsQCA analysis, each of the 6 condition variables (i.e., organizational digital literacy) and the result variable (i.e., the enterprise digital transformation) are considered as a set, and each company has a subordinate score in these sets. Calibration is hence the process of assigning set membership scores to cases [61]. In this study, we used the direct calibration method to convert data into fuzzy set membership scores based on theoretical criteria external to the data set [65]. In this study, the 95% quantile value is used as the threshold of full membership of high-level digital transformation (i.e., companies have higher digital transformations than 95% of all sample

⁸ <http://www.digiteco.com.cn/>

⁹ IMD (2018), World Digital Competitiveness Yearbook 2018, IMD, Switzerland, available at: <https://www.imd.org/wcc/world-competitiveness-center-rankings/world-digital-competitivenessrankings-2017/>.

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companies) [65]. 5% is the threshold of full non-membership (i.e., companies have higher digital transformations than only 5% of all sample companies), and 50% is the cross-over point (i.e., companies have higher digital transformations than only 50% of all samples companies). We focus only on the companies of full membership of high-level digital transformation for further analysis. Table 3 summarizes the calibration information for each condition variable and the result variable, which will be used to determine the level of condition variables and the result variables of companies.

===== Table 3 about here =====

4) *Necessity analysis of single conditions*: In fsQCA, if a single condition always appears in the result, it is a necessary condition of the result. Most researchers believe that a condition with consistency level greater than 0.9 is considered a necessary condition for the result [66]. The necessity analysis of single conditions is shown in Table 4. The six conditions all have a consistency level lower than 0.9, which means that there is no single necessary condition for enterprise digital transformation.

===== Table 4 about here =====

5) *Sufficiency analysis of condition configuration*: The sufficiency analysis of condition configuration explores the sufficiency analysis of different configurations formed by multiple condition variables, that is, whether these configurations are subsets of the result set. According to Rihoux & De Meur [67], it is necessary to determine the consistency threshold and frequency threshold before analysis. Existing literature has different criteria for threshold selection, such as 0.76 [66] and 0.8 [68]. This study considers the following four criteria for threshold selection: a. the frequency

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threshold should be determined according to the sample size, hence the frequency threshold of small and medium-sized samples should be 1 [61]; b. configurations with the result of 0 and 1 should be covered and roughly balanced [60]; c. the number of observation cases should not be less than 75% of the total cases [69]; d. possible simultaneous subset relationships should be avoided [61]. Eventually, we decided to use the consistency threshold of 0.82 and the frequency threshold of 1.

In line with previous studies of fsQCA, intermediate solutions were reported and combined with parsimonious solutions to distinguish core conditions (conditions that exist in both parsimonious solutions and intermediate solutions) and auxiliary conditions (conditions that only exist in intermediate solutions). Among these solutions, the meaning of coverage is similar to R^2 in regression analysis [70]. Table 5 shows the analysis results of the configurations consisting of six conditions of high-level enterprise digital transformation, which can be regarded as a combination of conditions for the higher level of enterprise digital transformation. In general, the overall consistency of the seven configurations was 0.7636, which is higher than the acceptable consistency level of 0.75 [61]; and the solutions coverage was 0.6059, indicating that about 61% of the cases were explained by all the configurations. This resulted in 25 companies. For the single configuration, the consistency values of the seven configurations were all higher than the accepted consistency threshold of 0.75 [61]. Among the seven configurations, the unique coverage (0.0637) and raw coverage (0.3528) of Configuration 1 were the highest, indicating that Configuration 1 was the configuration with the strongest empirical correlation among these seven configurations. The consistency of configuration 1 was 0.8090.

===== Table 5 about here =====

Configuration 1 shows that in a company where employees have a high level of digital knowledge

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and skills, a positive attitude towards digital technology and a high level of organizational soft digital literacy, even if there is a low level of organizational hard digital literacy, it can achieve a high level of enterprise digital transformation. This configuration shows the key role of organizational digital literacy in the process of enterprise digital transformation. This was found in seven companies.

