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Contents

Abstract

Schools are challenged to become innovative and adaptive organisations that facilitate and continuously develop appropriate teaching and learning approaches and environments. In this context, the central steering role of school leaders, strategic innovation strategies and knowledge management are highlighted in educational research (Bryk, 2010; Cheng, 2015; Chu, 2016; Fullan, 2016; Kovačević & Hallinger, 2019; Leithwood, 2021; Serdyukov, 2017). Collaborative innovation and engaging in networks of knowledge exchange are crucial for innovation (Chu, 2016; Harris, 2008; Torfing, 2019). However, schools predominantly rely on their internal knowledge, struggling to engage in knowledge exchange (Fullan, 2002; Pietsch et al., 2023). Overcoming the barriers to knowledge exchange, meaning that ideas and expertise must remain private property within organisations, is the central goal of open innovation (Chesbrough, 2003). Accordingly, external ideas and knowledge are equally as important as internal ideas and expertise in terms of enabling innovation. Managing knowledge across organisational boundaries enables flexible development tailored to individual circumstances and capacities (Bigliardi et al., 2021; Chesbrough & Bogers, 2014). While the concept of open innovation has been applied to the educational context, revealing the relevance of broad knowledge flows for school innovation (Pietsch et al., 2023; Pietsch et al., 2024), little is known about the necessary conditions for successfully implementing open innovation. On this basis, in this work, I analyse the interplay between individuals' attitudes and mindsets, leadership and innovative behaviour, as well as organisational capacities and knowledge-sharing practices, and the resulting effects on open innovation in schools.

The following research questions are examined in this dissertation:

1. How can open innovation be successfully implemented in schools?
2. To what extent can transformational leadership, leader-member exchange and knowledge-sharing practices facilitate the conditions needed for open innovation in schools?

3. How are the mindsets and attitudes of school leaders and teachers, as well as schools' absorptive capacity, interrelated in the process of implementing open innovation?

As part of this dissertation, three research articles were written that examined the overarching research questions using multivariate methodological approaches. These articles are contextualised and discussed within the theoretical background, followed by a presentation of the theoretical and practical implications.

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1. Introduction

"The knowledge-based 21st century requires changes to educational organisations and practices. Success in this emerging paradigm requires new skill sets for students, for teachers, and for educational administrators. These skills include: collaboration, problem framing, critical thinking, 'thinking outside of the box', innovation and creativity." (Hannay & Earl, 2014, p. 55).

The need for innovation in education and the expectation that educational institutions will become innovative organisations that build students' twenty-first-century competency skills is emphasised in the field of educational development (Fuad et al., 2022; Serdyukov, 2017). Innovative education will help students become creative and critically thinking people who can solve problems; however, this generally requires an educational system that fosters innovation and a favourable environment (Serdyukov, 2017). More fundamentally, innovation in education is intended to not only improve students' competency and learning quality but also increase equity, equality and efficiency and reduce educational costs (Fuad et al., 2022; OECD, 2016).

The main drivers of innovation in education are new digital technologies; limited funding or personnel; the changing needs of students and parents and larger system shocks, such as the COVID-19 pandemic (Vincent-Lancrin, 2023). In these quickly changing, dynamic environments, schools are confronted with complex challenges. They must complete daily business while continuously exploring possibilities for development and improvement, increasing the pressure and expectations on schools and school leaders (Pietsch et al., 2022). Accordingly, schools must become dynamic social organisations that learn to continuously develop (Goldring, 1996; Hargreaves, 1999). Especially for public organisations, collaborative innovation is promising because it makes structures and traditions more flexible, fosters the exchange of experiences from different fields and allows the engagement of diverse actors in creative solution development (Torfing, 2019). To participate in collaborative innovation, schools require strategic innovation and knowledge management (Cheng, 2021), especially considering that schools are traditionally weak in knowledge sharing (Fullan, 2002).

Against this background, the question arises as to which innovation strategies and methods can support schools in building networks and collaborations with external

knowledge partners, thereby creating knowledge and innovation. Whereas the concept of open innovation has recently been transferred to the educational context, offering a new approach to organising knowledge flows that cross school boundaries and showing positive effects on schools' innovation practices (Pietsch et al., 2023; Pietsch et al., 2024), little is known about its antecedents and the conditions needed to implement it successfully. However, research highlights the central steering role of school leaders in facilitating the conditions needed for innovation through knowledge management and creating an innovation climate that allows participation and collaborative development (Bryk, 2010; Chu, 2016; Leithwood, 2021; Stoll & Kools, 2017; Van Den Hooff & Ridder, 2004).

Within the scope of this dissertation, an investigation into how open innovation can be successfully implemented in schools is intended to shed light on this research gap. School leaders' role, leadership behaviour, mindsets and, attitudes, and schools' attitudes; schools' capacities and the interplay between school leaders and teachers are central topics. Researching them will offer deep insights into the diverse interrelations in schools that determine open innovation practices.

In this research project, I draw on a range of theoretical concepts and models that have been adapted to the educational context. These models were analysed using quantitative data analysis methods. Data from the Leadership in German Schools project (LineS), which were collected in 2021, were used for the first and second research articles. In this survey, 411 German school leaders were asked about various topics, but the questionnaire especially focused on innovation. The third research article analysed data on Malaysian school leaders (n = 54) and teachers (n = 1,178). The data were collected in 2024 and provided during a collaboration project with the University of Melbourne.

The following chapters of the dissertation will first outline the theoretical background of the dissertation. Second, the underlying research desideratum and questions are presented. Third, the three research articles are summarised and discussed concerning the research questions. To conclude, the research implications, contributions, limitations, and recommendations for future research will be discussed.

2. Theoretical Background

The relevant theoretical concepts and models are introduced and classified in this chapter. In the beginning, the meaning of innovation in general and in education and the Open Innovation concept will be described, followed by school leaders' role as change facilitators and innovation leaders. The third subchapter discusses the impact of schools as dynamic social systems and organisational factors influencing innovation. Based on this, the research desideratum, and underlying research questions of the dissertation will be presented.

2.1 Defining Innovation in Education

The term "innovation" is used extensively in various disciplines. Nevertheless, what an innovation is remains partially ambiguous. Multiple definitions highlight different features and contexts that characterise innovation (K. Brown & Osborne, 2012; Damanpour, 1991; King & Anderson, 2002). The Organisation for Economic Co-operation and Development (OECD) (2018) defines innovation as "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)." (p. 60). Generally speaking, an innovation is something new that is intended to change an organisation based on external circumstances or proactively influence the environment itself and thereby create value and increase effectiveness (Damanpour, 1988, 1991; OECD, 2018).

Various types of innovation can be identified. Accordingly, an innovation can affect organisational structures (changing processes and management), technical products (introducing new products or services), processes (technology or infrastructure) or the market (developing new geographic areas or market segment (Damanpour, 1988; Marques, 2014). Furthermore, innovations are classified regarding the degree of change that is created. Incremental innovations are based on available resources, existing knowledge, and organisational traditions, gradually leading to change and posing little risk. Radical innovations, on the other hand, cause more fundamental changes and require

exploring valuable external knowledge sources for the sake of development (Davila et al., 2012; Reinmann, 2005; Ritala & Hurmelinna-Laukkanen, 2013).

Collaborative innovations that are developed across organisational boundaries, profiting from diverse knowledge backgrounds, are radical (Ritala & Hurmelinna-Laukkanen, 2013) and produce greater and more diverse value for several actors, as well as fostering future collaborations (Torfing, 2019). In the context of complex problems and challenging environments, collaborative networks and co-creation significantly increase innovation development (Damanpour, 1991; Hartley et al., 2013).

Innovations in schools, however, are predominantly incremental, being partially embedded in superordinate reforms and building on existing knowledge and structures (Haas & Krieg, 2021). Goldenbaum (2012) defines the nature of innovation in educational contexts as "relatively new, targeted, intentional, and planned measures that bring about changes or improvements in the school education system (macro-level), in the individual school (meso-level) and/ or in the classroom or social interactions (micro-level) (intended)" (p. 81), thereby highlighting the various levels innovations that can be developed and implemented in the educational system. Innovations in education, as they are "relatively new", are incorporated into existing structures; they do not fundamentally redesign the grammar of schooling (Cuban, 2020).

Nevertheless, the relevance of collaboration, knowledge sharing and networks for innovation has been highlighted in educational research (Chu, 2016; Fullan, 2016; Harris, 2008). Knowledge is generally emphasised as the most critical resource for innovation (Cohen & Levinthal, 1990; Grant, 1996; Pereira & Bamel, 2021). Still, schools experience difficulties sharing knowledge (Fullan, 2002) and lack the capacity and resources to gain and implement the knowledge necessary for development (Hargreaves, 1999). Therefore, schools predominantly rely on the existing knowledge of school staff and are challenged when attempts are made to develop innovations individually (Pietsch et al., 2024).

Against the background of schools' difficulties involving collaborative innovation and a deficit of concepts describing how external knowledge can be shared and applied to support schools' innovation processes, the concept of open innovation has been adapted and transferred to the educational context (Pietsch et al., 2023; Pietsch et al., 2024).

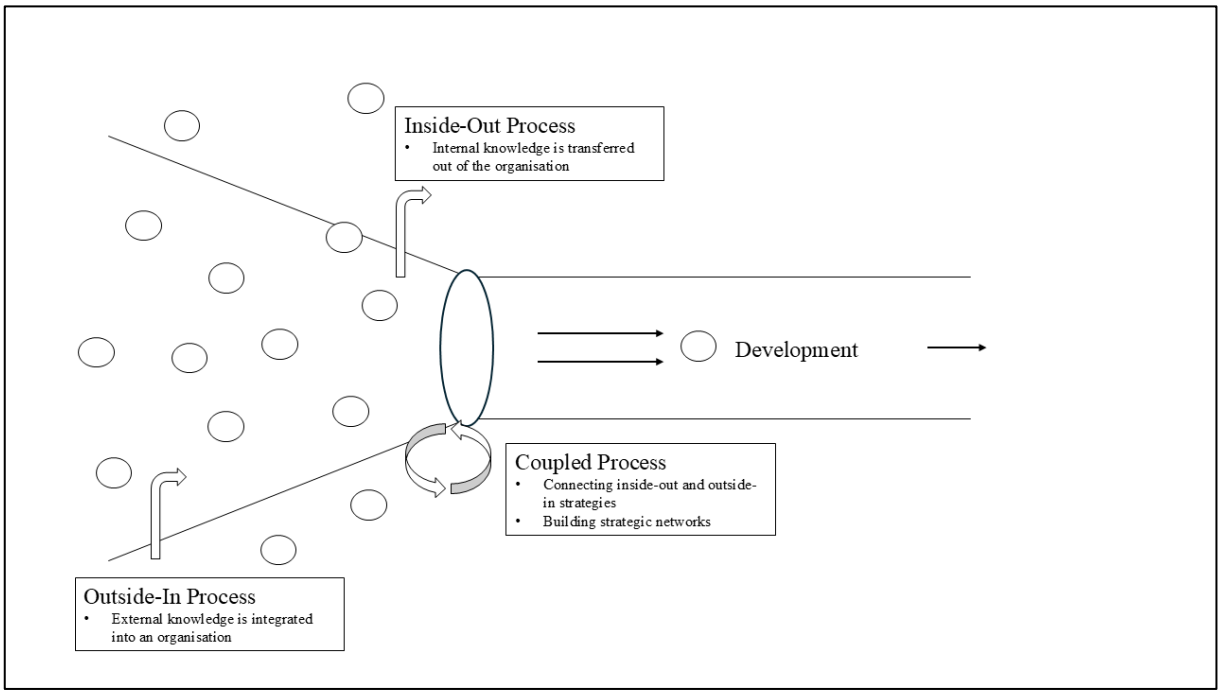
2.1.1 Open Innovation

Traditionally, closed innovation models, which have focused solely on existing internal expertise to develop innovations (Marques, 2014), have lost their efficacy in fast-changing global markets given the increasing availability of scientific research, expertise and knowledge in the twenty-first century (Chesbrough, 2003). Especially for public organisations, such as schools, open and collaborative approaches enhance innovation through partnerships, networks and shared governance (Hartley et al., 2013; Torfing, 2019). Outside of educational research, open innovation is known to be imperative for organising innovation (Bogers et al., 2019). It is defined as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model" (Chesbrough & Bogers, 2014, p. 17). The paradigm of open innovation focuses on sustained unlimited knowledge flows that allow flexible and dynamic developments aligned with evolving circumstances and possibilities as well as on cooperative knowledge exchange that can outweigh the limited resources of individual organisations (Bigliardi et al., 2021; Chesbrough, 2003). Accordingly, external ideas and knowledge are equally as important as internal ideas and expertise in terms of enabling innovation (Chesbrough, 2003). However, embracing knowledge sharing and receiving and incorporating external knowledge require organisations to change their exploration and exploitation principles by moving from closed research strategies to the open and targeted integration of external knowledge to create new ideas and maximise potential (Chesbrough, 2003, 2012; Wobser, 2022). An important prerequisite for external knowledge integration is absorptive capacity as it enables individuals and organisations to acquire, integrate and purposefully apply novel knowledge (Cohen & Levinthal, 1990).

According to the theory on open innovation, three processes for generating ideas for purposes of innovation exist (Figure 1). The outside-in process involves incorporating external knowledge through collaboration with external partners into the existing internal knowledge base. The inside-out process describes situations in which internal knowledge is transferred outside the organisation. The coupled process links inside-out and outside-in processes, allowing collaboration, shared values, alliances and networks to emerge (Enkel et al., 2009; Gassmann et al., 2010).

Considering the paradigm of open innovation, schools' knowledge management challenges and lack of the capacities and resources needed to develop autonomous innovation (Asad et al., 2022), open innovation offers effective approaches via which to organise and encourage knowledge exchange across school boundaries. The benefits of broad knowledge exchange have been encouraged in educational research. Whereas strategic knowledge mobilisation allows knowledge creation and targeted knowledge application (Harris, 2008), professional networks between schools and other external knowledge partners improve teaching practices and increase the motivation to change (C. Brown, 2023).

Figure 1: Theoretical Concept of the Open Innovation Processes



(Based on Gassmann and Enkel (2006) and Chesbrough (2006))

Beyond that, learning communities and cooperation with external knowledge partners are critical conditions for teachers' professional development, e.g., teachers' general pedagogical knowledge (Vanderlinde & van Braak, 2010). Recent research findings indicate that the strategic implementation of external knowledge (outside-in) has a substantial impact on schools' innovation implementation, particularly developing innovations that address digital and traditional teaching and learning methods (Pietsch et al., 2024).

Nevertheless, exploring external knowledge sources poses the risk of potential over-search. In such cases, organisations devote a vast amount of effort and resources into searching for valuable external knowledge that cannot be exploited or implemented sufficiently (Katila & Ahuja, 2002; Laursen & Salter, 2006). Accordingly, organisations' search behaviour can be differentiated between external search breadth, which refers to the number of different knowledge sources, and external search depth, which refers to the intensity with which organisations draw their knowledge from external sources (Laursen & Salter, 2006). Having too many parallel activities and knowledge sources can become a barrier to successful innovation in schools (Pietsch et al., 2023; Pietsch et al., 2024).

To avoid such negative effects, open innovation strategies must be aligned with an organisation's business models, internal structures, and functioning (Chesbrough, 2012; West & Bogers, 2014). Accordingly, strategic leadership and management are needed to adapt open innovation to individual organisational needs and redefine the role of research and innovation culture (Chesbrough, 2004; Yun et al., 2020). Beyond that, individual attitudes, mindsets and dynamic capabilities are crucial to facilitate open innovation and will be outlined in the following chapters.

2.2 School Leadership for Innovation

School leaders and their leadership behaviour are imperative for educational innovation and organisational learning (Bryk, 2010; Kovačević & Hallinger, 2019; Leithwood, 2021; Stoll & Kools, 2017). In educational research, school leaders are described as catalysts for change (Leithwood et al., 2004); knowledge brokers who bridge the gaps between various knowledge sources and stakeholders (E. Anderson & Weiner, 2023; Schechter & Qadach, 2016) and facilitators of learning, professionalisation and change (Hallinger, 2011; Leithwood, 2021; Mulford, 2008). These diverse and demanding responsibilities underscore the crucial role and impact of school leaders on effective school development and highlight the need to increase their knowledge about successfully leading change processes and innovation (Acton, 2021; Bros & Schechter, 2022).

On the one hand, school leaders must establish a culture of change and shared visions among the school staff to enable collaborations and make existing knowledge accessible (Harris, 2008; Kaya-Kasikci et al., 2023). Therefore, strategic knowledge man-

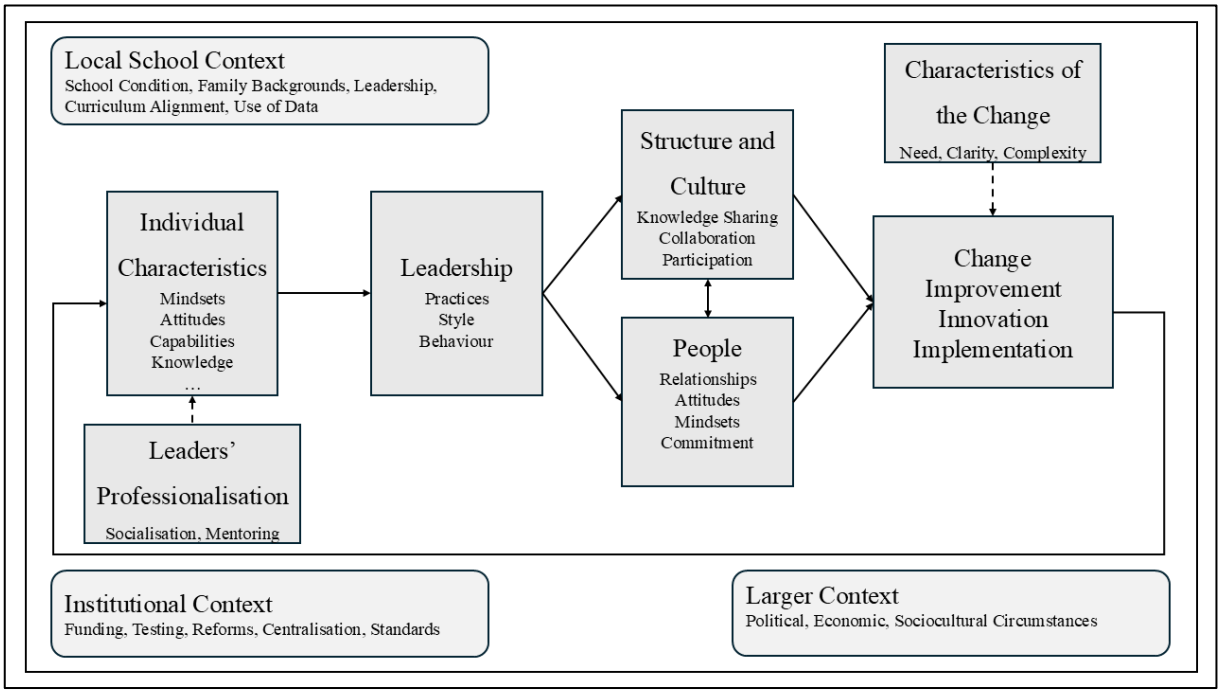
agement and knowledge-sharing activities that allow the exchange of experiences, observations and reflections help reduce internal knowledge barriers, and consequently, enhance teaching quality and performance (Asad et al., 2022; Horng et al., 2005; Rismark & Solvberg, 2011). Beyond that, knowledge management and specific leadership behaviours affect teachers' innovativeness and, professional development and, thereby, school improvement (Cheng, 2015; Polatcan et al., 2024; Zainal & Mohd Matore, 2021).

On the other hand, school leaders must cross boundaries, build networks with external knowledge partners and establish paths via which to bring new knowledge into their schools (Backfisch et al., 2021; Benoliel, 2017). They must also ensure that existing knowledge is exploited and that new knowledge is absorbed and effectively integrated into the existing knowledge base (Cohen & Levinthal, 1990; Da'as & Qadach, 2020; Zuckerman et al., 2018). Therefore, school leaders are responsible for interpreting and communicating policy messages and reform strategies to the school staff as well as leading their implementation (Bros & Schechter, 2022) while acting in dynamic fields affected by the local institutional school context and the larger political, economic and sociocultural context (Acton, 2021; Bros & Schechter, 2022; Hallinger, 2018; Mincu, 2022). To lead these complex processes in a participative and sustainable way, school leaders require capabilities, resources and access to social capital and networks, as these factors influence their leadership practices and individual openness (Daly & Finnigan, 2010; Leana, 2011; Liou & Daly, 2018).

This broad profile of contextual factors and capabilities needed to enable improvements and innovation implementation represents a substantial challenge, especially against the background of school leaders' professionalisation and preparation to lead change (Fullan, 2016). Figure 2, which was developed based on Kovačević and Hallinger (2019), Fullan (2016), Hallinger (2018) and Leithwood (2005), is intended to depict the complexity of educational leadership in relation to contexts, individuals, structures and cultures, particularly in terms of change and innovation. According to this conception, school leaders act within the broader school context, which is defined by local characteristics and other external factors. Their leadership behaviour, style, and practices result from their individual characteristics, e.g., their mindsets, attitudes, capabilities, and knowledge. However, these individual characteristics are also shaped by their professionalisation, socialisation, experiences and mentoring (Leithwood, 2005). Through their

leadership, school leaders can establish structures and cultures that foster development and change while also supporting their followers' individual growth, commitment and motivation to engage in innovation processes. Within schools, people, structures and cultures mutually define one another and, consequently, create change, improvement and innovation. Inversely, implementing innovation or change and the experienced benefits can also affect individual characteristics, such as leaders' attitudes and mindsets. However, the characteristics of a change, including its complexity and clarity and the perceived need for it, can also affect its sustainability and success. These characteristics can appear at various stages in the change process, even after the implementation, and decisively alter the initial idea for an innovation or change (Fullan, 2016).

Figure 2: Educational Leadership in the Context of Change and Innovation



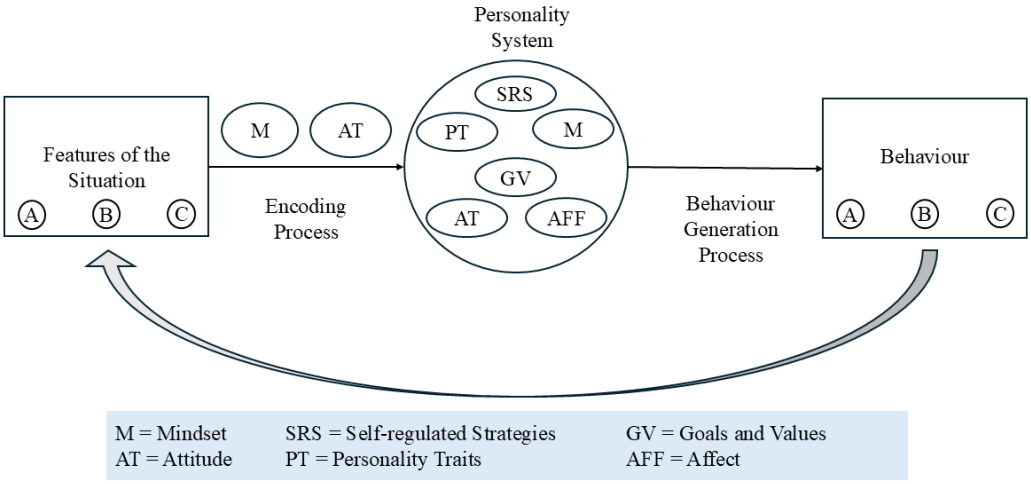
(Based on Kovačević and Hallinger (2019), Fullan (2016), Hallinger (2018) and Leithwood (2005))

2.2.1 The Role of Mindsets and Attitudes

In the context of innovation and transformation, individuals' mindsets and attitudes need to be considered antecedents that impact organisations' agility, collaborative capacities and willingness to take risks and experiment (Kane, 2019; Kouzes & Posner, 2019; Salehi & Asrar, 2022). In addition to mindsets, individuals' self-regulated strategies, i.e., their

strategies and competencies for planning actions; personality traits, goals and visions; affects (emotions and feelings), and their attitudes, are activated by specific situational features and determine the encoding and following behaviour generation process (Figure 3). The ultimate behaviour, in contrast, can affect the environment and social context, creating various situational features (Mischel & Shoda, 1995).

Figure 3: Theoretical Concept of the Impact of Mindsets and Attitudes on Leadership Behaviour



(Based on Mischel and Shoda (1995) and Gottfredson and Reina (2021), **Note:** A, B, and C symbolise the specific characteristics of a situation and the selected behaviour pattern; Affect= emotions and feelings)

Mindsets are part of people's cognitive-affective processing systems, which create meaning systems and determine the organisation of information (Dweck & Yeager, 2019). They can be defined as "mental lenses that selectively organize and encode information, thereby orienting an individual toward a unique way of understanding an experience that guides their actions and responses." Gottfredson and Reina (2021, p. 441). Following the theory on action phases and mindsets, different tasks require different mindsets, e.g., deliberative, implemental, actional or evaluative, and these different mindsets influence cognitive processing to varying degrees (Gollwitzer, 1990). Thus, the features of a situation influence how information is analysed and interpreted (Gottfredson & Reina, 2021). How a person perceives the features of a situation is based on individual thoughts, fantasies, experiences or imagination (Mischel & Shoda, 1995). Especially congruous infor-

mation is more likely to be encoded and retrieved more effectively (Gollwitzer, 1990). Accordingly, mindsets function as patterns that subconsciously encode information and determine sense-making and behaviour; they are thus fundamental elements in terms of understanding leaders' behaviour, as seen in Figure 3 (Gottfredson & Reina, 2021).

Especially in organisational development, the impact of mindset is highlighted as a crucial starting point and foundation for innovation (Slavec Gomezel & Rangus, 2019). Transformation processes in schools, e.g., digitisation, are decisively influenced by school leaders' mindsets (Chua & Chua, 2017; Mac Callum et al., 2014; McLeod et al., 2015). Whereas school leaders are expected to foster positive mindsets toward change and shared visions within their schools (Chua & Chua, 2017), they require a mindset for change that is continually refined through actions, reflections and theory development, thereby building the capacity to generate effective actions (Fullan, 1996). Accordingly, the mindsets, commitment and engagement of school leaders in terms of developing their schools as well as their openness and risk tolerance are vital (Davies & West, 2014; McLeod et al., 2015; Sterrett & Richardson, 2019). Fortunately, interventions can change these mindsets, thereby altering the way information is processed and helping leaders to increase their effectiveness (Gottfredson & Reina, 2021).

Regarding engaging in open innovation, a specific mindset called the open innovation mindset has been found to be a favourable precondition for open innovation (Engelsberger et al., 2022). The open innovation mindset comprises four capabilities: openness, creativity, a positive attitude toward knowledge sharing and sourcing, and risk and failure tolerance (Engelsberger et al., 2022). Openness refers to curiosity, interest in change and experimentation, and the capability to adapt and be flexible. Creativity is critical for leaders, as it enhances problem-solving and helps develop diverse solutions by allowing leaders to effectively combine ideas and information. Risk and failure tolerance refers to the ability to deal with uncertainties, develop self-consciousness, take risks and learn from failures (Bogers et al., 2019; van Oostrom & Fernández-Esquinas, 2017). A positive attitude toward knowledge sharing and sourcing is a readiness to work with and realise external and disruptive ideas, while revealing internal knowledge to external partners and contributors (van Oostrom & Fernández-Esquinas, 2017; von Briel & Recker, 2017). The combination of these four capabilities makes the open innovation mindset a dynamic capability that supports actions focusing on active knowledge sharing, partici-

pation, and collaboration, thereby fostering a culture of innovation (Engelsberger et al., 2022).

As another part of the personality system, attitudes decisively impact behaviour. According to Ajzen and Fishbein (2000), an attitude is "the evaluation of an object, concept, or behavior along a dimension of favor or disfavor, good or bad, like or dislike." (p. 3). This evaluation is based on a set of beliefs that are stored in memory and can be influenced by emotions and contexts (Ajzen & Fishbein, 2000). Furthermore, dual attitudes towards an object can exist simultaneously at different levels, i.e., implicit, explicit or habitual (Ajzen, 2001). Whereas attitudes are often considered relatively stable, they can also change when information is processed and an evaluation of an object is formed. However, this does not lead to the formation of a new attitude or the deletion of previous attitudes but, rather, to multiple attitudes that can be retrieved based on context and motivation (Bohner & Dickel, 2011).

A positive attitude towards knowledge sharing and sourcing can be a driving force for innovation, as valuing external knowledge is the basis for knowledge acquisition and creation processes (Cohen & Levinthal, 1990; Todorova & Durisin, 2007). However, if this attitude is negative, i.e., a rejection of external knowledge, it can become a bias that leads to the suboptimal utilisation or irrational rejection of external knowledge (Antons & Piller, 2015). In knowledge management research, this attitude is called 'not-invented-here syndrome' (Antons & Piller, 2015; Lichtenthaler & Ernst, 2006). It is a perception filter to protect individuals' values (Antons & Piller, 2015; Vanska & Hurmelinna-Laukkanen, 2023). Considering the value of external knowledge in the paradigm of open innovation (Chesbrough, 2003), not-invented-here syndrome is a barrier to successful knowledge transfer that influences the course and success of innovation. However, not-invented-here syndrome is embedded in and changes with social structures and organisational cultures (Burcharth et al., 2014; Lichtenthaler & Ernst, 2006). On the one hand, not-invented-here syndrome, as a social phenomenon poses a risk of leading to a collective rejection or biased perception of external knowledge. On the other hand, organisations with a culture of knowledge sharing and exchange can debias such negative attitudes and foster positive attitudes and a willingness to collaborate (Burcharth & Fosfuri, 2015; West & Bogers, 2014).

Even though school leaders' mindsets and attitudes are important factors to consider when innovation and change processes are investigated in schools, teachers' attitudes should not be disregarded, as they decisively impact the success of external knowledge and innovation implementation (N. R. Anderson & West, 1998; Fullan, 2016; Shulman, 1987). In particular, common beliefs and values are needed to create a learning atmosphere in schools (Stoll & Kools, 2017).

2.2.2 Leadership Approaches: Transformational Leadership and Leader-Member Exchange

In educational research, various leadership approaches and their effects on school development, teaching and student achievement have been investigated in the past to develop leadership practices that contribute to effective and equitable schooling (Gumus et al., 2013; Hallinger, 2003; Hallinger & Heck, 2010; Leithwood, 2021). The following subchapter outlines two of these approaches, transformational leadership and leader-member exchange, which have roots in different taxonomies; however, they have been found to be interrelated and to affect innovation in organisations (Basu & Green, 1997; Khalili, 2016, 2018). Following Graen and Uhl-Bien (1995), effective leader-member exchange relationships lead to transformational leadership. In contrast, other research studies underline transformational leadership as a condition leading to greater leader-member exchange (Özdemir et al., 2024; Vermeulen et al., 2022; Wang et al., 2005) or highlight the mediating role of leader-member exchange between transformational leadership and other organisational outcomes such as organisational commitment (Keskes et al., 2018; Lee, 2005).

Transformational leadership, which is based on attributed and behavioural charisma (Bass & Avolio, 1993), is highlighted in the research field as positively affecting the culture and communication, as well as the commitment and motivation, of school staff (Day et al., 2016; Vermeulen et al., 2022), thereby fostering school innovation (Hallinger, 2003; Khalili, 2016). As a distributed leadership approach, transformational leadership is intended to enable the individuals within an organisation to grow and engage in organisational goal achievement (Bass & Riggio, 2010). On this basis, leaders must help their followers to develop individually, as well as recognising the meaning of their actions for

the larger organisation (Bass & Avolio, 1995). More precisely, Bass and Riggio (2006) describe the role of transformational leaders as follows:

> "Transformational leaders, […], are those who stimulate and inspire followers to both achieve extraordinary outcomes and, in the process, develop their own leadership capacity. Transformational leaders help followers grow and develop into leaders by responding to individual followers' needs by empowering them and by aligning the objectives and goals of the individual followers, the leader, the group, and the larger organization." (p. 3)

Four components are key to transformational leadership: 1. Idealised influence (leaders serve as role models whom followers want to emulate), 2. inspirational motivation (leaders inspire and motivate others), 3. intellectual stimulation (leaders stimulate others to become creative and innovative) and 4. individualised consideration (leaders act as mentors who consider individuals' needs (Bass & Riggio, 2006). Fundamentally, these elements are intended to foster individual and collective capacity and build sustainable commitment to change (Bass & Riggio, 2006; Leithwood & Jantzi, 1990).

In educational research, transformational leadership has been extensively investigated since the 1990's and described as the leadership approach that fosters collaborative school cultures and enables change (Elliot & Asgahr, 2014; Hallinger, 2003; Khalili, 2016; Leithwood & Jantzi, 1990; Saleh & Khine, 2014). Primarily through open and democratic structures that allow participative development, transformational leadership effectively builds a foundation that sustainably changes followers' attitudes and willingness to collaborate and change (Bellibaş et al., 2021; Dexter, 2008; Franciosi, 2012; Leithwood & Jantzi, 2006). Accordingly, transformational leadership is assumed to indirectly affect change processes, being mediated by organisational structures and interactions (Leithwood & Sun, 2012; Leithwood et al., 2020).

Leader-member exchange, which is often referred to as LMX, on the other hand, is a relationship-based leadership approach that builds on social exchange theory (Blau, 1964; Graen & Uhl-Bien, 1995), assuming that high-quality relationships between leaders and followers lead to positive outcomes in terms of performance, work involvement, commitment, creativity and innovation (Khalili, 2018; Lee, 2005; Volmer et al., 2012). These relationships are reciprocal and described as dyadic exchanges ranging from high to low quality. In this context, quality refers to the level of trust, mutual linking, loyalty, respect,

and support that leads to role expectations and completion (Graen & Uhl-Bien, 1995; Lee, 2005; Volmer et al., 2012). According to Liden et al. (1997), "A high-quality LXM is based on social exchange, meaning that the leader and member must contribute resources valued by the other party and both parties must view the exchange as fair." (p. 50). Leader-member exchange develops over time and varies uniquely between each follower and leader, as do its quality, role expectations, performance, behaviours and attitudes (Graen & Uhl-Bien, 1995). Through episodes of role-making processes, which are shaped by individual characteristics, interpersonal relationships, actions, behaviours and context, the relationship between leaders and members and role behaviours change (Nahrgang & Seo, 2014). High leader-member exchange quality also positively affects followers' innovative behaviour, which may result from the leader's offered trust and the followers' attempt to fulfil their role expectations (Basu & Green, 1997).

Both approaches, transformational leadership and leader-member exchange, respect the individuality of followers and their needs and responses to leadership behaviour. Nevertheless, the development of meaningful leader-follower relationships is complicated by complex organisational contexts and the personality characteristics of followers and leaders, which requires leaders to adapt their leadership behaviour dynamically (R. A. Coleman & Donoher, 2022).

2.3 Schools as Dynamic Social Systems

Schools are systems with their own established routines, cultures and traditions. At the same time, they belong to a larger social system and reflect and share the values and principles of a society (Serdyukov, 2017). Within these complex overlapping systems, schools must become adaptive learning organisations continuously developing and innovating to secure effective teaching and learning strategies (Goldring, 1996; Hargreaves, 1999; Serdyukov, 2017; Stoll & Kools, 2017). Given this background, innovation in schools is a complex process and outcome that not only affects several stakeholders but is also affected by stakeholders and environmental circumstances. More precisely, innovation in schools involves "the interaction of individual, group, organisational and environmental characteristics and perceived innovation characteristics" (McGeown, 1980, pp. 148–149). To address with these internal and external challenges, schools require strategic innovation and knowledge management (Cheng, 2021). Whereas open innovation

already offers an approach to innovation in schools, little is known about the capacities schools need to access external knowledge, or the underlying internal social mechanisms and relationships that support collaborative innovation and, consequently, open innovation.

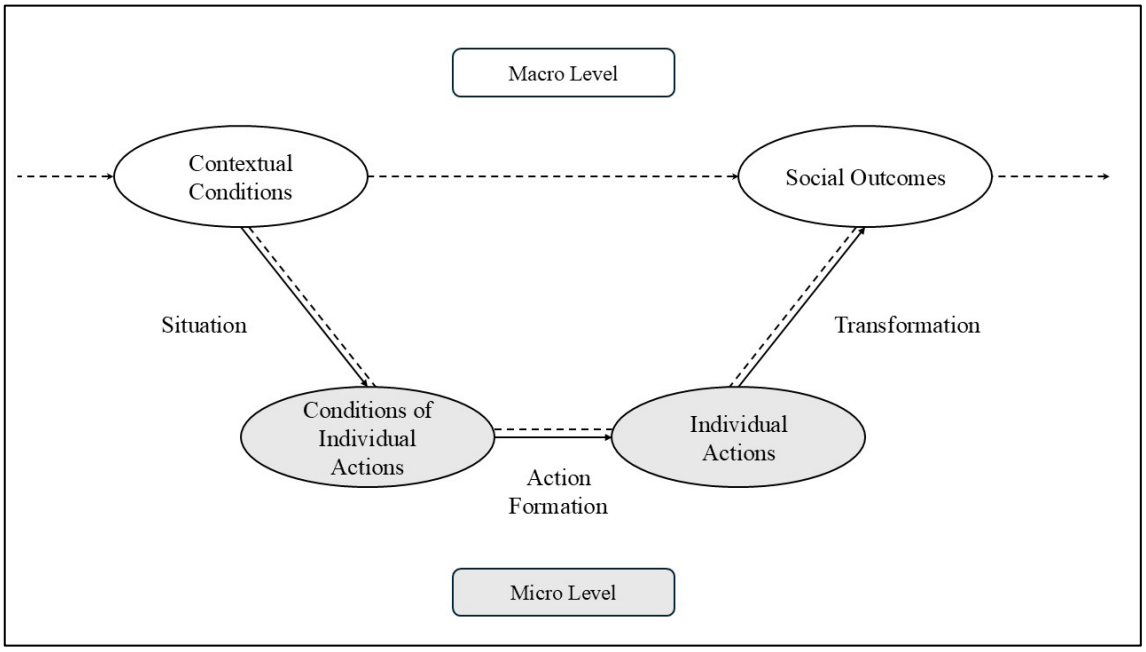
As outlined in the previous chapter on school leadership for innovation (2.2), school leaders play a central role in leading and mediating knowledge exploration, exchange and creation across school boundaries. On the one hand, they create the conditions and culture for knowledge exchange, collaboration and participation (Harris, 2008; Kaya-Kasikci et al., 2023). On the other hand, they can foster teachers' innovative behaviour through positive relationships, i.e., leader-member exchange (Ng, 2017; Vermeulen et al., 2022). However, schools, as learning organisations, are multilevel dynamic systems that are defined by the interrelations between organisational practices and cultures, team organisation and individual behaviour (Stoll & Kools, 2017). Thus, adopting a microfoundational perspective on schools can facilitate a deeper understanding of the multilevel relationships between organisational conditions, individual behaviours and the resulting impact on open innovation (Felin & Foss, 2006; Foss & Xu, 2024).