Configuration 2 indicates that none of the conditions are core. However, when executives have a high level of digital literacy, employees have a high level of digital knowledge and there is a high level of organizational digital literacy (both hard and soft), even if employees have resistance to new digital technology, the company can still achieve a high level of digital transformation. The consistency of this configuration was 0.8257, and the unique coverage was 0.0059, found in four companies.

Configuration 3 indicates that when senior executives have a high level of digital literacy, employees have a positive attitude towards digital technology and the company has a high level of organizational digital literacy (both hard and soft), even if the employee digital knowledge is low, the company can still achieve a high level of enterprise digital transformation. The configuration consistency level is 0.8262, the unique coverage is 0.0283, covering four cases. This configuration shows the essential role of senior executive digital literacy in the process of enterprise digital transformation.

In Configuration 4, the existence of employee digital skills and the absence of employee digital knowledge and organizational soft digital literacy are the core conditions. The existence of employee digital attitude is the auxiliary condition. This means when a company has employees of a higher level of digital skills and a positive attitude towards digital technology, despite a lack of employee digital knowledge and a low level of organizational soft digital literacy, it can still achieve a high level of

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enterprise digital transformation. The configuration consistency level is 0.8258, the unique coverage is 0.0131, covering one case. This configuration shows the important role of employees' digital literacy in the process of enterprise digital transformation.

In Configuration 5, the existence of executive digital literacy and employee digital skills and the absence of employee digital attitude are the core conditions, while the existence of employee digital knowledge is the auxiliary condition. This means that when a company has a higher level of senior executive digital literacy, employee digital skills and employee digital knowledge, even if employees are resistant to digital technology, they can still achieve a higher level of enterprise digital transformation. The configuration consistency level is 0.8372 and the unique coverage is 0.0104, covering one case.

Configuration 6 shows that when a company has higher levels of employee digital knowledge, digital skills and digital attitude and a higher level of organizational hard digital literacy, it can still achieve a higher level of enterprise digital transformation despite a low level of senior executives' digital literacy and organizational soft digital literacy. The consistency level of this configuration, covering 5 cases, is 0.8269 with a unique coverage rate of 0.0609.

In Configuration 7, the core conditions are the existence of senior executive digital literacy, organizational digital literacy (both hard and soft) and an absence of employee digital skills, while the existence of employee digital knowledge is an auxiliary condition. This means that when a company has a high level of senior executive digital literacy, a high level of organizational hard digital literacy and organizational soft digital literacy and a high level of employee digital knowledge, it can still achieve a high level of enterprise digital transformation despite a lack of employee digital skills. This

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configuration, covering four cases, has a consistency level of 0.8252 and a unique coverage rate of 0.0082.

The above seven configurations reveal how different combinations of the organizational digital literacy of companies can facilitate higher-level enterprise digital transformation. In general, they provide evidence that attributes of organizational digital literacy (i.e., employee, senior executive, and hard/soft organizational) serve as important conditions for digital transformation, but higher-level digital transformations are driven by a combination of these conditions through different configurations.

6) *Robustness test*: To test the robustness of the analysis, we adjusted the consistency level from 0.82 to 0.83, and used two criteria (i.e., the differences in the parameters of fit and the set-relational status of the different formulas) proposed by Schneider & Wagemann [61] for fsQCA analysis. Since the consistency level is more parsimonious, there are 5 resulting configurations instead of 7 (see Table 6). Since the new configurations are a subset of the original configurations with similar consistency values, we can conclude that the original configuration is robust.

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===== Table 6 about here =====
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IV. DISCUSSION

According to the core conditions specified, we classified the seven configurations into three digital transformation modes: leadership-driven, employee-driven and organization-driven digital transformations. These three modes emphasize the important role of employee digital literacy, senior executive digital literacy and organizational digital literacy in higher-level enterprise digital transformation.