2.3.1 Microfoundations of Open Innovation in Schools

The roots of microfoundations lie in the social theory of J. S. Coleman (1990), who developed a model known as "Coleman's bathtub" or "Coleman's boat" (Palmié et al., 2023). Following Coleman's theory, changes at the system level of an organisation or society (macro level) impact the underlying interactional and individual components (micro level), which leads to a change in individuals' behaviour and action and, consequently, influences social outcomes on the macro level (J. S. Coleman, 1990; Felin & Foss, 2019). Overlooking micro-level factors when analysing the relationship between two macro-level factors will lead to a superficial explanation at the macro level, which will not consider the individuals involved in or affected by the changes at the system level (J. S. Coleman, 1990). Especially in the context of producing innovation, in which individuals are one driving force (Dahlander et al., 2016; Fleming & Waguespack, 2007) and organisational conditions and cultures are another (Brachos et al., 2007; Chesbrough, 2003), investigating the interconnectedness between macro- and micro-level factors is key to enabling successful and holistic innovation. A microfoundational perspective reveals where

a macro-level factor, such as open innovation, originates and how it is mediated and influenced by micro-level factors, e.g., relationships and individuals' attitudes (Felin & Foss, 2019) (Figure 4). Based on this model, a contextual condition at the macro level impacts the conditions of individual actions at the micro level of an organisation, e.g., a relationship, knowledge, skills, or interests. In turn, these action conditions influence individual actions, e.g. behaviour or performance, which determine the outcome at the macro level (Felin & Foss, 2019).

Figure 4: Theoretical Model of Microfoundations



(Based on Felin and Foss (2019) J. S. Coleman (1990), **Note**: doted lines= indirect effect, solid line= direct effects)

Adapting this microfoundations model to the context of schools and innovation, open innovation is a social outcome at the macro level that is indirectly influenced by the contextual conditions of a school. These contextual conditions can result from specific leadership behaviour and create the conditions of action in schools, which determine the conditions of individual action. The relationships between the organisational members of the school, e.g., leader-member exchange, influence individual actions, such as teachers' not-invented-here syndrome. These micro-level factors, in turn, influence schools' open innovation practices.

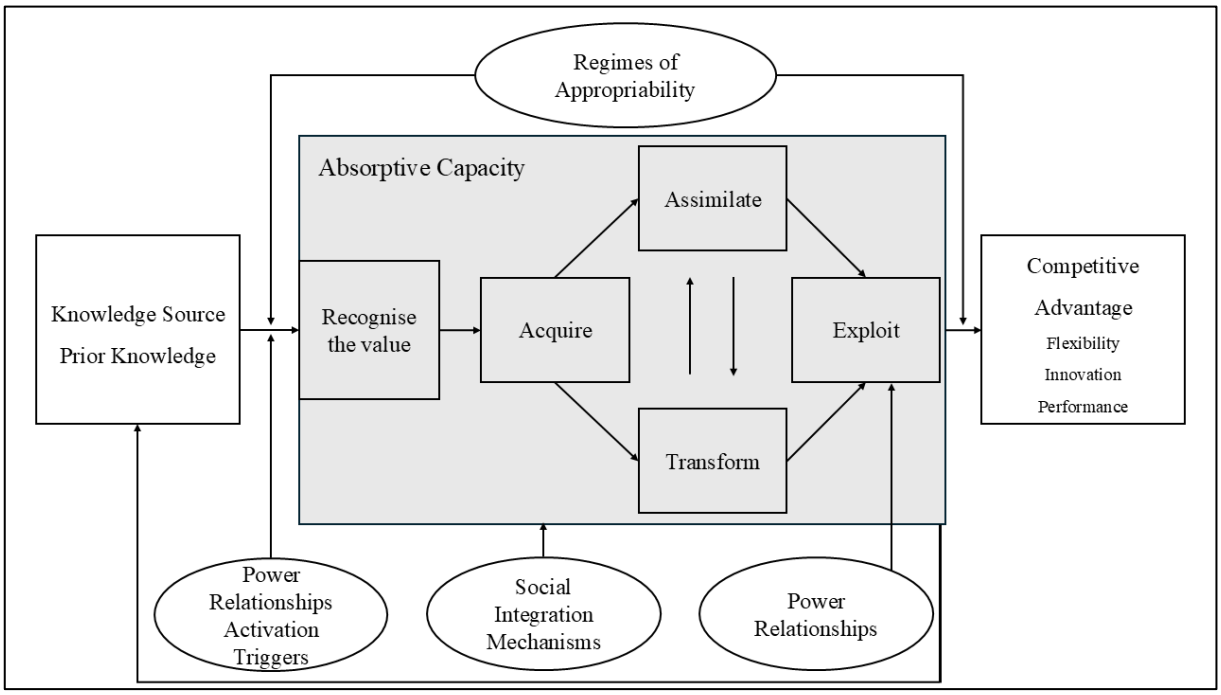
This microfoundational perspective on open innovation allows us to reveal the interplay between contextual and individual factors and, explains how organisational-

level capabilities are defined by individual-level factors (Lowik et al., 2017). Another factor that comes into play when analysing the microfoundations of open innovation in dynamic school systems is the capacities schools need to access and apply external knowledge successfully.

2.3.2 Absorptive Capacity

The extent to which organisations can benefit from external knowledge sources depends on their absorptive capacities, i.e., their capability to recognise and value new external knowledge, assimilate it and purposively apply it (Cohen & Levinthal, 1990). Especially in the context of open innovation, in which external knowledge is one of the most important resources for innovation (Bogers et al., 2019), these capabilities are critical (Schweisfurth & Raasch, 2018; Teece et al., 1997). In general, absorptive capacity combines four dynamic capabilities: recognition, assimilation, transformation and exploitation, which are embedded in organisational routines and processes (Figure 5) (Lowik et al., 2017; Zahra & George, 2002).

Figure 5: Theoretical Model of Absorptive Capacity



(Based Todorova and Durisin (2007))

However, environmental circumstances, opportunities for knowledge exchange and individual attitudes impact organisations' external knowledge search strategies (Chesbrough, 2017; Cohen & Levinthal, 1990). Furthermore, absorptive capacity exists on the individual level, such as individual skills and knowledge, and the organisational level, e.g., the available expertise, capabilities and structures within an organisation (Lane et al., 2006; Tutida et al., 2023). Accordingly, organisations' absorptive capacities are dynamic and result from the prior knowledge and experiences of the individual members (Cohen & Levinthal, 1990; Lowik et al., 2017) as well as feedback loops consisting of previously absorbed and applied knowledge (Todorova & Durisin, 2007). In addition, influential relationships and key stakeholders, such as school leaders, must recognise and value new knowledge. Social integration mechanisms, such as interactions and relationships, impact how external knowledge is acquired, assimilated, transformed and exploited within an organisation (Todorova & Durisin, 2007; Zahra & George, 2002).

Given the high complexity of schools as social learning organisations; the need for dynamic innovation practices and school leaders' growing responsibilities for continuous development, professionalisation, and effective teaching, it is vital to investigate the microfoundations of innovation practices and absorptive capacity.

3. Research Desideratum and Questions

Based on the theoretical background, three research questions were developed, which served as the impetus for this dissertation's research. The central aim of this dissertation is to extend the empirical evidence on open innovation in education and derive practical implications regarding creating efficient and sustainable innovations based on broad knowledge flows that extend beyond the boundaries of individual schools.

The urgent need for schools to become adaptive organisations that continuously develop and innovate has been outlined in the introduction and theoretical background of the thesis. Beyond that, research findings on the relevant key factors enabling school development, such as leadership and collaborative knowledge exchange, were discussed. Overall, previous research highlights not only a lack of innovation but also the insufficiency and ineffectiveness of innovation (Serdyukov, 2017). Consequently, there is an

imperative for strategies and approaches that promote innovation and facilitate its successful implementation in schools. On this basis, the concept of open innovation offers a way to meet the emerging challenges schools face (Pietsch et al., 2023; Pietsch et al., 2024). Although initial research findings on open innovation in schools indicate positive effects on the part of implementing external knowledge sources in schools' innovation (Pietsch et al., 2023), research on the conditions needed to implement open innovation and access its benefits has yet to be conducted. On this basis, the first research question was developed as follows: ***How can open innovation be successfully implemented in schools?***

The central role of school leaders as key actors in leading change processes and facilitating the conditions and culture for innovation is not new in the educational research context (Bryk, 2010; Kovačević & Hallinger, 2019; Leithwood, 2021; Stoll & Kools, 2017). Research on open innovation management also highlights the fact that innovation is brought into practice by the individuals of an organisation (Bogers et al., 2019; Lowik et al., 2017). Accordingly, knowledge sharing activities are vital to express tacit knowledge and experiences and consequently create knowledge and ideas collaboratively (Asad et al., 2022; Horng et al., 2005; Rismark & Solvberg, 2011). Whereas leadership in schools primarily affects organisational outcomes indirectly, for example, students' learning through teachers' capacities (Leithwood et al., 2004), it is imperative to ascertain how leadership can foster conditions that are conducive to enhancing teachers' innovativeness and willingness to engage in knowledge exchange. Considering the research history of educational leadership and its effects on change processes and individual capacities (Bass & Riggio, 2010; Bellibaş et al., 2021; Hallinger, 2003; Leithwood & Jantzi, 2000), the second research question was developed: ***To what extent can transformational leadership, leader-member exchange and knowledge-sharing practices facilitate the conditions needed for open innovation in schools?***

According to the conception of schools as dynamic social organisations and the social theory of microfoundations as outlined in Chapter 2.3, innovations develop across various organisational levels. Accordingly, contextual conditions alone are insufficient to explain complex phenomena such as open innovation. The individuals, their mindsets and attitudes as well as relationships between them are micro-level factors that either contribute to organisations' innovation capacities or become barriers in this regard (Burcharth et

al., 2014; Chesbrough, 2006; Engelsberger et al., 2022). Especially in education, regarding which several stakeholders are directly involved in transformation processes and responsible for facilitating high-quality and effective learning for students, it is vital to understand how internal attitudes are related to schools' open innovation and how absorptive capacities influence knowledge acquisition and transformation processes. Considering the fact that individuals' actions are decisively influenced by their attitudes and mindsets (Gollwitzer & Keller, 2016; Lichtenthaler & Ernst, 2006), the third research question is as follows: ***How are the mindsets and attitudes of school leaders and teachers, as well as schools' absorptive capacity, interrelated in the process of implementing open innovation?***

4. Research Articles of the Dissertation

Based on the theoretical background, research desideratum and questions, three research studies were carried out and published or accepted for publication. In the following, the articles are summarised, and they are subsequently discussed in Chapter Five.

4.1 Research Article 1: Leading Digital Innovation in Schools: The Role of the Open Innovation Mindset

The first research article included in this dissertation focused on school leaders' mindsets as an antecedent of their leadership behaviour and knowledge management, and how these factors affected the implementation of digital innovation.

Implementing technologies in schools is a complex process that must be strategic to ensure holistic integration and improvements in educational settings (Lim et al., 2013). School leaders play a central role in navigating digitisation, providing digital technologies and internal structures and cultivating a collaborative environment (Dexter, 2008; Kaya-Kasikci et al., 2023; Vanderlinde et al., 2012). Transformational leadership is considered essential, On the one hand, to support teachers' positive beliefs about digital technologies and, on the other hand, to ensure the meaningful integration in teaching and learning settings through increased commitment and individual visions (Backfisch et al., 2021;

Schmitz et al., 2023; Yee, 2000). Systematic knowledge management is necessary to enable teachers to express their tacit knowledge, reflect on experiences and develop common knowledge practices (Horng et al., 2005; Ilomäki & Lakkala, 2018).

However, digital transformations begin with people's mindsets (Kane, 2019), and changes in mindset can lead to changes in behaviour and determine innovation success (Kouzes & Posner, 2019; Salehi & Asrar, 2022). The open innovation mindset was shown to positively impact organisations' open innovation performance (Engelsberger et al., 2022; Slavec Gomezel & Rangus, 2019). On this basis, the central aim of this research project was to determine whether this applies to the educational context. Accordingly, this study examined whether and, if so, how school leaders' open innovation mindset promotes digital innovation in schools.

The analysis was based on a random sample of 411 German school leaders collected in 2021. Using a stepwise procedure, confirmatory factor analysis was applied to analyse the construct created to measure school leaders' open innovation mindset. In the second step of the analysis, structural equation modelling was used to test the direct and indirect effects between school leaders' open innovation mindset, their transformational leadership and knowledge management as well as their impacts on the dependent variable, the implementation of digital technologies in schools.

The results show that the open innovation mindset of German school leaders has three facets: openness and creativity, a positive attitude towards knowledge sharing and sourcing, and risk and failure tolerance. The open innovation mindset significantly positively affects school leaders' transformational leadership behaviour. Furthermore, all three facets of the open innovation mindset had a positive indirect effect on schools' digital innovation when this relationship was mediated by transformational leadership and knowledge management. Transformational leadership, however, did not directly affect digital innovation. Again, the effect was significantly positive only if knowledge management mediated the relationship between transformational leadership and digital innovation.

Overall, this study highlights the fact that implementing digital innovation requires school leaders to have an open innovation mindset, a transformational leadership approach and the ability to foster a collaborative culture of knowledge exchange.

4.2 Research Article 2: Not-invented-here, Not Shared Here: How School Leaders' Attitudes Towards External Knowledge Affect Collaborative Innovation and Collective Teacher Innovativeness in Germany

According to the knowledge-based view, external knowledge is a vital resource for knowledge production and innovation (Kaplan et al., 2001; Low & Ho, 2016). However, accessing widely dispersed knowledge requires specific capabilities, such as absorptive capacity, which enables organisations to value, acquire and use external knowledge for internal purposes (Cohen & Levinthal, 1990; Schweisfurth & Raasch, 2018). Especially in the context of schools' pedagogical content knowledge, previous research highlights the need for continuous development and professionalisation, as they enable effective teaching and learning solutions adapted to student needs (Fenstermacher, 1994; Shulman, 1987). Furthermore, absorptive capacity is domain specific; accordingly, absorbing new pedagogical knowledge requires specific capabilities, i.e., pedagogical knowledge absorptive capacity (Schweisfurth & Raasch, 2018). Beyond that, a culture of knowledge sharing in schools is crucial for collaborative knowledge creation, as it enables accessing existing knowledge and exploring new external knowledge (Cummings, 2003; Wiewiora et al., 2013). School leaders are responsible for creating and managing internal knowledge sharing and building partnerships with external stakeholders (Benoliel, 2017; Fullan, 2002). Nevertheless, school leaders' beliefs and personal experiences decisively impact their leadership behaviour (Murphy et al., 2006). A negative attitude towards external knowledge, such as not-invented-here syndrome, can hinder knowledge exchange and acquisition (Antons & Piller, 2015; Lichtenthaler & Ernst, 2006).

Against this background, the second research article investigated the impact of external knowledge sources on teachers' collaborative innovativeness while also considering schools' pedagogical absorptive capacities. Also school leaders' knowledge sharing and not-invented-here syndrome were analysed to reveal how these factors determine the relationship between external knowledge and teachers' innovativeness.

Based on the same sample of German school leaders used in the first research study (see Chapter 4.1), structural equation modelling, mediation analysis and latent moderated structural equation modelling were applied. In the context of the research design, not-invented-here syndrome was positively connotated, meaning that a high value on this scale indicated a positive attitude towards external knowledge sharing and sourcing.

The results indicate that pedagogical knowledge absorptive capacity is needed to absorb external knowledge and increase teachers' collaborative innovativeness. Furthermore, the findings show that school leaders' positive attitudes towards external knowledge and knowledge-sharing activities enhance external knowledge acquisition and increase teachers' opportunities to develop innovations collaboratively.

4.3 Research Article 3: Microfoundations of Open Innovation in Schools: Overcoming Teachers' Not-Invented-Here Syndrome with Transformational Leadership and Leader-member Exchange

Open innovation theory suggests that innovations emerge through social interactions, as they foster knowledge creation within collectives (McGahan et al., 2021). Following the microfoundational view, macro-level associations, i.e., between leadership and innovation at the organisational level, are mediated by micro-level actions and interactions (J. S. Coleman, 1990; Felin et al., 2015). Accordingly, specific leadership approaches, such as transformational leadership, can create the conditions for innovation at the macro level and positively affect interactions and collaborations between organisational members at the micro level, e.g., leader-member exchange (Bellibaş et al., 2021; Day et al., 2016; Vermeulen et al., 2022). However, individuals' attitudes, such as not-invented-here syndrome, are another micro-level factor that can influence knowledge exchange and, consequently, open innovation (Burcharth et al., 2014; Fernandes et al., 2023).

In this context, the third research article investigated how transformational leadership, as a macro-level factor, influences schools' open innovation and is mediated by two micro-level factors: leader-member exchange and teachers' not-invented-here syndrome. Because schools are complex social organisations and innovation processes depend on the individuals within an organisation (Lowik et al., 2017), a multilevel analysis that combined teacher and school leader data was applied. This approach allowed the assessment of relationships that reached across levels of analysis. Based on the sample of 1,178 teachers and 54 school leaders from Malaysia collected in 2024, doubly latent multilevel structural equation modelling was applied. Again, not-invented-here syndrome was positively connotated, meaning that a high value on this scale indicated teachers' positive attitudes towards external knowledge sharing and sourcing.

The study's findings show that transformational leadership had a significantly negative effect on open innovation at the macro level. However, transformational leadership positively affected leader-member exchange, which positively affected teachers' not-invented-here syndrome. On the other hand, teachers' not-invented-here syndrome positively affected schools' open innovation. If the relationship between transformational leadership and open innovation was mediated by leader-member exchange and teachers' not-invented-here syndrome, the effect was significantly positive.

Overall, the results highlight the fact that open innovation in schools is a macro-level phenomenon that is influenced by micro-level factors. The relationships between school leaders and teachers and teachers' attitudes determine the success of open innovation. Transformational leadership alone, however, is insufficient to foster open innovation.

5. Summary and Discussion

The subsequent chapter begins with a concise summary of the fundamental research questions and key findings derived from the three research articles (see Table 1). Afterwards, the findings are discussed in light of the research questions and theoretical background.
Overarching research questions:

1. How can open innovation be successfully implemented in schools?
2. To what extent can transformational leadership, leader-member exchange and knowledge-sharing practices facilitate the conditions for open innovation in schools?
3. How are the mindsets and attitudes of school leaders and teachers, as well as schools' absorptive capacity, interrelated in the process of implementing open innovation?

Table 1: Key Findings of the Research Articles

Article	**Key Takeaways**
Article One	• School leaders' open innovation mindset is a crucial antecedent of their transformational leadership practices and indirectly influences the implementation of digital innovation in schools. • Transformational leadership predicts knowledge management in schools, which is essential for implementing digital innovations.
Article Two	• External knowledge is a vital resource for teachers' collective innovativeness. • Schools' pedagogical knowledge absorptive capacity determines whether external knowledge can be absorbed and utilised. • School leaders' not-invented-here syndrome and knowledge-sharing practices are significant antecedents of teachers' collective innovativeness.
Article Three	• Open innovation in schools is influenced by several factors on the macro and micro levels. • Transformational leadership can create essential conditions for open innovation; however, leader-member exchange and teachers' not-invented-here syndrome are crucial mediators. • High-quality relationships between school leaders and teachers (leader-member exchange) and teachers' not-invented-here syndrome are underlying social mechanisms that influence open innovation practices in schools.