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A. Employee-driven Digital Transformation

Configurations 1, 3, 4, 5 and 6 (see Table 5) represent the employee-driven digital transformation (using employee digital literacy as a core condition). That is, companies achieving enterprise digital transformation through higher employee digital literacy. In previous studies, digital transformation was mainly explained from the perspectives of digital technology and digital strategy [1] [71]. However, these configurations correspond to recent researchers' view that firms can develop and use digital tools to promote and support the contribution of "ordinary employees" in the digital innovation process. Employee-driven digital transformation is mainly based on intrapreneurial activities [72], which means employees can create digital tools that can not only provide better services, but also improve the efficiency of an organization [73]. Obviously, high-skilled individuals [74] play a key role in this process. Higher employee digital skills and positive attitude towards digital tools would be facilitating a higher-level enterprise digital transformation. Enterprises can thus support internal entrepreneurial activities by developing employee digital literacy. This provides support to our proposition 1.

B. Leadership-driven Digital Transformation

Configurations 3, 5 and 7 (see Table 5) represent the leadership-driven enterprise digital transformation (using senior executive digital literacy as a core condition). That is, senior executive digital literacy playing a leading role in promoting the enterprise digital transformation. From the perspective of new institutional theory [75], digital transformation can be successful only when digital change gains legitimacy in the organizational belief system [76]. Digital leadership is considered to be a basic element of organizational values and belief systems for enterprises to carry out digital transformation [7]. A higher level of senior executive digital literacy means that leadership has

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‘desirable’ attributes or practices which can promote digital cultures, embedding core values related to digital innovation, or promoting the legitimacy of digital transformation. A digital leader creates the platform to support the prosperity of a company’s digital culture and drives stakeholders (such as employees) to act responsively. Digital leadership can influence the agility of an organization and the digital transformation of the organization by creating a digital friendly culture through mission and vision that guides employees to acquire the necessary knowledge and skills [77]. Therefore, a higher level senior executive digital literacy will facilitate a higher level of digital transformation. This supports our Proposition 2.

C. Organization-driven Digital Transformation

Configurations 1, 6, and 7 represent the digital transformation driven by the organization (using organizational hard and/or soft digital literacy as core conditions). Companies can provide support mechanisms for effective knowledge sharing through building digital infrastructures (such as shared databases) and digital process (e.g., code of conduct), for example. Companies can also improve the level of employee digital skills and knowledge through training. An employee with a higher level of digital knowledge will become motivated and willing to participate in digital related works, which usually means a higher level of digital technology readiness [3]. Therefore, a higher level organizational digital literacy (both hard and soft) will bring a higher level of enterprise digital transformation. This provides support to our propositions 3 and 4.

D. Combination of Conditions as Drivers of Digital Transformation

Although employee digital literacy, senior executive literacy and organizational hard/soft literacy can each facilitate enterprise digital transformation, as shown in configurations 1, 2, 3, 5, 6, and 7, a

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combination of these organizational literacy attributes appeared to be more important than any single attribute. For example, in configuration 2, none of the conditions are core to the digital transformation. However, strong senior executive digital literacy and strong employee digital knowledge, as well as strong organizational hard/soft literacy are auxiliary conditions together for higher-level digital transformation. Likewise, in configuration 7, strong senior executive digital literacy and strong organizational hard/soft literacy co-exist as core conditions in companies with higher-level digital transformation, whilst strong employee digital knowledge is an auxiliary condition for higher-level digital transformation. Proposition 5 is thus supported.

V. CONCLUSION

Previous scholars have paid close attention to the role of digital technology in promoting enterprise digital transformation. However, the importance of organizational digital literacy in the process of enterprise digital transformation has only been highlighted rather recently. Based on the perspective of Organizational Affordance Theory, this study used the fsQCA method to examine the effect of six conditions of higher-level enterprise digital transformation (i.e., employee digital knowledge, employee digital skills, employee digital attitudes, senior executive digital literacy and organizational hard/soft digital literacy). Different configurations of these six conditions are identified and facilitate different modes of enterprise digital transformation.

Firstly, we found evidence of employee-driven digital transformation in this research. Higher-level employee digital skills, digital knowledge and positive attitude toward digital tools facilitate a higher-level enterprise digital transformation. This finding enriches existing research on employee digital literacy and enterprise digital transformation, and echoes Cetindamar et al.'s [2] call for more empirical research on employee digital literacy and enterprise digital transformation.

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Secondly, we also found evidence that leadership-driven digital transformation is an important mode of enterprise digital transformation. Digital literacy of senior executives plays an essential role in promoting enterprise digital transformation strategy. This enhances the Organisational Affordance Theory, which tends to overlook the importance of leadership role during digital transformation.

Thirdly, we also identified organization-driven digital transformation as another important mode of enterprise digital transformation. Higher level organizational digital literacy (both hard and soft) will provide important infrastructure and processes for employees to implement and adopt new technology and will bring about a higher-level enterprise digital transformation.

Fourthly, what we have found in this study is that digital transformation of companies is more likely to be facilitated by a combined effect of different attributes of organizational digital literacy (i.e., employee digital literacy, senior executive digital literacy and organizational hard/soft digital literacy). Any single attribute of organizational digital literacy does not constitute a necessary condition for high-level enterprise digital transformation. Instead, we found seven different configurations of organizational digital literacy which enable a higher-level of digital transformation. Each of these configurations consists of a combination of different digital literacy conditions. Thus, different attributes of organizational digital literacy do not work in isolation. For example, a higher level senior executive digital literacy can result in a digital friendly strategy, which can facilitate a higher level of employee digital literacy through targeted recruitment and job expectations. A higher level senior executive digital literacy can also facilitate pro-digital organizational culture and structure, and set higher goals of digital transformation. Likewise, better organizational literacy will facilitate employees' engagement with digital technology through organizational routines and training.

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A. Theoretical implications

This research contributes to existing literature in three aspects. Firstly, we build on Organizational Affordance Theory [4] [5], but also extend it to examine the relationship between organizational digital literacy and enterprise digital transformation. Although a number of studies recognize the role of digital literacy at the organizational level and emphasize the embeddedness of digital literacy in organizational practices, most of these studies are conceptual rather than empirical. From the perspective of Organizational Affordance Theory, we found that there are different organizational conditions affecting the way digital technology is implemented in specific organizational contexts, and therefore the organisation's affordance [4]. By incorporating senior executive digital literacy into the research model (leadership affordance), we have expanded the understanding of organizational digital literacy and enriched the Organizational Affordance Theory. We suggest that digital literacy at the organizational level should be understood as a multi-dimensional concept consisting of employee level, leadership level and organizational level digital literacy. A high level of enterprise digital transformation depends on right configurations of these digital literacy dimensions.

Secondly, we have made the typology of organizational digital literacy, which responded to a previous call for research on the socio-technological dimension of digital literacy [14] [78] more sophisticated. Previous research into digital literacy focused mainly on the cognitive dimension of digital literacy. As a result, we have extended the study to look into organizational dimensions of digital literacy, and in particular, to emphasize the importance of the combined effect of different attributes of digital literacy.

Thirdly, although previous studies have empathized the importance of employee digital literacy for digital transformation, they have mainly understood the issue from the perspective of digital economy at the national level (e.g., DCFC of EU). In this study, we developed a big data analytical

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tool based on text analysis and machine learning to understand the employee digital literacy of listed companies. By using this tool, we were able to capture a big data set of employee digital literacy which is not publicly available. This data not only allowed our analysis of enterprise digital transformation, but also set the scene for the current trend of employee digital literacy development emphasized by contemporary businesses.

B. Practical Implications

Successful enterprise digital transformation requires corresponding changes in the organizational strategy. Our results should help with the understanding of the key conditions needed by contemporary companies during digital transformation. Our research brings some implications for practitioners from the perspective of organizational digital literacy. First, our study shows how the configuration of six digital literacy conditions can facilitate the digital transformation of companies. Therefore, our study can provide managers with a tool to help with understanding the role of different attributes of organizational digital literacy to achieve enterprise digital transformation.