Jointly, the research articles investigated various factors supporting open innovation implementation in educational contexts. Whereas the first article focused on school leaders' open innovation mindset as an antecedent of their transformational leadership behaviour and an indirect factor influencing the implementation of digital innovation, the second examined how external knowledge can be accessed and utilised for teachers' collective innovativeness. In this context, school leaders' attitudes towards external knowledge and

knowledge-sharing practices were analysed as mediating and moderating factors. The final research article extended the investigation by adding teachers' perspectives into the analysis and provided valuable insights into the microfoundations of open innovation in schools. On this basis, relationships and interactions between school leaders and teachers, as well as teachers' attitudes, were identified as decisive micro-level factors determining the implementation of open innovation.

5.1 Discussion

The subsequent section will provide a detailed discussion of the primary findings of the three research articles, synthesising these findings within the context of the theoretical background. The section will conclude with an approximation of the overarching research questions.

Considering the paradigm of open innovation, in which innovations develop through "purposively managed knowledge flows […] in line with the organizations' business model" (Chesbrough & Bogers, 2014, p. 17), the successful implementation of this paradigm in the school context requires bearing a few general things in mind: first, how and by whom knowledge flows are managed in and across schools and what is needed to create the conditions for collaborative knowledge exchange? Second, there is the business model of schools, including the stakeholders, strategies and relationships that shape innovative and effective teaching practices. Especially when diverse stakeholders interact, a deeper understanding of the relationships and dependencies involved allows us to derive implications regarding leading innovation in a participative and collaborative way. Third, there is the impact of diverse contexts, such as institutional, community, national cultural, economic and political contexts, which lead to various interpretations of theoretical conceptions, e.g., leadership and innovation, and their performance (Hallinger, 2018).

Previous research highlights the central role of school leaders in facilitating knowledge exchange and bridging the gaps between stakeholders within and outside schools, thereby enabling collaborative knowledge creation and professional development (see Chapter 2.2). Within schools, teacher innovativeness is essential in developing and implementing innovations and changes (Nguyen et al., 2021; Thurlings et al., 2015). Thus, it is vital to understand how school leaders can create the conditions that will allow teachers to actively participate in knowledge exchange, knowledge to flow across internal

and external boundaries and the targeted utilisation of both existing internal and new external knowledge for innovation.

One essential aspect is the knowledge management and knowledge-sharing practices of schools, which build the foundation for exploring new external knowledge, making tacit knowledge accessible, and facilitating collaborative knowledge creation (Asad et al., 2022; Cheng, 2015; Rismark & Solvberg, 2011). As supported by the findings of the research studies in this dissertation, knowledge management, knowledge-sharing practices, and schools' absorptive capacities functioned as crucial mediators, positively affecting innovation and teachers' collaborative innovativeness. Accordingly, the establishment and continuous development of knowledge-sharing practices, as well as fostering the acquisition of absorptive capacities, are fundamental tasks of school leaders.

However, as outlined in the theory on school leadership for innovation and the role of mindsets and attitudes (see Figure 1 and Figure 2), structures and cultures, such as knowledge sharing, are decisively influenced by school leaders' leadership practices, which, in turn result, from their individual characteristics, such as mindsets and attitudes (Fullan, 2016; Hallinger, 2018; Kovačević & Hallinger, 2019; Leithwood, 2005). Through the findings of these research studies, the relevance of school leaders' mindsets and attitudes towards external knowledge, as patterns of sense-making and behaviour formation, has been clarified. Leading open innovation in education begins with the mindsets and attitudes of school leaders. With an open innovation mindset characterised by openness and creativity, a positive attitude towards external knowledge and a certain amount of risk and failure tolerance, school leaders are likely to implement innovations and lead in a transformational way. Beyond that, school leaders' not-invented-here syndrome significantly affects schools' absorptive capacities and knowledge-sharing practices. Accordingly, school leaders' mindsets and attitudes are critical antecedents that define their leadership behaviour and, consequently, the school's innovation climate, culture and innovation practices.

In the context of change, it is essential to consider that mindsets and attitudes are not stable; they can change through experiences in specific situations, direct interventions and in relation to the environment of action and its receptiveness to change (Burcharth & Fosfuri, 2015; Gottfredson & Reina, 2021; West & Bogers, 2014). On the one hand, school leaders' behaviour is influenced by contextual conditions and situational encoding

and sense-making processes. On the other hand, school leaders influence and change the context in which they act through their leadership behaviour (Mischel & Shoda, 1995). In this regard, mindsets and attitudes form a dynamic foundation for open innovation in education.

The impact of transformational leadership was investigated in Research Articles 1 and 3 of this dissertation. In these two studies, the effect of transformational leadership on the school's digital innovation and open innovation was only significantly positive if mediated by other variables. Thus, transformational leadership alone is insufficient to foster open innovation. However, the indirect effects on digital innovation and open innovation, as well as the direct positive effects of transformational leadership on knowledge management and leader-member exchange, suggest that transformational leadership is crucial for creating an environment with established routines of knowledge exchange and high-quality relationships between school leaders and teachers.

The positive effect of leader-member exchange on teachers' not-invented-here syndrome, as found in Research Article 3, highlights the benefits of high-quality relationships between school leaders and teachers, as well as how these affect innovative behaviour (Basu & Green, 1997). Thus, teachers are empowered and individually supported and can act in a context of trust and shared commitment, visions and goals (Bass & Riggio, 2006; Khalili, 2018; Lee, 2005; Vermeulen et al., 2022; Volmer et al., 2012). Nevertheless, it is vital to bear in mind that high-quality relationships develop within specific contexts and situations and over time (Graen & Schiemann, 2013; Somech & Wenderow, 2006; Vermeulen et al., 2022). For school leaders, this means being sensitive to the varying needs of individuals as well as the characteristics of various situations and the organisation (Leithwood, 2005). Furthermore, they must be able to adapt their leadership behaviour dynamically (R. A. Coleman & Donoher, 2022).

Another objective of the research studies in the dissertations was to examine teachers' individual attitudes and their collective innovativeness, which requires attention in the dynamics of school innovation. Whereas the results of the second research article highlight the need for absorptive capacity in schools to enable external knowledge absorption and thus foster teacher innovativeness, the third research article's findings indicate the relevance of teachers' positive attitudes towards external knowledge to implement open innovation. Following the research on school leaders as knowledge brokers

(E. Anderson & Weiner, 2023; Schechter & Qadach, 2016), school leaders can initiate and manage knowledge flows within their schools and establish networks with external knowledge partners. However, whether this knowledge is absorbed and purposively applied in teaching and learning settings depends on schools' absorptive capacity and teachers' attitudes towards external knowledge.

Overall, the three research articles provide an approximation of the overarching research questions and the identification of several key factors that positively affect open innovation in schools. However, in this dissertation, the first research question cannot be answered completely. Successfully implementing open innovation in schools depends on the unique circumstances, contexts and individuals of a school and the larger educational system. Accordingly, it would be too early to define a framework of generic practices for open innovation in education. As for the leadership practices mentioned by Hallinger (2018), more cross-national comparative and longitudinal studies, including qualitative and quantitative research methods that recognise the diverse contextual factors involved, are needed. Generally, it is essential to understand the complexity of system levels and the dependencies of various stakeholders in schools, as well as how they are connected and interrelated, to develop leadership strategies and approaches that align with individual and organisational needs, visions, and goals.

Nevertheless, the analyses and findings of the research articles included here have revealed that in the German and Malaysian contexts, transformational leadership can create the conditions needed for open innovation. However, to fully realise the expected positive effects on the schools' open innovation practices and implementation, leader-member exchange and knowledge management are required. Beyond that, school leaders' and teachers' mindsets and attitudes are closely related to leadership behaviour, organisational capacities and innovative behaviour. Adapting the open innovation mindset and not-invented-here syndrome to the school context revealed the relevance of individuals' attitudes and mindsets, especially in situations of change and innovation.

5.2 Limitations and Future Research

This dissertation has provided novel insights into the diverse factors influencing the implementation of open innovation in schools. Nevertheless, the following limitations must be considered.

The data analysis performed in all three research articles is based on school leaders' and teachers' self-reports, which poses the risk of measuring unilateral perspectives. Whereas Articles 1 and 2 relied on school leader data derived from Germany only, the analysis of the third article combined teacher and school leader data obtained from Malaysia in a multilevel analysis. Thus, data from school leaders and teachers with different cultural backgrounds and the various relationships between school leaders' and teachers' perceptions extended the findings on the predictors of open innovation in schools. Nevertheless, the effects of the implemented innovation on students' learning were not measured and could not be analysed. Generally, measuring innovation success is a challenge that is critically discussed in research (Nandal et al., 2020). Especially in education, measuring innovation success is complex, as the relationship between innovation and performance is not straightforward but, rather, dependent on individual situations and contexts (Halász, 2018). Still, including student performance data and students' individual perceptions of their teachers' and school leaders' innovativeness and the overall school climate would significantly enrich the results and reveal the value of the implemented innovations.

Furthermore, the analysed data were cross-sectional; accordingly, changes in school leaders' and teachers' behaviour were not observed, and the results cannot be generalised. Considering that mindsets and attitudes can change, e.g. through experiences and debiasing practices (Burcharth & Fosfuri, 2015; West & Bogers, 2014), measuring longitudinal data would provide valuable insights regarding how open innovation practices change knowledge cultures and individuals' innovativeness over time. Also, examinations of the sustainability of implemented innovations and continuous adaptation processes are of great interest in quickly changing knowledge societies. Given the individual nature of the open innovation strategies that can be effective for organisations (Chesbrough & Bogers, 2014), the inclusion of control variables in the analysis, e.g., school location, school size and years of experience as a school leader or teacher, would provide more profound insights and allow for specific recommendations regarding schools' innovation practices.

Overall, the design of the separate research articles positioned school leaders as central actors with the responsibility to create the conditions for open innovation. Against this background, school leaders' mindsets, attitudes and leadership behaviour were pre-

dominantly modelled as independent variables. However, recognising the emerging and multilayered contexts in which school leaders act (Bryk, 2010; Hallinger, 2011), more research is needed on the antecedents of leader emergence, behaviour and attitudes. Regarding the hypothesised circularity of open innovation capacities, shedding more light on mutual independencies and larger contextual conditions would provide more extensive insights and allow researchers to derive implications for professional and system development.

Another topic that should be of concern for future investigations is the relationship between the effects of stress, emotions and job demands on creativity and individuals' resistance to collaboration and change. Mainly, time pressure negatively affects individuals' creativity (Huang & Yu, 2025), and emotions determine how stressful situations are perceived, leading to enhanced performance or cognitive overload, which reduces the resources devoted to creative thinking (Fredrickson, 2001; McEwen, 2007; Sweller, 1988). Thus, school leaders' innovation management plays an important role in reducing stress through organisational structures (Hakan Toytok, 2016). Observing and analysing these factors could provide a deeper understanding of the sources of negative attitudes and mindsets and how they determine the resources that allow schools to be creative and innovative organisations in demanding contexts.

5.3 Research Implications and Contributions

The dissertation's findings have important implications and make contributions that will be useful for scholars and practitioners, as they offer novel insights into open innovation in education. The central aims of the dissertation were to extend the knowledge base and empirical evidence regarding how open innovation can be implemented in education and to pave the way to meaningful innovation in a modern educational environment, with schools being adaptive and innovative organisations.

The multilevel research design of the third article revealed the multidimensionality and interconnectedness of the various school stakeholders that must be considered when analysing innovation practices in schools. Knowledge sharing and acquisition; incorporating individual groups' perspectives, backgrounds and attitudes and anticipating the effects on macro-level outcomes are fundamental for developing future research studies and practical interventions.

Research Articles 2 and 3 offered different perspectives on the dynamics of open innovation in the school context. On the one hand, external knowledge was revealed to be a vital resource for teacher innovativeness. On the other hand, specific conditions in schools and teachers' positive attitudes towards external knowledge are crucial in implementing open innovation. Combining the theories of open innovation and absorptive capacity and arranging the processes circularly, the advantages that result from external knowledge acquisition and utilisation can transform schools' knowledge bases and capabilities. Eventually, these concepts even sustainably change individuals' attitudes and future processes of knowledge exchange and open innovation (Todorova & Durisin, 2007). Accordingly, implementing open innovation in schools may also encourage individual and organisational development and enable effective leadership, responsibility appreciation, tangible goal setting and the development of action plans (Kohn, 2024; Kwan et al., 2022).

Furthermore, the results of the research articles underscore the fact that open innovation depends primarily on the individuals within an organisation their attitudes, mindsets and capacities. Strengthening awareness of how powerful one's attitudes and mindsets are can create room for self-reflection and critical analysis and an understanding of individual behaviour, capacities and biases. Thus, teachers' and school leaders' professionalisation programs should address the impact of fixed and growth mindsets as well as negative attitudes and facilitate strategies to overcome these. Therefore, understanding the origins and development of mindsets and considering the role of individual desires in action formation could be a starting point in the professional development of school leaders (Gollwitzer, 1990; Gollwitzer & Keller, 2016). More fundamentally, rethinking the professions of school leaders and teachers would be appropriate in the context of the changing environments, requirements and growing networks in which school leaders and teachers operate. Following Fullan (2016), teachers and school leaders shifting professions necessitate a new skill set focusing on collaboration, openness and less control. However, developing new skills requires changing the perspective and developing different ways of thinking that enable collaboration and capacity building (Kaser & Halbert, 2009).

Overall, the dissertations' results support the central role of school leaders in managing knowledge creation and innovation in a quickly changing global world. Holding

that responsibility, school leaders must, on the one hand, be educated about methods and strategies via which to foster knowledge exchange and a positive innovation climate in their schools. On the other hand, they must be aware of their impact and the relevance of their mindsets and attitudes on innovation and knowledge sharing. At the same time, it is essential to make room and take time to consciously consider existing internal knowledge, capacities and attitudes and explore and realise the potential of external networks and partnerships for future innovation (Ismail et al., 2023).

Open innovation should not be understood as the master key that helps school leaders manage easily and automatically boost innovation and school development in a top-down process. However, if realised holistically in line with individual schools' needs, possibilities and goals through specific leadership that creates an environment and culture of collaboration and co-creation with opportunities for active knowledge exchange and participation, the benefits of open innovation can be accessed and support schools in becoming adaptive organisations.

Against this background, open innovation in education not only offers a new approach to organising knowledge exploration and transfer (Pietsch et al., 2023; Pietsch et al., 2024), but also paves the way for schools to become innovative organisations that can develop effective teaching and learning settings based on the knowledge, perceptions and experience of diverse experts.

6. References

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7. Appendices

7.1 Research Articles

1. Research Article: Leading digital innovation in schools: the role of the open innovation mindset

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Leading digital innovation in schools: the role of the open innovation mindset

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ABSTRACT

Schools' digitalization requires a shift of stakeholders' mindsets, specific forms of leadership, and strategic knowledge management to deal with current and future educational challenges. The relationship between school leaders' open innovation mindset, transformational leadership, knowledge management practices, and the effects on digital innovation are presented. A random sample of German school leaders is analyzed through confirmatory factor analysis to investigate the construct of school leaders' open innovation mindset followed by structural equation modeling. Results show that digital innovations and transformational leadership in schools require school leaders with an open innovation mindset who foster a collaborative culture of knowledge exchange.

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Introduction

School leaders are central to strategically navigating schools' digitalization while ensuring enhanced teaching, learning, and leadership (Fullan et al., 2023; Håkansson Lindqvist & Pettersson, 2019; Yee, 2000). On the one hand, they are crucial actors in designing internal school structures and providing digital technologies (Dexter, 2008; Vanderlinde et al., 2012). Beyond that, they are central to cultivating a positive, supportive, and collaborative environment with clear and shared visions among the school staff (Kaya-Kasikci et al., 2023). On the other hand, they are important boundary spanners, building bridges between actors outside the school (e.g. authorities and companies) and actors within the school (e.g. teachers) (E. Anderson & Weiner, 2023; Benoliel & Schechter, 2017).

According to Hitt and Tucker (2016) unified model of leadership practices for school effectiveness, the following five practices are essential: (1) establishing and conveying a vision, (2) facilitating educational technology use for students, (3) building professional capacity, (4) creating a supportive organization, and (5) connecting with external partners. Within a systematic review, Dexter and Richardson (2020) analyzed the literature on technology integration in schools, finding that these five leadership practices are also vital for leading digital innovation; however, research examining specific leadership practices on technology integration is still scarce.

Transformational leadership (TL) and networking of school leaders are considered essential prerequisites for integrating digital technologies in schools and their meaningful use, with technology integration in schools being considered an important educational innovation (Backfisch et al., 2021). Further, Yee (2000) found several parallels between technology leadership and TL characteristics that help school leaders ensure information and communication technology (ICT)

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enhances learning, teaching, and work processes management, increases staff commitment, and shifts individual visions to value ICT in education.

Consequently, the most significant conditions for implementing digital media and technology in schools unfold under TL, as it significantly impacts teachers' positive beliefs about digital technology (Schmitz et al., 2023), increases the speed of digital implementations while focusing on educational goals (Ruloff & Petko, 2021), and stimulates knowledge sharing and creation and thus, building a culture of innovation (Afshari et al., 2010). TL is assumed to indirectly affect change and innovation processes, mediated through organizational interaction forms and structures (Leithwood et al., 2020; Leithwood & Sun, 2012).

Besides, most studies stress school leaders' strategic guidance and leadership capabilities to initiate networks, create a culture of change, and realize digital school improvement and change (Bryk, 2010; Hallinger, 2011; Leithwood et al., 2020; Lomos et al., 2023; Timotheou et al., 2023). Notably, schools' knowledge-based innovation processes significantly benefit from external networks and cooperation (Pietsch, Brown, et al., 2023). Additionally, knowledge spaces, that support collaborative knowledge sharing are crucial to make tacit knowledge explicit in schools (Harris, 2008). In this context, school leaders act as boundary spanners, facilitating exchange through TL and knowledge management (KM), thus establishing networks to bring new knowledge into the school, make existing knowledge accessible, and thereby lead schools digital innovation and technology transformation processes (Benoliel & Schechter, 2017).

Research on social networks for school development highlights the increasing role of school leaders' access to social capital and their connectedness within networks as these structures were found to impact leadership practices, their openness toward risk-taking, and the overall innovation climate at the school (Daly & Finnigan, 2010; Leana, 2011; Liou & Daly, 2018). In this background and considering 21st-century developments, digital media tools have become necessary for effective school leadership (Cox & McLeod, 2014). Following Richardson et al. (2019), digital technologies and social media platforms, e.g. Twitter, can be beneficial to increasing school leaders' networking by offering communities of practice, interpersonal connections, access to professional expertise, and research findings. Beyond that, digital media increases information distribution and transparency (Cox & McLeod, 2014) and strengthens the school community by connecting people around shared goals and visions (Richardson et al., 2019; Richardson & Sterrett, 2018).

To date, only a few studies have provided evidence-based practices for educational technology leaders on engaging stakeholders and building productive relationships when leading technological innovation and change in schools (Dexter & Richardson, 2020; McLeod & Richardson, 2011). However, studies on technology integration in schools revealed that there are successful technology leaders who transformed their schools digitally (Hofer et al., 2023; McLeod et al., 2015; Sterrett & Richardson, 2019); it is now to expand the understanding of these individuals' attitudes, mindsets, strategies, and methods to develop implications for school leaders professionalization.