Second, managers should realize that enterprise digital transformation not only depends on the cognitive development of individuals, but also depends on the organizational context formed by employees, leadership and the organizational infrastructure and routines. According to the framework proposed by us, the underlying affordance of organizational and senior executives will help to establish pro-digital expectations of employees in the process of digital transformation. Therefore, employee, senior executive and organizational digital literacy are integrated parts of the enterprise digital transformation.

Third, it is important to realize that digital transformation is a radical institutional change. Practitioners should not only emphasize the adoption of digital technology by employees, but also consider how to enhance leadership engagement by developing their appropriate digital leadership skills and attributes. Our research shows that senior executive digital literacy, such as technical

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background, is an important condition for organizations to carry out digital change.

Fourth, our findings can also guide the human resources management in developing targeted training programmes and recruitment plans to facilitate companies' digital literacy and successful digital transformation.

C. Limitations and Future Studies

This study has four limitations. First, despite studying multiple industries, our research is based in China. There needs to be caution when applying the results to other countries, where the level of digital development is significantly different from that of China. Future research may examine whether changes in contextual conditions in other countries will affect the facilitating role of organizational digital literacy. Second, this study used a big data analytic tool to evaluate the digital literacy of employees with only the "data analyst" position of sample companies. However, there are many other digital related posts in contemporary firms, such as cloud computing, artificial intelligence and blockchain, which might be considered for future research. Third, our study proposes different configurations of organizational digital literacy conditions to facilitate higher-level enterprise digital transformation without indicating the antecedents of any of these conditions. Future research may examine linear relationships between these conditions in different configurations of organizational digital literacy.

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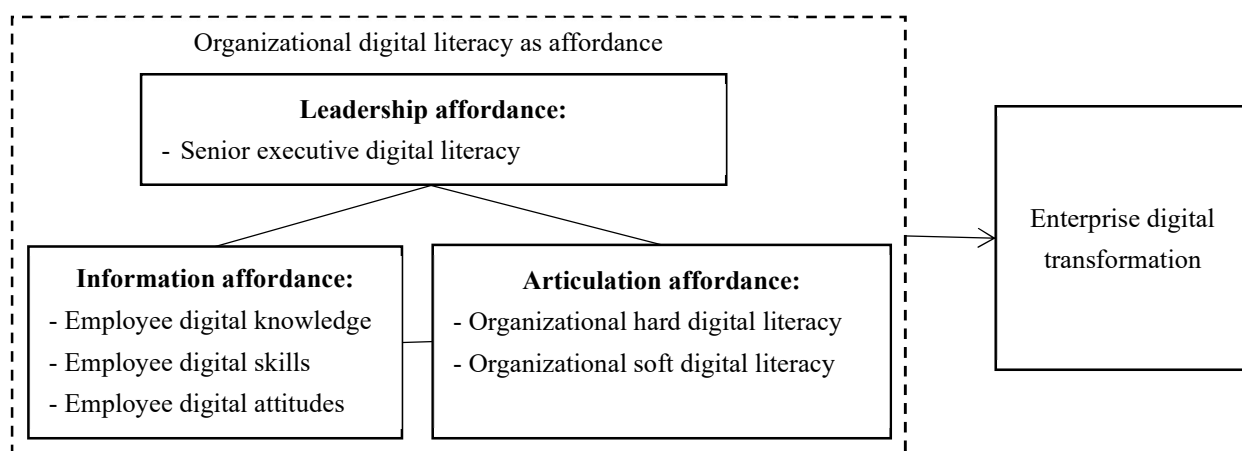


Fig. 1. Conceptual framework

TABLE 1

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TOP 10 JOB TITLE WORDS

Job position	Job title words
Data analyst	data analyst, big data analyst, data specialist, data analyst, data analyst, business data analyst, data analysis assistant, data analysis engineer, software data analyst, data analyst