Irrespective of this discussion, Kane (2019) argues that successful digital transformation always starts with a mindset shift at the employee, leadership, and organizational levels, which leads to agility, risk tolerance, experimentation, and collaboration, thereby improving innovation outcomes or leading to their failure (Kouzes & Posner, 2019; Salehi & Asrar, 2022). The relevance of school leaders' and teachers' mindsets was also found to be essential in schools' digital transformation processes (Chua & Chua, 2017; Mac Callum et al., 2014; McLeod et al., 2015). McLeod and Richardson (2013) highlight school leaders' primary responsibility in developing a culture and climate to promote technology learning and "to enact sustained initiatives of communication and education until long-term change mindsets are firmly in place that digital technologies are here to stay, that they are important, and that they will continuously and disruptively foster numerous changes in schooling practices." (p. 255).

On this behalf, school leaders have a superior role in cultivating a positive environment for schools' digital transformations (Kaya-Kasikci et al., 2023), and previous research highlights the

impact of mindsets and beliefs on successful technology integration in schools (P. M. Davies, 2010; Kim et al., 2013; McLeod et al., 2015; Richardson & Sterrett, 2018). Nevertheless, school leaders face challenges requiring professional development and a specific risk mindset to reduce fears of negative consequences and staff resistance (McLeod et al., 2015; Richardson & Sterrett, 2018; Sincar, 2013). According to Chua and Chua (2017), school leaders should further stimulate change for positive mindsets, support network thinking, and develop a shared vision and mission within the school.

However, what constitutes such a mindset and how it affects school digitalization has yet to be researched. The concept of Open Innovation (OI) seems promising for the educational discourse, as it has been proclaimed the key to innovation by promoting an open digital world that enables co-creation among all societal stakeholders through strategic knowledge sharing (Bogers et al., 2019). OI is defined as "a distributed innovation process based on purposefully managed knowledge flows across organizational boundaries" (Chesbrough & Bogers, 2014, p. 12) that primarily addresses an open, distributed mindset of actors, organizations, and involved stakeholders to create and implement new digital technologies (Chesbrough, 2017). In this regard, Salampasis et al. (2015, p. 49) state: "Open innovation is a dynamic organizational mindset that encourages the exploration and exploitation of diverse knowledge inflows and outflows, leading to innovation continuity and incremental organizational change, through the establishment of trustworthy, culturally sensitive and sustainable relationships." Recently, Engelsberger et al. (2022) developed a construct of what constitutes such an OI mindset (OIM), and Slavec Gomezel and Rangus (2019) showed that organizational innovation always starts with such a mindset of leaders. However, whether this also applies to schools and school leaders has not been investigated.

Against this background, our study examines whether and, if so, how school leaders' OI mindset (OIM) promotes digital innovation in schools. Therefore, we rely on the preliminary work of Engelsberger et al. (2022) and examine the effects of such a mindset on TL and digital innovation in schools. Since OI is always about knowledge flows, we consider internal KM within schools to play a central role in whether TL affects digital innovation in schools. Our study aims to contribute to the knowledge field of schools' digital transformation processes by transferring the concept of the OIM to the educational context and investigating school leaders' OIM as an antecedent of TL and, consequently, of digital innovation in schools. We rely on a sample of German school leaders, as in Germany, schools' digitalization, i.e. technical supplies, wireless network availability, and IT support mechanisms, is far behind international standards (ICILS 2018) (Eickelmann et al., 2019). Even though in 2022, a nationwide representative survey of German school leaders revealed that after the COVID-19 Pandemic, technical equipment and its integration in schools increased, adequate assistance and technology support are still deficient (Tulowitzki et al., 2023). Furthermore, school leaders are missing professional and systematic qualification programs that help them not only use digital technologies at their schools but also address those technologies and function as role models and experts in technology integration (Tulowitzki et al., 2023).

Theoretical background

Digital innovation in schools

Hund et al. (2021) define digital innovation as "the creation or adoption, exploration of an inherently unbounded, value-adding novelty (e.g. product, service, process, or business model) through the incorporation of digital technology" (p. 6). Accordingly, digital technology is embedded in digital innovation and goes beyond implementing digital inventions into organizational structures. Consequently, digital innovations require deliberate approaches using technologies to transform those technologies into innovations (Wiesböck & Hess, 2020).

Educational research highlights the need to rethink the impact of digital technologies and participative cultures (Halverson et al., 2018). Furthermore, supporting students' knowledge and

skills acquisition, teachers' professionalization, ensuring inclusion, and organizational and professional practices requires a holistic digital transformation (Kazu & Yalçın, 2022; M. H. Lin et al., 2017; Timotheou et al., 2023). Empirical findings also emphasize the diverse benefits of systematically integrating ICT and digitalization. ICT in education increases schools' organizational agility, supports future innovation, and enriches a variety of teaching and learning methods, thereby supporting the achievement of educational standards (Dörner & Rundel, 2021; Kang, 2021).

However, digital transformation in education leads to pedagogical, didactical, administrative, and policy challenges, which could hinder its success and undermine its benefits (Schmidt & Tang, 2020). Accordingly, implementing technology in schools needs to be holistic, allowing integration into the broader system and advancing the system by considering fundamental changes in pedagogical work, curricula, forms of communication, and social relationships (Lim et al., 2013). Research on technology leadership in schools assigns significant responsibility to the school leaders, their strategic thinking, ICT competencies, and their beliefs and attitudes toward technology integration (Arafeh, 2015; Chang et al., 2008; P. M. Davies, 2010; Richardson et al., 2012; van Niekerk & Blignaut, 2014). McLeod and Richardson (2011) state that *"school leaders who do not understand how to navigate this change will be doing a disservice to their schools and students"* (p. 236), pointing to the need for school transformation in a technology-driven society.

In this regard, school leaders, their mindset, leadership style, and established KM practices are decisive in creating a culture of change, allowing participative development, and exploring new and existing knowledge within and beyond the organization (Dexter & Richardson, 2020).

Knowledge management for digital innovation

While schools have traditionally been weak in knowledge sharing (Fullan, 2002), systematic KM is relevant for their innovation and change processes, especially for digital transformation (Zhao, 2010). According to Chu (2016), KM in schools is "the formulation of the processes in establishing an environment to foster organizational members to create, share, learn and use knowledge comprising experience in the know-how" (p. 1106). In this respect, the KM infrastructure concerns the structure, technology, and culture of the organization (Kılıç & Uludağ, 2021), with processes having the strategic aim of mobilizing the knowledge of all members involved in schooling (Jesacher-Roessler, 2021). For public sector organizations in general, effective knowledge management is necessary to ensure the success of their digital transformation (Alvarenga et al., 2020).

Empirical findings in educational research show the impact of KM on enhanced teaching and learning processes and increased performance (Asad et al., 2022). Especially organizationally managed knowledge-sharing activities allow teachers to express their tacit knowledge, reflect on experiences and observations, and consequently support creativity and knowledge-creation processes, and reduce barriers between schools' different stakeholders (Horng et al., 2005; Rismark & Solvberg, 2011).

On the one hand, knowledge practices at the school level that give orientation, support common knowledge practices, and allow exchange and collaboration within the teachers' community are essential for digital school development (Ilomäki & Lakkala, 2018). On the other hand, social practices and knowledge exchange that go beyond the school level are essential for teachers' professional development and meaningful adoption of technology in teaching (Ley et al., 2022).

Whereas KM is a medium and outcome of innovation focusing on communities of practice and knowledge sharing within and across organizations to overcome structural barriers to innovation processes (Scarbrough, 2003), knowledge transfer practices are a central part of KM in organizations. All communication channels that enable organizations' members to exchange and develop existing knowledge are knowledge transfer practices (Donate & Sánchez de Pablo, 2015). Accordingly, digital transformation and the associated changes in knowledge flows and communication forms make KM a crucial dynamic capability to adapt knowledge transfer practices,

ensure optimized use of technologies, and foster digital innovation (Di Vaio et al., 2021). It increases organizations' abilities to use existing and explore new knowledge by providing conditions and channels for knowledge sharing, donating, and creating (Antunes & Pinheiro, 2020; H.-F. Lin, 2007; Van Den Hooff & Ridder, 2004).

Schools face specific challenges in implementing KM as they often lack financial resources and infrastructures and are confronted with staff's low motivation and missing professionalization (Raudeliuniene et al., 2020). However, strategic leadership offers solutions to those obstacles (Fullan, 2002). Mainly engaged and committed leaders supporting knowledge and learning activities are the driving force of KM practices in organizations (Donate & Sánchez de Pablo, 2015). Moreover, leaders are responsible for creating a communication and social interaction culture that supports members' willingness to share their knowledge (H.-F. Lin, 2007; Van Den Hooff & Ridder, 2004). Specifically, TL behavior significantly impacts knowledge-sharing processes by building trust, offering inspiration, and increasing motivation to participate in knowledge exchange activities (Al-Husseini & Elbeltagi, 2018).

Transformational leadership for digital innovation

Transformational Leadership (TL) is one of educational research's most intensively investigated leadership approaches and significantly affects change and innovation processes (Hallinger, 2003; Khalili, 2016). Generally, the effects of TL on school outcomes are indirect, as TL affects organizational conditions and, consequently, teaching and learning outcomes (Leithwood & Jantzi, 2000; Leithwood & Sun, 2012). Outside of education, KM practices have been found to have a mediating function, that is-TL improves KM, which improves organizational performance (Birasnav, 2014; Kılıç & Uludağ, 2021).

One decisive factor in TL is the increase in employees' active participation in development processes and the decrease in leaders' direct and instructional management and control methods (Hallinger, 2003). Accordingly, leaders are facilitators of diverse development processes on individual and organizational levels. Following Bass and Riggio (2010), they inspire and help followers to grow and engage through empowerment and goal alignment. Furthermore, TL supports leaders in creating a clear, shared vision and becoming positive, motivating role models (Leithwood & Jantzi, 2006). The central aim of TL is to change followers' attitudes and aspirations, support individual development, and enhance sustainable innovation. Especially during critical periods, e.g. digital disruptions, TL skills are critical to educational development (Yang, 2014).

Looking at the postulated requirements and leadership strategies to support digital transformation in education (Dexter & Richardson, 2020), TL offers concrete strategies for creating those conditions and requirements (Dexter, 2008; Schmitz et al., 2023), ensures the active integration of staff into creation and collaboration processes (Franciosi, 2012), and thereby helps to sustainably integrate technologies in schools (Ruloff & Petko, 2021). Furthermore, leading technology integration in schools benefits from distributed leadership approaches that provide diverse sources of knowledge and draw on experts (Sheppard & Brown, 2014).

Leaders' Open Innovation Mindset: an antecedent for digital Innovation

However, how leadership is enacted depends heavily on the implicit assumptions and theories leaders have about themselves, that is, their mindset (Kouzes & Posner, 2019). Generally, a mindset represents a multidimensional combination of beliefs or implicit theories activated in the interaction between a sensemaker's mind and its context (Rauch, 2021). Mindsets are domain-specific; thus, for digitalization, school leaders' beliefs about leading digitalization are, for example, more relevant than beliefs about good leadership (Hughes, 2015). Further, mindsets are distal predictors of performance, meaning that several attributes, contexts, and processes mediate the relationships between mindsets and outcomes (Burnette et al., 2013). Digitalization

requires a specific mindset to successfully lead digital transformation, as it frames how leaders think about and manage a business, resulting in opening or closing opportunities (Kane, 2019).

On this behalf, school leaders' mindsets are vital to support school development on various levels. They can be described as the fundament of establishing an open, collaborative, and risk and failure-tolerant culture within the school (Tirri et al., 2021).

According to Hofer et al. (2023), transforming learning and technology leadership in education depends on innovative educators with interconnected mindsets, skills, and competencies. Further, Dexter and Richardson (2020) have shown that school leadership that promotes technology integration and digitalization must be characterized above all by participation, collaboration, co-creation, and regular knowledge sharing with all stakeholders. Sterrett and Richardson (2019) claim that technology integration in schools strongly depends on leaders' ability to empathize with the learning group's needs, foster change, and their willingness to take risks and use opportunities for innovation. Moreover, school leaders' mindsets, their commitment to technically transform their schools, their engagement in learning communities and networks, and their openness to disruptive ideas are vital to learning from success and failure (R. S. Davies & West, 2014; McLeod et al., 2015; Sterrett & Richardson, 2019). Thus, schools' digitalization requires a leadership mindset and actions focusing on active knowledge sharing, participation, and collaboration.

Based on the research on Open Innovation (Chesbrough, 2003, 2006; Chesbrough & Bogers, 2014) and following up the research on risk mindsets for innovation and development (Sterrett & Richardson, 2019), Engelsberger et al. (2022) refer to such a mindset as an Open Innovation Mindset (OIM). The OIM comprises four capabilities: openness, creativity, a positive attitude toward knowledge sharing and sourcing (KSS), and risk and failure tolerance (Engelsberger et al., 2022). Openness refers to being open to change and curious about experimenting (Slavec Gomezel & Rangus, 2019). Creativity means solving problems and generating products by recombining knowledge to create ideas, integrating knowledge into systems, and adapting systems to inventions (Bogers et al., 2019). A positive attitude toward KSS describes the willingness to accept, work with, and realize external and disruptive ideas (von Briel & Recker, 2017). Risk and failure tolerance, the last facet of OIM, encompasses the ability to deal with uncertainties, failure, and willingness to take risks (Engelsberger et al., 2022).

Theoretical model and research hypotheses

Based on the previous discussion, we propose that school leaders' OIM is an antecedent of TL that indirectly influences digital innovation. TL acts as a predictor of KM and digital innovation in schools. KM is mediating the relationship between transformational leadership and digital innovation (Figure 1).

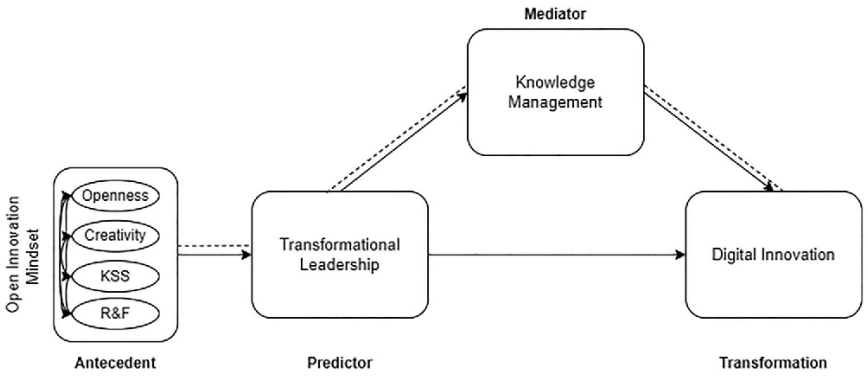

Figure 1. Conceptual model. Note: dotted lines = indirect effects.

The following hypotheses guided our study:

1. H1: A school leader's OIM affects his or her TL practices.
2. H2: TL positively impacts the implementation of digital innovations in schools.
3. H3: TL positively impacts KM practices in schools.
4. H4: KM positively impacts the implementation of digital innovation in schools.
5. H5: TL indirectly impacts the implementation of digital innovation in schools mediated by KM.
6. H6: A school leader's OIM indirectly affects the implementation of digital innovation through TL and KM in schools.

Methodology

Survey procedure

The data was collected within the Leadership in German Schools (LineS) study a biennial survey of German school leaders launched in 2019 (Cramer et al., 2021). For our analysis, data was collected from August to November 2021, explicitly emphasizing innovation. Forsa, the German Institute for Social Research and Statistical Analysis, organized and performed participant acquisition and questionnaire provision. A random sample of 1000 people aged 14 years and older surveyed daily resulted in the identification of $N = 411$ school leaders, a nationally representative sample for Germany. All participants were given access to an online questionnaire, with data collection following ESOMAR standards. The online format allowed random allocations of items as sections, filter questions, question blocks, and varying question formats such as closed-, half-open-, and open-ended questions. Furthermore, the variation of item wording and randomly rotated and scrambled item blocks across individual surveys minimized common method bias (Podsakoff et al., 2012).

Sample

The sample consists of 411 German school leaders; 103 participated in the first two waves of measurement, and 308 were subsequently recruited as a refreshment sample for the third wave of measurement. 247 (60.1%) of participants were female, 163 (39.7%) were male, and 0.2% were divers. Most of the school leaders were in the age between 50 and 59 (207, 50.4%), 106 were in the age between 40 to 49 (25.8%), 82 (20%) of the school leaders were 60 years old and above, and only 16 (3.9%) were 39 years old and younger. 91% of the participants worked at public schools, 8.5% at private schools. 15.3% of the school leaders worked at schools located in a town (less than 3000 inhabitants), 25.8% in a village (3000 – 15 000 inhabitants), 34.3% in a small city (15 000—100 000 inhabitants), 18.2% in bigger cities (100 000—1 000 000 inhabitants), and 6.1% in a metropolis (more than 1 000 000 inhabitants). The participants also provided information on the type of school they were leading. Of our sample, 53% worked in primary education, 38.2% at secondary schools, and 8.5% at other schools, including special-needs schools.

Measures

Due to our study's different context and culture, all items from previous investigations were translated and adapted accordingly (see Appendix). **The Open innovation mindset (OIM)** measures four dynamic capabilities of school leaders: openness, creativity, positive attitude toward knowledge sharing and sourcing (KSS), and risk and failure tolerance (R&F). Based on their factor loadings, we carefully selected eight items from Engelsberger et al. (2022) OIM scale to measure openness, creativity, and R&F. Two items measured **openness** ($\omega = 0.771$). An example item was: "I see myself as someone who is original and comes up with new ideas". We used three items each to measure **creativity** ($\omega = 0.858$) and **R&F** ($\omega = 0.646$); an example item of creativity

was: "I often have new and innovative ideas." and an example item of R&F was: "I believe that failure is a necessary part of success". For **KSS** ($\omega = 0.836$), we used three items based on Antons et al. (2017) that measure attitudes toward collecting and sharing knowledge; an example item was "I look for opportunities to exchange with persons having a different knowledge background".

To measure **transformational leadership** ($\omega = 0.688$), we used four items from the Multifactor Leadership Questionnaire (MLQ; (Bass & Avolio, 1995), indicating idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. We modeled the construct unidimensional following Heinitz et al. (2005). An example item was: "I help my schools' teachers to develop their strengths". Following the research on knowledge-oriented leadership (Donate & Sánchez de Pablo, 2015), we used six items to measure **knowledge management** ($\omega = 0.828$) in schools by investigating knowledge transfer practices during the last 12 months. An example item is: "Self-organized groups existed at the school in which teachers could learn from each other and exchange knowledge, e.g. communities of practice". Answers for all the above items were given on a unipolar verbal Likert rating scale to measure the intensity of specific characteristics, going from 1: fully disagree to 4: fully agree.

The model's dependent variable, **digital innovation**, was measured by a multi-step procedure based on the European Community Innovation Survey (Behrens et al., 2017). To avoid misconceptions when measuring innovation, we initially defined the term. Accordingly, innovations are new to the schools' pedagogical work but can be known and established in the educational sector (OECD/Eurostat, 2018). First, the participants answered on a binary-coded variable (0= no, innovations have not been introduced; 1= yes, innovations have been introduced) if they introduced any process innovation in the schools within the last 12 months; "Have any process innovations been introduced at your school in the last 12 months?". Second, the respondents named the top three innovations in open fields. Third, the participants ordered those innovations based on relevance and the extent of the innovations' value within their school. Fourth, the notified innovations were rated regarding their incremental or radical nature on a scale from 1 (incremental innovation- improving, supplementing, or adapting existing strategies) to 10 (radical innovation- implementing something entirely new for the school). 78.8% of the schools introduced any innovation, 19.2% did not introduce innovations, and two percent of answers were missing.

For our analyses, we binary-coded the open-ended responses from step two (0= no digital innovation, 1= digital innovation), with digital innovation referring to the appropriate use of digital media in teaching and learning. Digital innovations compromised, e.g. the integration of tablets in the classrooms, setting up digital tools for parental involvement, and the creation of virtual classrooms, but mainly followed level 1 (replacement) and level 2 (augmentation) of the substitution augmentation modification redefinition (SAMR) model (Hamilton et al., 2016; Puentedura, 2006). Based on this, we created a variable indicating the radicalness (or disruptiveness) of the digital innovations (1= incremental to 10= radical), with "no digital innovation" coded as 0. Accordingly, the variable we use is a ratio scale that contains an absolute or true zero (Stevens, 1946), indicating the total absence of digital innovations in a given school.

Analytical strategy

We used structural equation modeling (SEM) to examine our hypotheses. We applied Harman's one-factor test to test for common method bias (Harman, 1960). The total variance extracted by one factor was far below the 50% threshold (15.88%), ensuring no common method bias in our study (Lance et al., 2010). The total of missing data was 1.5%. Data analysis was performed in Mplus version 8.3 (Muthen & Muthen, 2017) using the diagonally weighted least squares estimator (WLSMV) to ensure the assumption of a normal latent distribution of the categorically and ordinally observed data (Brauer et al., 2023).

Before estimating the SEM, construct validation of the measurement models was performed through confirmatory factor analysis (CFA). Regarding the complexity and novelty of the latent

construct OIM in the educational context, we examined its factor structure progressively by computing several CFAs. The procedure allowed us to verify the predicted factor structure, avoid cultural and construct bias, and assess the measurement model for further analyses (J. C. Anderson & Gerbing, 1992).

To evaluate the model's goodness of fit, we used the following fit indices and ranges: standardized root mean square residual (SRMR, <0.08), the root mean square error of approximation (RMSEA, <0.06, 90% CI < 0.06), the comparative fit index (CFI, >0.95), and the standardized factor loadings (Schermelleh-Engel & Moosbrugger, 2003). As we estimated an indirect path model, we further tested the robustness of the mediation effects through bootstrapped mediation analysis that provides 95% bias-corrected bootstrap confidence intervals with 2,000 bootstrap replications (Hayes, 2018; Preacher & Hayes, 2008). Indirect effects are significant if the 95% confidence intervals (CIs) do not include zero (Hayes, 2018).

Results

Table 1 presents the means (*M*), the standard deviation (*SD*), and the correlations of the model variables. The means of the OIM facets show that, among the surveyed school leaders, a positive attitude toward knowledge sharing and sourcing ($M = 3.57$) is stronger pronounced than their openness ($M = 2.99$) and creativity ($M = 3.20$) and their risk and failure tolerance ($M = 2.96$). Furthermore, the correlation matrix shows that the four facets are statistically significantly correlated, underlining that these variables are related and form the OIM. TL is used often by the surveyed school leaders ($M = 3.22$, $SD = .44$). Further, the statistically significant correlations between TL, the OIM facets, and KM indicate a relationship between the constructs (r between .233 and 1.000, $p < .05$). KM is maintained by the school leaders moderately ($M = 2.99$, $SD = .59$) and is the only variable statistically correlated with digital innovation ($r = .171$ $p < 0.05$). Digital innovation has a mean of $M = 3.28$ (SD = 3.77), meaning that the implemented innovations, on average, were rated as incremental rather than radical.

Confirmatory factor analysis

The results of the measurement model estimations are depicted in Table 2. Regarding the OIM, we tested five models: 1. single-factor model; 2. four-factor first-order model; 3. four-factor second-order model; 4. three-factor first-order model; and 5. three-factor second-order model. In models 2 and 3, we followed Engelsberger et al. (2022) and modeled four distinct factors: openness, creativity, KSS, and R&F. However, we found a high correlation between the facet's openness and creativity ($r = 1.00$, $p < .001$), a fact that is well-known from research on personality traits (Karwowski & Lebuda, 2016; King et al., 1996). Consequently, we combined the items of both facets into one factor (OC_G) and tested an alternative first-order (model 4) and a second-order model (model 5). Both models fitted the data equally well (RMSEA= 0.06, CFI= 0.97, SRMR= 0.04); introducing

Table 1. Means, standard deviations and correlations of all variables.

	Variable	M	SD	1	2	3	4	5	6
1	Openness	2.99	.63						
2	Creativity	3.20	.51	**1.000**					
3	KSS	3.57	.41	**0.453**	**0.547**				
4	R&F	2.96	.51	**0.587**	**0.587**	**0.498**			
5	TL	3.22	.44	**0.528**	**0.647**	**0.554**	**0.576**		
6	KM	2.99	.59	**0.295**	**0.352**	**0.287**	**0.233**	**0.435**	
7	Innovation	3.28	3.77	−0.031	−0.037	0.063	0.010	0.021	**0.171**

Note: KSS = Positive Attitude Toward Knowledge Sharing and Sourcing, R&F = Risk and Failure Tolerance, TL = Transformational Leadership, KM = Knowledge Management, bold correlations statistically significant at least at $p < 0.05$.

Table 2. Model fit indices.

Model	CFI	SRMR	RMSEA
1. OIM Single-factor model	0.87	0.10	0.15
2. OIM Four-factor model	0.97	0.04	0.06
3. OIM Four-factor second-order model	0.97	0.05	0.07
4. OIM Three-factor first-order model	0.97	0.04	0.06
5. OIM Three-factor second-order model	0.97	0.04	0.06
6. TL Single-factor model	1.00	0.01	0.00
7. KM Single-factor model	0.97	0.03	0.08

Note: OIM = Open Innovation Mindset, TL = Transformational Leadership, KM = Knowledge Management.

Table 3. Standardized direct effects.

Direct effects	β	SE	*p*
OC_G → TL	0.362	0.095	0.000
KSS → TL	0.297	0.094	0.002
R&F → TL	0.204	0.104	0.050
TL → Digital Innovation	−0.096	0.075	0.201
TL → KM	0.476	0.059	0.000
KM → Digital Innovation	0.216	0.074	0.003

Note: OC_G = Openness&Creativity, KSS = Positive Attitude Toward Knowledge Sharing and Sourcing, R&F = Risk and Failure Tolerance, TL = Transformational Leadership, KM = Knowledge Management.

Table 4. Standardized indirect effects.

Indirect Effects	β	95% CI	SE	*p*
TL → KM → Digital Innovation	0.103	0.032 – 0.198	0.041	0.012
OC_G → TL → KM → Digital Innovation	0.037	0.010 – 0.078	0.019	0.045
KSS → TL → KM → Digital Innovation	0.031	0.009 – 0.076	0.016	0.059
R&F → TL → KM → Digital Innovation	0.021	0.003 – 0.062	0.015	0.172

Note: OC_G = Openness&Creativity, KSS = Positive Attitude Toward Knowledge Sharing and Sourcing, R&F = Risk and Failure Tolerance, TL = Transformational Leadership, KM = Knowledge Management.

a second-order factor did not improve the measurement model, so we followed Marsh et al. (2014) and rejected model 5. The fit indices of KM (RMSEA= 0.08, CFI= 0.97, SRMR= 0.03) and TL (RMSEA= 0.00, CFI= 1.00, SRMR= 0.01) approved a good measurement quality (Table 2).

In the next step, we tested the conceptual model by estimating the SEM. The fit indices of the structural model confirmed a moderate but acceptable fit to the data ($\chi 2 = 315.403$, $df = 199$, RMSEA= 0.04, CFI= 0.98, SRMR= 0.05). The standardized direct effects are listed in Table 3, and the indirect effects in Table 4.

As all OIM facets positively impact TL (OC_G on TL: $\beta = 0.369$, SE = 0.098, $p < 0.000$; KSS on TL: $\beta = 0.204$, SE = 0.091, $p < 0.025$; R&F on TL: $\beta = 0.301$, SE = 0.119, $p < 0.011$), H1 was accepted: school leaders' OIM is an antecedent to their TL behavior. Hypothesis H2 was rejected as TL does not directly affect digital innovation ($\beta = -0.076$, SE = 0.070, $p < 0.280$). However, TL significantly affects KM ($\beta = 0.448$, SE = 0.069, $p < 0.000$), which, in turn, positively impacts digital innovation ($\beta = 0.209$, SE = 0.070, $p < 0.003$). On this behalf, hypotheses H3 and H4 were supported. Even though we could not find a direct relationship between TL and digital innovation, we found evidence for hypothesis H5. R^2 was 0.514 for TL, 0.226 for KM, and 0.036 for digital innovation.

Mediation analysis

The indirect path from TL on digital innovation, mediated by KM, shows a statistically significant effect of $\beta = 0.103$ [95% CI: 0.032 – 0.198]. Besides, the indirect paths revealed statistically significant effects from OC_G *via* TL and KM on digital innovation ($\beta = 0.037$, 95% CI:

0.010 – 0.078), from KSS *via* TL and KM on digital innovation (β = 0.031, 95% CI: 0.009 – 0.076), and from R&F *via* TL and KM on digital innovation (β = 0.021, 95% CI: 0.003 – 0.062). Based on these findings, H6 was accepted. All three dimensions that form the OIM have a statistically significant indirect effect on implementing digital innovation in schools. Implementing digital innovation in schools depends on KM, which relies on school leaders' TL. The OIM functions as an antecedent and necessary capability for TL, positively impacting KM and thus enhancing digital innovation processes in schools.

Discussion

TL and KM are vital for successfully leading digital transformation. Besides, previous research on organizational innovation processes underlines the relevance of leaders' mindsets and all those involved in the transition process to overcome the obstacles to sustainable and integrated developments. Research evidence on school leaders' mindsets and the resulting impact on digital innovation in schools is still scarce. However, theory assumes that the mindset of school leaders is essential for positive educational change (Gallagher & Thordarson, 2018; Hofer et al., 2023) and qualitative research on technology integration in schools highlights the relevance of school leaders as technology leaders who pave the way to schools' digital and technological transformation (Cox & McLeod, 2014; P. M. Davies, 2010; McLeod & Richardson, 2011; Sterrett & Richardson, 2019; Yee, 2000). Accordingly, a risk mindset, fostering a culture of change, strong communication, and professional networks, as well as shared vision-setting were identified as essential leadership behaviors for technology integration (McLeod et al., 2015; Richardson & Sterrett, 2018; Tirri et al., 2021; Yee, 2000).

By transferring the concept of the OIM to the educational context and linking it with TL and KM practices, our study contributes to the research field on schools' digitalization and educational technology leadership. The OIM of school leaders is a dynamic capability, defined as the capacity to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments characterized by deep uncertainty (Bogers et al., 2019). This capability is comprised of three facets: openness and creativity, a positive attitude towards knowledge sharing and sourcing, and risk and failure tolerance.

In line with research findings on the impact of an OIM on innovation outcomes (Engelsberger et al., 2022), our study's results show that school leaders' OIM indirectly positively impacts digital innovation in schools. More precisely, all three facets of the OIM are essential, enabling school leaders to create the conditions for implementing digital innovations. Beyond that, we found that the OIM is a crucial precondition for TL in schools, supporting the idea that such a leadership style promotes collaboration and knowledge transfer within the organization (Dexter & Richardson, 2020) and largely depends on a school leaders' mindset. This finding is in line with previous studies on technology school leaders, who were found to be open to taking risks and engaging others within their organization to develop and test new approaches to technology integration (Hofer et al., 2023; McLeod et al., 2015; Sterrett & Richardson, 2019).

The indirect effect of TL on digital innovation, mediated by KM practices, highlights the complexity of schools' digital transformation processes. This finding is in line with the research of Schmitz et al. (2023), stating that TL distally predicts technology integration but is mediated by certain variables. Moreover, our findings support previous findings on successful technology leadership as a distributed and essentially TL approach (Dexter, 2008; Sheppard & Brown, 2014; Yee, 2000). Furthermore, the implemented digital innovations were predominantly incremental changes on the substitution and augmentation level, functioning as substitutions that generated functional improvements (Hamilton et al., 2016).

On the one hand, our study proves the relevance of KM practices as a mediating variable for implementing digital innovation. On the other hand, our findings support the vital role of TL in overcoming barriers to KM practices (Al-Husseini & Elbeltagi, 2018), which in turn

enhances the success of schools' digital transformation (Alvarenga et al., 2020). Therefore, solely TL does not significantly facilitate digital innovation; instead, it fosters KM practices that create a participative culture of innovation and consequently leads to the implementation of digital innovation. These results reflect the findings of previous studies on technology leadership in education, highlighting the relevance of organizational KM (Ilomäki & Lakkala, 2018; Rismark & Solvberg, 2011) and social networks within and across schools for innovative technology integration (Daly & Finnigan, 2010; Leana, 2011; Liou & Daly, 2018). Furthermore, our findings support the vital role of school leaders as knowledge brokers who span the boundaries between the stakeholders of the learning organization by facilitating, supporting, and visioning technology transformation (Chang et al., 2008; Cox & McLeod, 2014; Richardson et al., 2012; 2019; van Niekerk & Blignaut, 2014).

Limitations

Although our study has provided many insights into the design and organization of schools' digital innovation, it is necessary to note the following limitations. Due to the cross-sectional nature of our data, the results are not generalizable, and causality can only be assumed. As all the participants were German school leaders, neither a comparison to other contexts nor the perceptions of other school stakeholders, e.g. teachers and students, were measured to contrast the self-reports. Considering the relevance of peoples' mindsets for digitalization, it is necessary to assess teachers' and students' mindsets too to develop an extensive strategy for digitalization. Furthermore, measuring the development of school leaders' OIM over time and the resulting impacts on TL, KM, and digital innovations is required. Following the research on measuring personality traits and considering the length of the scale we used to assess the facets (Karwowski & Lebuda, 2016), it is unsurprising that the scales of openness and creativity could not be divided empirically. The low value of the explained variance of the dependent variable indicates the need for further research on impact factors on digital innovation. It is relevant to note, however, that despite this low R^2 and the distal nature of the OIM, significant indirect effects were still observable.

Conclusion and implications

The findings of our study support the assumption that digital transformation processes start with the mindset of the involved people and require a shift in thinking to improve and transform existing paradigms (Kane, 2019; McLeod et al., 2015; McLeod & Richardson, 2011; Richardson & Sterrett, 2018). Concerning the challenges schools face when digitally transforming pedagogical methods, forms of teaching, and leadership and management tools (Schmidt & Tang, 2020), school leaders with a pronounced OIM can address those challenges more fundamentally, facilitating conditions for a participative and knowledge-based digital innovation process.

Whereas school leaders have a central role in navigating schools' digitalization (P. M. Davies, 2010; Dexter, 2008; Håkansson Lindqvist & Pettersson, 2019; McLeod & Richardson, 2011; Vanderlinde et al., 2012), investigating school leaders' OIM as the root of their leadership behavior allows us to derive practical implications for technology leadership practices and school leaders' professionalization. Accordingly, we recommend that professionalization programs emphasize fostering dynamic capabilities, i.e. openness and creativity, KSS, and R&F, thereby strengthening school leaders' OIM and attitudes toward digital innovation and strategic technology integration. As previous research highlighted the complexity of technology leadership (Arafeh, 2015), opportunities to develop mindsets complemented by technology knowledge, skills, and specific leadership approaches are vital to creating holistic, sustainable, and flexible transformations (Hofer et al., 2023).

Furthermore, school leaders must establish a participative culture through TL and KM practices to develop digital innovations strategically interlaced with educational goals. Nevertheless,

digital technologies and their diverse applications in schools' exploration, creation, and communication processes are simultaneously the outcome and source of innovation and should be integral components of school development.

Our research thus adds to the existing evidence on technology leadership in education but also highlights the importance of an according OIM on the part of school leaders: on the one hand, school leaders who are instrumental in integrating technology in schools must be willing to take risks (McLeod et al., 2015; Sterrett & Richardson, 2019), be creative (R. S. Davies & West, 2014), require access to social capital via professional networks (Daly & Finnigan, 2010; Liou & Daly, 2018), and act as knowledge brokers (Richardson et al., 2019). These prerequisites allow them to create visions and take and lead all those involved in a given school on the path to future education (Leana, 2011). Communication and knowledge sharing are the keys to successful technology integration in schools (Cox & McLeod, 2014; Ilomäki & Lakkala, 2018; Rismark & Solvberg, 2011; Sheppard & Brown, 2014).

On the other hand, the integration of technology in schools is regarded as a pivotal educational innovation (Backfisch et al., 2021), with the concept of OI positing that boundaryless knowledge flows are essential for organizations to create and profit from technology (Chesbrough, 2003, 2006; Chesbrough & Bogers, 2014). This necessitates the adoption of an appropriate mindset at all levels of the educational institution (Salampasis et al., 2015) and the implementation of novel leadership and management strategies as dynamic capabilities in technology integration (Bogers et al., 2019).

Our research demonstrates that supplementing the field's existing, predominantly qualitative research with supplementary methodological approaches can be advantageous. In addition to the method employed here, there are other potential avenues. For instance, assessing creativity using deep learning techniques and automated scoring (Sung et al., 2024) vanderli, measuring risk-taking using experiments (Smoleń et al., 2023), or capturing openness to experience with personalized mobile sensing approaches (Mayer & Bryan, 2024). A corresponding multi-method triangulation thus appears to be a logical approach to obtaining more differentiated insights in the future.

Besides, more research is needed to investigate other forms of KM in schools, e.g. knowledge storage, application, and creation, as our study focused on knowledge transfer practices only. Linking those internal KM strategies with the external search strategies of OI and schools' networking (Pietsch, Brown, et al., 2023; Pietsch, Cramer, et al., 2023; Richardson et al., 2019) as well as with the concept of knowledge absorptive capacity (ACAP; Da'as & Qadach, 2020; Lichtenthaler & Lichtenthaler, 2010) could offer relevant insights on how knowledge flows within and across schools are organized and beneficial for their innovation performance and technology integration. Even though we gained essential insights by finding the OIM as an antecedent of TL, intense research is required to specify conditions that support and foster digitalization-related TL leadership in schools.

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Appendix

Items and scales

Innovation outcome

Introduction: We would now like to know whether, and if so, to what extent process innovations, i.e. innovations or changes in the pedagogical work of the school that did not previously exist, have been introduced at your school within the last 12 months.

Measurement of innovativeness

Have any process innovations, i.e. innovations or noticeable changes that affect the pedagogical work of the school, been introduced at your school in the last 12 months?

Item measured on a binary scale (0 = no; 1 = yes).

Measurement of concrete innovations

(If yes) What were the most important innovations in this area in the last 12 months? Please name a maximum of three examples, ordered by importance!

Free-form fields

Justification of relevance of innovations

(always related to each of the mentioned innovations) Please explain in one sentence why this innovation was important for your school.

Free-form fields

Measurement of innovation radicalness

(always related to each of the mentioned innovations) Are these changes incremental (improving and/or supplementing and/or adapting what already exists) or radical (introducing something completely new) for your school?