TABLE 2

TOP 50 SEED WORDS BASED ON DCFC

Categories	Words
Digital knowledge	digital, aware, data, knows, can, by, on, online, as, content, with, services, use, social, personal, devices, user, different, used, environments, information, internet, technologies, about, applications, may, images, media, systems, tools, access, behaviour, communication, from, impact, learning, might, people, software, their, algorithms, have, life, new, output, accessibility, activities, example, physical, program
Digital skills	how, knows, digital, for, use, content, data, online, conditions, by, tools, able, create, services, can, devices, from, identify, social, time, using, complex, when, with, information, order, messages, open, apply, media, personal, platforms, public, shared, software, video, access, activities, apps, based, copyright, manage, mobile, produce, share, technologies, text, through, appropriate, available, recognise,
Digital attitudes	digital, open, inclined, content, data, online, technologies, information, services, systems, use, willing, considers, how, human, internet, co, devices, risks, appropriate, benefits, could, create, help, impact, more, products, strategies, ways, accessibility, creating, design, environmental, explore, new, opinions, reliability, resources, rights, safety, share, social, society, value, collective, constructive, curiosity, driven, engage, opportunities

TABLE 3

CALIBRATION INFORMATION

Conditions and result variables	Fuzzy sets calibration value		
	Full membership (higher than 95% of the sample)	Cross-over point (higher than 50% of the sample)	Full non-membership (higher than 5% of the sample)
Enterprises digital transformation	80.4	34.6	2
Senior executive literacy	0.5908	0.1429	0
Employee digital knowledge	0.2680	0.0566	0.0093
Employee digital skills	0.2365	0.0461	0.0091
Employee digital attitudes	0.1714	0.0357	0.0079
Organizational hard digital literacy	100	64	31.65
Organizational soft digital literacy	0.1546	0.0479	0.0049

TABLE 4

NECESSARY CONDITIONS OF HIGHER-LEVEL ENTERPREISE DIGITAL TRANSFORMATION

Conditions	High level of enterprises digital transformation		Conditions	High level of enterprises digital transformation	
	Consistency	Coverage		Consistency	Coverage
SENIOR EXECUTIVE LITERACY	0.6980	0.5725	DIGITAL ATTITUDES	0.6566	0.5921
senior executive digital literacy	0.6762	0.5564	digital attitudes	0.7196	0.5429
DIGITAL KNOWLEDGE	0.6574	0.5896	HARD LITERACY	0.7963	0.5697
digital knowledge	0.7020	0.5320	hard literacy	0.6477	0.6248
DIGITAL SKILLS	0.6491	0.6022	SOFT LITERACY	0.7968	0.6651
digital skills	0.7202	0.5309	soft literacy	0.7069	0.5718

Notes: Capital letters indicate that the condition exist, and lower case letters indicate absence of the condition.

TABLE 5
CONFIGURATION OF HIGHER-LEVEL ENTERPRISE DIGITAL TRANSFORMATION

Conditions	Configuration						
	1	2	3	4	5	6	7
Senior executive literacy		●	●	⊗	●	⊗	●
Employee digital knowledge	●	●	⊗	⊗	●	●	●
Employee digital skills	●			●	●	●	⊗
Employee digital attitudes	●	⊗	●	●	⊗	●	
Organization hard literacy	⊗	●	●	⊗	⊗	●	●
Organization soft literacy	●	●	●	⊗	⊗	⊗	●
Consistency	0.8090	0.8257	0.8262	0.8258	0.8372	0.8269	0.8252
Raw coverage	0.3528	0.3043	0.2924	0.2505	0.2422	0.3144	0.3137
Unique coverage	0.0637	0.0059	0.0283	0.0131	0.0104	0.0609	0.0082
Solutions consistency	0.7636						
Solutions coverage	0.6059						
Case companies	Neusoft Group; Anke Innovation Technolog; Taier Heavy Industry; iFLYTEK; Hisco Pharmaceutical Group; Wuhan Gaode Infrared; Sichuan Jiuyuan Yin Hai Software	Zhejiang Zhonghe Technolog; Duolun Technolog; Beijing North Information Technolog; Beijing Chen'an Technolog	Shanghai Zhijie Clean System Technolog; Jiangsu Kangyuan Pharmaceutical; Beijing Huichen Zidao Information; Beijing Wanji Technolog	Luzhou Laojiao	Weichai Power	Huayi Brothers Media; Zhejiang Zhengtai Electric Appliance; Shanghai Laiyifen; Shanghai Mercury Home Textiles; Wanxiang Qianchao	Zhejiang Zhonghe Technolog; Zhongkechuangda Software; Beijing North Information Technolog; Qisheng Technolog