Item measured on a ten-point scale (1 = incremental to 10 = radical).

This explanation was shown to the participants throughout the questionnaire block for all questions on innovation: "Process innovations include new or noticeably changed processes with regard to the pedagogical work of the school (e.g. teaching and instruction)."

Open innovation mindset

Base Question: Now we would like to know how you perceive yourself with regard to your own innovativeness, creativity and willingness to take risks. Please answer all the questions quickly and trust your spontaneous judgment. How much do you agree with the following statements?

- I see myself as someone who is original and comes up with new ideas. +
- I see myself as someone who is curious about many different things. +
- I exhibit creativity on the job when given the opportunity to. *
- I often have new and innovative ideas. *
- I come up with creative solutions to problems. *
- I think it's good when other people draw on my knowledge. #
- I think that different knowledge backgrounds may be helpful for the progress of a project. #
- I look for opportunities to exchange with persons having a different knowledge background. #
- My friends would say that I'm a risk taker.!
- I believe that failure is a necessary part of success.!
- I see a mistake as an opportunity to learn.!

+*openness*, *creativity, ! risk and failure tolerance (Engelsberger et al., 2022), *#positive attitude toward knowledge sharing and sourcing* (Antons et al., 2017)

All items were measured on a four-point scale (1 = strongly disagree 4 = strongly agree).

Knowledge Management (Knowledge Transfer Practices)

Base Question: In order for (new) knowledge to be sustainably integrated in a school, it is helpful to exchange information in a variety of ways. How did knowledge transfer take place within the school in the last 12 months?

- Information technologies (internet, intranet, e-mail, etc.) were used in order to encourage information flows and improve communication among teachers.
- The school's objectives and goals were clearly communicated repeatedly to all teachers.
- There were frequent, well-distributed internal reports that informed teachers about the schools' developments.
- There were formal mechanisms that guaranteed best practices to be shared in the school (e.g., between subjects, grades, or departments).
- There were projects involving interdisciplinary teams or working groups to share knowledge.
- Self-organized groups existed at the school in which teachers could learn from each other and exchange knowledge, e.g., communities of practice.

All items were measured on a four-point scale (1 = strongly disagree 5 = strongly agree) (Donate & Sánchez de Pablo, 2015).

Transformational leadership

Base Question: Now we would like to know something about your leadership behavior. For this purpose, statements that describe you as a leader are listed below. Please answer all questions quickly and trust your spontaneous judgment. How do you assess yourself in your current leadership role?

- I talk optimistically about the future.
- I seek different perspectives when solving problems.
- I talk with teachers about their most important values and beliefs.
- I help my schools' teachers to develop their strengths.

All items were measured on a four-point scale (1 = very rarely or never to 4 = very often) (MLQ; Bass & Avolio, 1995).

2. Research Article: Not invented here, not shared here: How school leaders' attitudes towards external knowledge affect collaborative innovation and collective teacher innovativeness in Germany

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Not invented here, not shared here: How school leaders' attitudes towards external knowledge affect collaborative innovation and collective teacher innovativeness in Germany

Jasmin Witthöft, Burak Aydin, and Marcus Pietsch

Abstract

Teacher innovativeness and pedagogical knowledge are crucial for sustainable development and implementation of innovation initiatives in schools. Although schools often lack resources and capabilities to innovate, external knowledge sources can essentially enrich their innovation processes. How external knowledge is valued, acquired and used depends on individual attitudes, organisational absorptive capacities and knowledge management. Therefore, school leaders are considered crucial knowledge brokers and facilitators who foster innovation. This study explores the impact of external knowledge sources on collective teacher innovativeness, mediated by schools' pedagogical absorptive capacity, and school leaders' knowledge-sharing practices and not-invented-here syndrome. A random sample of German school leaders was analysed through structural equation modelling, mediation analysis and latent moderated structural equation modelling. The results indicate that pedagogical knowledge absorptive capacity is vital for schools to ensure that they benefit from external knowledge sources. School leaders' not-invented-here syndrome and effective knowledge-sharing are significant antecedents of collective teacher innovativeness. Fostering school leaders' openness towards external knowledge, schools' absorptive capacities and developing strategic knowledge-sharing practices are essential for enhancing teacher innovativeness and developing innovative teaching practices.

Keywords

Not-invented-here syndrome, absorptive capacity, knowledge-sharing, collective teacher innovativeness, school innovation, school leadership

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Introduction

Innovations in schools aim to enhance the quality of teaching and learning and support schools in processes of change when adapting to societal developments (Blömeke et al., 2021; Nguyen et al., 2021; Serdyukov, 2017). Previous research on school effectiveness and improvement has investigated the factors that impact the development and implementation of innovation strategies in education, highlighting the fundamental role of collaborative innovation and teachers' collective innovativeness (TI) (Anderson and West, 1998; Fullan, 2016). At the level of individuals, factors such as attitudes, values, competencies and openness to change determine the successful implementation of innovations (McGeown, 1980). Perceived impracticability, conflicts with existing knowledge and poor knowledge management can easily lead to stakeholders' resistance and rejection of innovation processes (Rahmat, 2020). Furthermore, the development of effective and innovative teaching and learning solutions designed to cater to students' needs depends on teachers' general pedagogical knowledge (GPK) and pedagogical content knowledge (Fenstermacher, 1994; Shulman, 1987). Since various individual and contextual factors influence teachers' existing knowledge, their collective participation in knowledge exchange and acquisition of new knowledge is required to continuously extend their GPK (Garet et al., 2001; Shulman, 1986). Beyond that, professional learning opportunities and development, as well as an innovative school climate, are essential antecedents that foster TI (Blömeke et al., 2021; OECD, 2019).

Hence, as knowledge brokers, change facilitators and policy implementers, school leaders must effectively explore and lead knowledge-sharing (KS) initiatives or processes (Anderson and Weiner, 2023; Benoliel and Schechter, 2017). Especially, the implementation of reforms requires a coherent understanding of all stakeholders and needs adjustment to the schools' preferences (Bros and Schechter, 2022; Fullan and Quinn, 2015). Knowledge of leading change processes regarding broader educational contexts is fundamental for school leaders to ensure the success and sustainability of reforms (Acton, 2021). On the one hand, they must explore and identify valuable external knowledge sources for their schools (Polatcan et al., 2024; Zainal and Mohd Matore, 2021). On the other hand, they must establish a culture of innovation and trust within their schools, thus facilitating KS, professional learning and increasing teachers' encouragement (Buske, 2018; Dedering and Pietsch, 2023). Despite the extensive discourse on the significance of TI and GPK, research on the dynamic processes and capabilities that are required to access and utilise external knowledge successfully remains scarce.

In other fields of research, knowledge is emphasised as one of the most critical resources for innovation (Cohen and Levinthal, 1990; Grant, 1996; Pereira and Bamel, 2021). From the knowledge-based view (KBV), organisational development, performance, success and innovation are the result of effective knowledge production and transfer (Kaplan et al., 2001; Low and Ho, 2016). As valuable knowledge and resources are often widely dispersed (West et al., 2008), benefitting from existing and novel knowledge requires specific capabilities and integration and coordination systems, which can reduce absorption and integration boundaries (Figure 1) (Kaplan et al., 2001; Pereira and Bamel, 2021). Da'as and Qadach (2019) and Da'as et al. (2020) emphasised school leaders' importance in facilitating teachers' acquisition of external knowledge while promoting internal learning processes and highlighted that a school's absorptive capacity (ACAP) plays a decisive role in this interplay. Cohen and Levinthal (1990) mentioned that ACAP enables individuals and organisations to recognise, assimilate, transform and purposively apply new knowledge. ACAP is domain-specific, which means that different capabilities are required to absorb and integrate knowledge from various fields (Schweisfurth and Raasch, 2018). The acquisition and

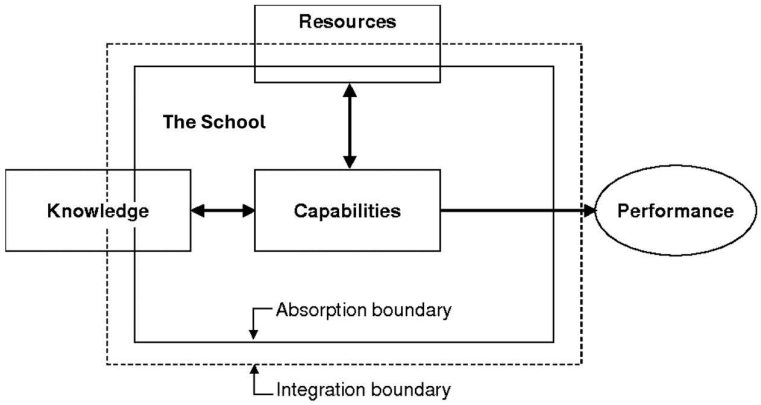

Figure 1. Theoretical concept of knowledge creation from the knowledge-based view (KBV) Adapted from Kaplan et al. (2001).

utilisation of novel pedagogical knowledge necessitate a specific form of ACAP, namely pedagogical knowledge ACAP (PACAP). Furthermore, ACAP, strategic knowledge management and the creation of a collaborative and trustful innovation climate are essential to overcome barriers to knowledge exchange (Lichtenthaler and Ernst, 2006; Mehrwald, 1999). Individuals' attitudes and beliefs primarily influence the course of their knowledge processes (Lowik et al., 2017). A negative attitude towards external knowledge, such as the not-invented-here syndrome (NIH), can hinder knowledge exchange and acquisition (Antons and Piller, 2015; Lichtenthaler and Ernst, 2006). This study aims to analyse collaborative innovation processes in schools from a KBV while considering school leaders and their openness to external knowledge as facilitators of knowledge exchange and TI. The following research question guided our research: To what extent does school leaders' NIH affect collaborative innovation and TI in schools?

Theoretical background

Collective teacher innovativeness

TI is a critical component and resource to transform schools, enable prosperous innovation processes and enhance creativity (Anderson and West, 1998; Nguyen et al., 2021). TI is defined as teachers' receptivity, openness and willingness to embrace change (Fullan, 2016) and their internalisation of innovative changes and active participation in change-related activities (McGeown, 1980). At the individual level, it refers to an individual's openness and readiness for change (Mazman Akar, 2019), and at the collective level, it refers to teams' or organisations' capabilities to change (Buske, 2018). Collective TI includes collaborative and collective endeavours and consciousness of an organisation's employees towards shared visions and goals (Buyukgoze et al., 2024).

Following Dedering and Pietsch, collective TI can be defined as 'an organisational climate characteristic for assessing teachers' collective innovativeness at the school level', as expressed by the school leaders' perceived working climate and innovativeness of their team of teachers. Thus, TI is a characteristic of psychological and organisational climate (Blömeke et al., 2021).

Collective TI is influenced by teachers' perceptions, attitudes and participation in professional learning (Blömeke et al., 2021; Buyukgoze et al., 2024; Nguyen et al., 2021). According to KBV theory and research on the impact of teachers' pedagogical knowledge, continuous knowledge acquisition and exchange are crucial for innovative teaching practices (Fenstermacher, 1994; König and Pflanzl, 2016; Low and Ho, 2016; Vanderlinde and van Braak, 2010). At the organisational level, an innovative and collaborative school climate positively supports TI, enhancing teachers' practices, network activities and perceptions regarding the schools' openness and risk tolerance (Nguyen et al., 2021). Thus, school leaders' knowledge management and leadership style impact conditions that foster collective TI (Buske, 2018; Buyukgoze et al., 2024; Dedering and Pietsch, 2023).

External knowledge sourcing for innovation

External knowledge sources are key for developing new ideas and driving innovation (Bogers et al., 2019; Brunswicker and Vanhaverbeke, 2015), as solely inward-oriented innovation leaves valuable knowledge and ideas unexploited (Chesbrough, 2012). Active exchange and purpose-driven use of knowledge in- and outflows accelerate organisational innovation (Chesbrough et al., 2006).

Schools are knowledge-creating organisations that are expected to adapt and develop continuously; they need 'a strong awareness of the external environment, including opportunities (…) and pressures (…), and a capacity to recognise, assimilate and exploit external knowledge' (Hargreaves, 1999: 126). However, schools predominantly rely on internal sources within their innovation processes (Pietsch et al., 2023a), facing knowledge management challenges within and across school borders and lacking the capabilities and resources that enable autonomous innovation (Asad et al., 2022). Nevertheless, several studies have pointed to the benefits of broad knowledge exchange and sourcing in education. On the one hand, the strategic mobilisation of knowledge allows the creation and targeted use of knowledge (Harris, 2008) and the development of professional networks that increase motivation to change and improve teaching practices (Brown, 2023). On the other hand, external knowledge sources that are systematically linked to internal knowledge significantly predict school innovations (Pietsch et al., 2023b).

From the perspective of teachers' GPK, the value of external knowledge is also evident. GPK is defined as 'the broad principles and strategies of classroom management and organisation that appear to transcend subject matter' (Shulman, 1987: 8), allowing teachers to effectively manage instructional processes and students' learning, motivation and development (Leijen et al., 2022). GPK is initially developed and acquired by an individual during university studies and practical school training; however, it undergoes refinement mainly through self-reflection and experimentation during the later stages of an individual's career (König and Pflanzl, 2016; Weyers et al., 2024). However, pedagogical knowledge needs to be constantly in the current state of knowledge to enable innovative teaching practices in dynamic contexts (Levin et al., 2013). Thus, professional learning communities, intense cooperation with external knowledge partners and context-specific applicability of new knowledge are essential conditions to foster GPK (Vanderlinde and van Braak, 2010). However, the diverse nature of external knowledge sourcing provides access to various knowledge domains and stakeholders through collaboration and networks (Brunswicker and Vanhaverbeke, 2015); hence, environmental circumstances, opportunities, individual experiences and attitudes towards KS across organisational boundaries affect the initiation and implementation of external search strategies (Chesbrough, 2017; Cohen and Levinthal, 1990).

Absorptive capacity

Advantaging from external knowledge sources requires recognition and valuation of new external knowledge and its assimilation and purposive application (Cohen and Levinthal, 1990). These capabilities are called absorptive capacity (ACAP) and are critical to access external knowledge for internal change, knowledge-creation and innovation processes (Schweisfurth and Raasch, 2018; Teece et al., 1997). ACAP combines the following dynamic capabilities: (1) recognition, referring to searching and evaluating the opportunities of external knowledge; (2) assimilation: adapting acquired knowledge to organisational contexts; (3) transformation: combining acquired knowledge with prior knowledge and (4) exploitation: internalising new knowledge in routines and structures (Lowik et al., 2017).

Zahra and George (2002) further emphasised that ACAP is embedded in organisational routines and processes. They also differentiated between potential ACAP, which encompasses knowledge acquisition and assimilation capabilities and realised ACAP, which encompasses transforming and exploiting acquired knowledge. Knowledge acquisition refers to identifying and acquiring externally generated knowledge. Notably, these two forms of ACAP are complementary, and organisations that lack capabilities in terms of either potential or realised ACAP face substantial difficulties in improving their performance (Zahra and George, 2002). ACAP exists at two levels: the individual level that pertains to individuals' skills, knowledge, experiences, commitment and mental models that influence knowledge assessment and the organisational level that encompasses the available expertise and capabilities and established routines and processes within the organisation (Lane et al., 2006; Tutida et al., 2023; Zahra and George, 2002). In general, organisational ACAP depends on individuals' abilities and is leveraged through organisational structures and routines (Cohen and Levinthal, 1990; Todorova and Durisin, 2007). According to dynamic model designed by Todorova and Durisin (2007) (Figure 2), ACAP depends on several factors. First, knowledge recognition and acquisition rely on valuing new knowledge sources, existing knowledge and previous experiences. In this context, they mention feedback loops as an essential aspect of the dynamic concept of ACAP, as 'future absorptive capacity is determined by the current absorption of new knowledge [...]' (Todorova and Durisin, 2007: 783). Second, powerful relationships and key stakeholders are necessary for valuing new knowledge before it can be acquired and utilised for an innovative outcome. Third, all dynamic capabilities of ACAP are framed by social integration mechanisms that are expected to influence social interactions and, thereby, all processes of ACAP within organisations (Zahra and George, 2002). Hence, the valuation and acquisition of external knowledge can be considered to affect schools' PACAP and thereby TI.

This study specifically explores schools' PACAP and its impact on TI. Different knowledge types and prior knowledge in specific domains require distinct ACAP types (Schweisfurth and Raasch, 2018). Further, Lane et al. (2006) outlined the impact of specific characteristics, tacitness and the complexity of knowledge that affect its absorption and assimilation. Pedagogical knowledge is a specific type of knowledge that exists at the organisational and individual levels in schools. Therefore, the absorption and utilisation of new external pedagogical knowledge rely on specific ACAP and prior pedagogical knowledge. According to the definition of GPK by Shulman (1987), PACAP refers to schools' capacity to recognise, assimilate and apply new pedagogical knowledge to improve teaching practices. Schools with high PACAP are actively searching for external pedagogical knowledge and translating and applying it to innovative teaching practices.

The impact of ACAP on various organisational factors and employees' innovativeness has been investigated intensively (Kang and Lee, 2017; Schweisfurth and Raasch, 2018). However, research

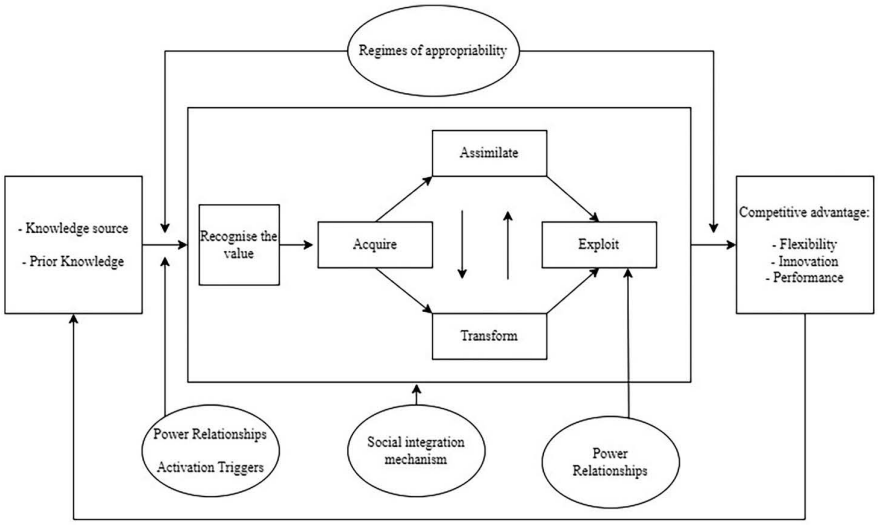

Figure 2. Theoretical model of absorptive capacity (Todorova and Durisin, 2007).

in educational contexts remains scarce (Da'as and Qadach, 2019; Tutida et al., 2023) and highlights that schools with high ACAP are expected to successfully implement educational reforms, exploit acquired knowledge and utilise it through improved and effective teaching practices (Da'as and Qadach, 2019). Furthermore, teachers' internally existing knowledge and skills, active opportunities to engage in knowledge transfer, sense-making processes and active interaction with the environment are predictors of effective ACAP (Zuckerman et al., 2018). Consequently, these factors are likely conducive to sustainably developing PACAP in schools.

H1: External knowledge positively affects schools' PACAP.
H2: PACAP positively affects TI.
H2a: PACAP mediates the effect between external knowledge and TI.