Notes: ●=Presence of core condition and at a high-level, ⊗=Presence of core condition but at a low level, ●= Presence of auxiliary conditions and at a high level, ⊗=The presence of auxiliary conditions but at a low level, “Space” indicates that the condition can be absent.

TABLE 6
ROBUSTNESS TEST

Conditions	Configuration				
	1	2	3	4	5
Senior executive literacy	●	●	●	⊗	●
Digital knowledge	●	●	●	●	⊗
Digital skills		⊗	●	●	●
Digital attitudes	⊗		⊗	●	●
Hard literacy	●	●	⊗	⊗	●
Soft literacy	●	●	⊗	●	●

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Consistency	0.8257	0.8252	0.8372	0.8336	0.8604
Raw coverage	0.3043	0.3137	0.2422	0.3024	0.2636
Unique coverage	0.0070	0.0120	0.0290	0.0935	0.0175
Solutions consistency	0.7949				
Solutions coverage	0.4917				

Notes: ●=Presence of core condition and at a high-level, ⊗=Presence of core condition but at a low level, ●= Presence of auxiliary conditions and at a high level, ⊗=The presence of auxiliary conditions but at a low level, “Space” indicates that the condition can be absent.



Li Zhao, received the Ph.D. degree in School of Management, Fudan University, China, in 2009. She is currently an Associate Professor in Human Resource Management at School of Business Administration, Shanghai Lixin University of Accounting and Finance, China. Her active areas of teaching and research include Human Resource Management, Organizational Behavior, Entrepreneurship, Environmental Responsibility. She has widely published in over 50 refereed journal articles in reputed journals and international conferences such as International Journal of Operations & Production Management, Journal of Business Research, EurOMA Conference.



Qile He (Corresponding author), PhD, is a Professor of Strategy and Performance Management at the University of Derby, UK and the Chair of the College Research Committee at the College of Business, Law and Social Sciences, and the interim University Theme Lead on Business, Economic and Social Policy. His research interest lies in the area of knowledge transfer in the context of interfirm alliances and sustainable supply chain management, supply chain optimization, as well as innovation strategies and processes of organizations. He has published over 90 papers in refereed journals, books, and leading international conference proceedings. He is a council member of the British Academy of Management.



Lei Guo (Corresponding author), received the Ph.D. degree in Management Science and Engineering from Fudan University, Shanghai, China, in 2013. He is an Associate Professor with the School of Business Administration, Shanghai Lixin University of Accounting and Finance, China. His research interests include Information technology and data analytics, big data and machine learning. He has more than 20 publications, including three books. He also provides IT and management consulting for some well-known companies in Shanghai.



David Sarpong, PhD, is a Professor of Strategy and Head of the Marketing and Strategy Subject Group at Aston Business School. Before joining Aston, he was Professor of Strategic Management at Brunel University London, where he also served as Head of the Strategy, Entrepreneurship, and International Business (SEIB) Research Group. He is a Member of the International Committee of the Chartered Association of Business Schools (CABS). He is also an elected Vice Chair of the British Academy of Management (BAM), and a former Convenor of the Annual Doctoral Symposium of the Academy. He is an Associate Editor for the Journal of Strategy and Management.