The roles of school leaders and KS in schools

School leadership is imperative for organisational learning (Stoll and Kools, 2017) and educational innovation (Bryk, 2010; Kovačević and Hallinger, 2019). Its contribution to school development and student learning has been extensively studied (Hallinger, 2011; Leithwood, 2021). By acting in dynamic contexts, school leaders influence and are influenced by several organisational factors (Hallinger, 2011). Larger school contexts, cultures and policies impact school leaders' roles and possibilities. Their responsibilities develop with policy changes and reform strategies (Acton, 2021; Bros and Schechter, 2022; Mincu, 2022). Especially when implementing policies, school leaders have to interpret and frame the policy messages, communicate them to their staff and lead the implementation process (Bros and Schechter, 2022; Park and Jeong, 2013). Controversy regarding authorities and reform goals can thereby influence school leaders' capacities and behaviour (Bros and Schechter, 2022). With their behaviour, leadership style and decisions,

they shape circumstances of organisational learning, and thereby affecting teachers' work and students' perceptions and learning (Mulford, 2008). In the background of dynamic school development and continuous improvement, strategic leadership in schools, emphasising KS, engaging staff members and coordinating and supporting development and implementation of innovative ideas is critical (Farrell et al., 2019; Zuckerman et al., 2018). Furthermore, specific leadership behaviours and knowledge management activities affect teachers' professional development, innovativeness, problem-solving abilities and, consequently, schools' successful improvement (Cheng, 2015; Leithwood et al., 2004; Polatcan et al., 2024; Zainal and Mohd Matore, 2021). In particular, disruptive societal changes, e.g. caused by global climate crisis, wars or the fast development of digital media and artificial intelligence, knowledge distribution and continuous capability advancements have become major challenges (Mulford and Silins, 2011; Schechter and Atarchi, 2014). On this behalf, KS is crucial for knowledge creation and practical implementations' development, as it enables access to existing internal knowledge and novel external knowledge (Cummings, 2003; Wiewiora et al., 2013). Although external knowledge absorption and ACAP are influenced by interactions among organisational members (Todorova and Durisin, 2007; Zahra and George, 2002), school leaders are key stakeholders in fostering KS internally and building learning communities within their schools (Fullan, 2002). Some empirical findings support the relevance of organisationally managed KS activities in schools, as they reduce barriers between different stakeholders in the school and allow them to express their knowledge and experiences, thereby fostering creative cooperation and professional learning (Asad et al., 2022; Rismark and Solvberg, 2011). KS can be considered a social integration mechanism managed by school leaders that fosters trustful knowledge transfer, interaction and communication among individuals, leading to a collective outcome (Tortoriello, 2015; Tutida et al., 2023). In other words, school leaders' KS is an essential factor impacting schools' PACAP and moderates the effect of external knowledge on TI.

On the one hand, school leaders are responsible for establishing a collaborative culture and trust, facilitating opportunities for continuous learning and active involvement (Dedering and Pietsch, 2023; Levin and Datnow, 2012). On the other hand, they act as mediators who ensure knowledge creation and exchange within and across the school, as they explore and integrate potentially beneficial external knowledge for the school's development (Benoliel and Schechter, 2017). Accordingly, school leaders are referred to as knowledge brokers who bridge the gaps among various knowledge sources and stakeholders and are accountable for KS and schools' strategic organisational learning (Anderson and Weiner, 2023; Schechter and Qadach, 2016). However, school leaders' knowledge base, personal experiences, characteristics and beliefs are pivotal antecedents that impact their leadership behaviours (Murphy et al., 2006). Effectively leading change in schools demands that school leaders are open and willing to draw on multiple knowledge sources, engage with the broader community and encourage staff to actively engage in school improvement (Fullan, 2010; Holmes et al., 2013; Williams, 2008).

H3: School leaders' KS positively affects PACAP.
H3a: PACAP mediates the effects between school leaders' KS and TI.
H3b: School leaders' KS moderates the relationship between PACAP and TI.

Not-invented-here syndrome

Openness towards inter- and intra-organisational knowledge exchange is vital for enjoying the benefits of knowledge transactions and enabling innovation processes (Lichtenthaler and Ernst, 2006).

Organisational and management structures are essential to facilitate KS; however, social psychology highlights the human aspect as another powerful factor that hinders or supports the acquisition, processing and utilisation of external knowledge (Bohner and Dickel, 2011; Marzi et al., 2023), because individual attitudes, as precursors of knowledge perception, valuation and processing, determine innovative behaviour (Spithoven et al., 2010). One of the most widely mentioned constructs in the knowledge management domain is NIH (Antons and Piller, 2015; Lichtenthaler and Ernst, 2006). According to Antons and Piller (2015), NIH is an individuals' attitude-based bias that stems from negative attitudes towards external knowledge and leads to suboptimal utilisation or rejection of the same (197). This attitude limits external knowledge acquisition and sharing and thus decreases organisational performance (Katz and Allen, 1982). NIH as an attitude is not only an individuals' filter to perceive information and protect individual values, but is also a social phenomenon that changes with social contexts, group dynamics and organisations' ACAP (Burcharth et al., 2014; Lichtenthaler and Ernst, 2006). Threats of organisational identities through external knowledge and a lack of trust may also trigger NIH as a form of protection, e.g. individuals' or divisions' knowledge, roles and responsibilities within an organisation (Hannen et al., 2019; Vanska and Hurmelinna-Laukkanen, 2023). Furthermore, shared social experiences, relationships, values and beliefs within organisations result in a collective interpretation of knowledge and can also lead to biased perceptions and evaluation of useful external knowledge (Burcharth and Fosfuri, 2015). Positive experiences, professional training, socialisation and debiasing practices and dynamic organisational capabilities (i.e. ACAP) have been shown to help overcome NIH and enable innovation through the implementation of knowledge from external sources (Burcharth and Fosfuri, 2015; Cohen and Levinthal, 1990; Hannen et al., 2019; West and Bogers, 2014). Therefore, the effects of NIH on innovative behaviours and innovation outcomes are likely mediated by other organisational factors such as KS and PACAP. Considering the initial definition of ACAP (Cohen and Levinthal, 1990; Todorova and Durisin, 2007), valuing external knowledge is the basis for subsequent acquisition and knowledge-creation processes. Accordingly, higher levels of NIH can either increase or decrease knowledge absorption and sharing processes, thus affecting innovation processes. Hence, drawing on the study by Antons et al. (2017) for measuring NIH, i.e. school leaders' positive attitudes towards external knowledge, the following hypotheses were proposed:

H4: NIH positively affects school leaders' KS and the schools' PACAP.
H4a: NIH positively affects PACAP mediated by KS.
H4b: NIH positively affects TI mediated by KS and PACAP.
H4c: NIH moderates the relationships among school leaders' KS and schools' PACAP, external knowledge and PACAP, as well as among school leaders' KS and TI and schools' PACAP and TI.

NIH has been extensively investigated in many research fields; however, to the best of our knowledge, no research on school leaders' NIH has yet been conducted. This study aims to close this research gap and add to the knowledge base on the antecedents of effective leadership that help bring change in the education sector by investigating the interdependencies among school leaders' KS practices, schools' PACAP and TI (see Figures 3 and 4).

Methodology

Theoretical model

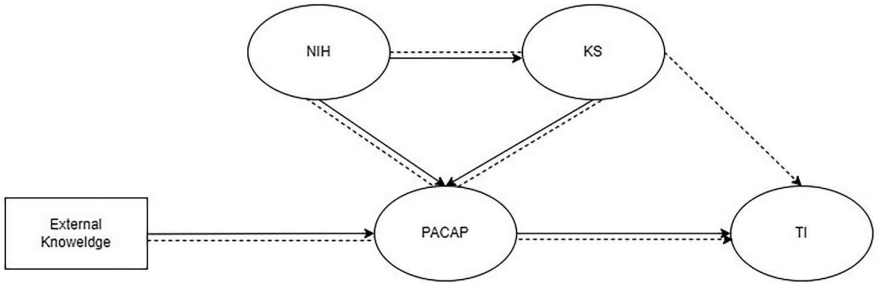

Figure 3. Direct and indirect effects.
Note: Direct linear effects and mediation effects, dotted lines: indirect effects. PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness.

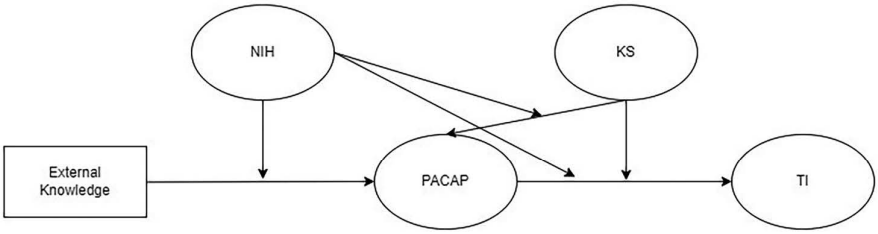

Figure 4. Moderation effects.
Note: Direct linear effects and mediation effects, dotted lines: indirect effects. PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness.

Study context. The study is part of an international project conducted in Austria, Chile, China, Uganda, Germany, Kazakhstan, Kyrgyzstan, Malaysia, Nigeria, Switzerland, Türkiye and Ukraine (e.g. see Özdemir et al., 2024; Pietsch et al., 2025). In this study, data from Germany were analysed.

The decentralised education system in Germany is complex, with varying educational structures. Educational policies are generally developed and implemented by the country's 16 states. Nevertheless, nationwide graduation examination standards and general educational standards have been developed to serve as the basis for curricular development (Tulowitzki et al., 2018). Across all states, school attendance is compulsory. Students aged 6–10 attend primary schools and those aged 11 and older attend secondary schools that were traditionally divided into three types (Hauptschule, Realschule and Gymnasium) and have been recently reformed, including current comprehensive schools (Pietsch et al., 2023b).

Before applying for the position of principal, school leaders require education and experience in teaching. Even though management experience is preferable, formal qualifications, such as a master's degree in educational leadership, are not required (Tulowitzki, 2015). Differences among states exist in terms of leadership responsibilities, decision-making authorities and the teaching mandate of school leaders. School leaders across Germany are expected to continuously develop their schools, programmes, pedagogical work and objectives according to school-specific needs (Brauckmann and Schwarz, 2015). However, school leaders' autonomy and decision-making power remain limited, as most decisions (e.g. organisational structures and resource allocation) are made at the levels of the system or state (Klein, 2017; Pietsch and Tulowitzki, 2017). School leaders are required to find a balance between implementing reform strategies and fostering local innovations, while ensuring that the school runs smoothly (Huber, 2008). Studies on school leaders' exploitation and exploration activities have revealed that German school leaders focus more on exploitive than explorative activities (Pietsch et al., 2022; Röhl et al., 2022). Furthermore, schools rely predominantly on internal knowledge sources to develop innovation (Pietsch et al., 2023b). Consequently, school leaders in Germany focus on maintaining the existing status of the school instead of searching for new knowledge to innovate and are less experienced in innovation strategies, such as open innovation.

Sample. The database of the study is drawn from the Leadership in German Schools study (LineS). Within this longitudinal study, data was collected at three measurements from a random and representative sample of school leaders in Germany (Cramer et al., 2021; Dedering & Pietsch, 2023; Röhl et al., 2022). The following analysis relies on the cross-sectional data from the third measurement, collected from August to November 2021. Following ESOMAR professional standards (see: https://standards.esomar.org/resources/international-codes), participants' data were collected using an online questionnaire allowing random allocations of items, sections, filter questions, question blocks and varying question formats. The variation in item wording, random rotations and scrambling of the item blocks across the survey minimised common method bias (Podsakoff et al., 2012).

The sample consisted of 411 German school leaders, of which 247 (60.1%) were women, 163 (39.7%) were men and 0.2% were diverse. In terms of participants' age, 3.9% were aged 39 or less, 25.8% were aged 40–49, 50.4% were aged 50–59 and 20% were aged 60 or more. Within the sample, 53% of the participants worked at primary schools, 38.2% at secondary schools and 8.5% at other school types (e.g. schools for special educational needs). For more detailed information on the study's context and sample description, see Cramer et al., 2021; Pietsch et al., 2023a; Pietsch et al., 2023b; Witthöft et al., 2024.

Measures

We used five scales from the *LineS* questionnaire, which were translated from English and adapted to the German educational context by following the framework proposed by Hambleton et al. (2004). If not stated differently, responses were collected on a one-to-four-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. All scales and items are provided in the Appendix.

The model's dependent variable, *TI*, was measured by four items from TALIS 2018 (OECD, 2019), as suggested by Anderson and West (1998). For example, an item on the scale was 'Most teachers at my school try to develop new ideas for teaching'. The internal consistency of the scale was reported as McDonald's omega as $\omega = 0.81$.

External knowledge was measured in a two-step procedure. First, the participants were asked whether they had implemented any innovations in their schools in the past 12 months. This binary-coded variable revealed that of all the participants, 78.8% introduced innovations, 19.2% did not introduce any innovations and 2% did not answer. For the following analysis, all values of those who did not answer or did not introduce innovations were coded as 0. Second, a scale, according to Laursen and Salter (2006), which referred to various external sources schools relied on to develop innovations, was presented to those participants who did introduce innovations. The scales' structure consisted of the following item stem: 'The knowledge we used for the innovation came from…' with eight response options (parents/guardians, other schools, authorities/state institutes, universities/other scientific institutions, independent school-improvement consultants, commercial companies, professional training and/or conventions and professional literature) (Pietsch et al., 2023b). The items were measured on a six-point Likert scale ranging from 'not at all' to 'an exceptionally high degree'. External knowledge represented the mean of those variables and had an internal consistency of $\omega = 0.76$.

A scale from Schweisfurth and Raasch (2018) was used to measure the school's *PACAP*. The scale was adapted by addressing the recognition, assimilation and application of new pedagogical knowledge at the school level. The scale was introduced with two explanations: (1) the relevance of adapting effective new knowledge according to teachers' needs and (2) the definition of pedagogical knowledge, which states that 'pedagogical knowledge comprises knowledge about learning and teaching that relates to the organisation of teaching situations and can be applied independently of the subject, i.e. to different subjects and areas of education', as given by Shulman (1986). For example, an item for recognising knowledge was 'We are constantly looking for new pedagogical knowledge to innovate teaching', that for assimilating knowledge was 'We create new ideas for teaching from existing pedagogical knowledge' and that for applying knowledge was 'We constantly consider how we can use new pedagogical knowledge to improve teaching'. The scales' internal consistency was $\omega = 0.85$.

According to Van Den Hooff and Ridder (2004), three items of their knowledge-donating scale measure the models' moderating variable *KS*. For example, an item was 'I share the information I have with the teachers at my school', and the scale's internal consistency was $\omega = 0.75$. The second moderating variable, *NIH*, was measured using three items based on Antons et al. (2017). The applied items measured school leaders' positive attitudes towards external knowledge exchange, sourcing and acquisition. For example, one item was 'I look for opportunities to exchange with persons having a different knowledge background', and the scale's internal consistency was $\omega = 0.72$.

Analytical strategy

The data analysis was performed using Mplus version 8.3 (Muthén and Muthén, 2017), with maximum-likelihood and robust standard error as this estimator is robustness to non-normality (Cheung et al., 2021). First, the descriptive and reliability statistics were estimated, followed by estimating correlations between the model's latent constructs. Confirmatory factor analysis (CFA) was applied to confirm the adequacy of the measurement models. Goodness-of-fit was assessed based on the following fit indices and ranges: standardised root mean square residual (SRMR < 0.08), the comparative fit index (CFI > 0.95) and the standardised factor loadings (>0.4) (Schermelleh-Engel and Moosbrugger, 2003). Root mean square error of approximation was not used for model evaluation, as it is sensitive to the applied method and ordinal indicators (Shi and Maydeu-Olivares, 2020).

Structural equation modelling (SEM) (model A) was then estimated to assess direct effects and the model fit, which served as a baseline model for the following comparative model evaluation because Mplus does not provide conventional fit indices for interaction models (Muthén, 2012). Following the SEM, a mediation analysis (model B) was performed by adding the indirect effects to model A. To obtain the partially standardised results of the mediation effects, the regression coefficients were divided by the standard deviation (*SD*) of the dependent variable *TI* (Preacher and Kelley, 2011). The fully standardised effects of the mediation analysis were estimated by standardising the manifest variable (external knowledge) and fixing the latent variables' (*KS*, *NIH*, *PACAP*) variances to one, which standardised the means of all latent variables to zero with an *SD* of one. The 95% bias-corrected bootstrap confidence intervals (CIs) with 1000 replications were estimated with the maximum-likelihood (ML) estimator to evaluate the robustness of the mediation effects (Hayes, 2018; Preacher and Hayes, 2008). The indirect effects are considered significant if the 95% CI excludes the value of zero (Hayes, 2018).

After testing the moderation effects, latent structural equation modelling (LMS) was applied, following the study by Cheung et al. (2021). To estimate the interaction effects, the commands 'TYPE = RANDOM' and 'ALGORYTHM = INTEGRATION' were added to the Mplus code to request random slopes and numerical integration. The LMS model fit was assessed using the log-likelihood ratio test *D*, which compares the relative fit of the LMS with the fit of the baseline model (model A) and is distributed as χ^2 (Klein and Moosbrugger, 2000; Maslowsky et al., 2015). The change in the R^2 of the two-way interaction model was estimated based on the following: 1 – residual variance of *Y*/Total variance of *Y*. In this way, it was ascertained whether including the latent interactions explained additional variance in the dependent variable (Cheung et al., 2021). The effect size of the significant interaction effects was determined based on Cohen's f^2 (Cohen, 2013; Dawson, 2014).

Statistically significant interaction effects were analysed through a simple slope test with bootstrapping using ML as an estimator. The Johnson–Neyman technique (Johnson and Neyman, 1936) and an Excel file provided by Cheung et al. (2021) were used to plot the unstandardised and standardised results. As all variables were measured using the same instrument, common method bias was assessed by loading all items on a single unrotated factor (Harman, 1960). With a total variance extracted of 25.16%, the threshold of 50% was not exceeded, and a common method bias was rejected.

Results

Descriptive statistics and measurement evaluation

The descriptive statistics and correlations among the models' constructs were based on the observed total scores (Table 1). The mean (*M*) and *SD* of external knowledge showed that schools use external knowledge sources for developing internal innovation to a medium but rather low degree ($M = 2.39$, $SD = 0.67$). The mean value of PACAP ($M = 2.87$, $SD = 0.50$) explained that schools' recognition, assimilation and application of new pedagogical knowledge were moderately pronounced. However, their stronger pronounced KS values ($M = 3.62$, $SD = 0.43$) highlighted that school leaders often share their knowledge, information and new insights with the teachers in their schools. NIH ($M = 3.57$, $SD = 0.41$) represented a predominantly positive attitude towards knowledge sourcing and sharing among the surveyed school leaders.

The correlation matrix indicated that external knowledge statistically significantly correlates with PACAP ($r = 0.251$, $P < 0.001$) and TI ($r = 0.202$, $P < 0.001$). All four constructs were

Table 1. Descriptive statistics.

	Variable	*N*	*M*	*SD*	1	2	3	4	5
1	External knowledge	398	2.39	0.67	1				
2	PACAP	401	2.87	0.50	**0.251**	1			
3	KS	411	3.62	0.43	0.036	**0.315**	1		
4	NIH	410	3.57	0.41	0.097	**0.259**	**0.297**	1	
5	TI	411	3.12	0.48	**0.202**	**0.634**	**0.271**	**0.227**	1

Note: PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness; correlation coefficients: standardised results.
Bold values: significant for $P \leq 0.001$.

Table 2. Direct linear effects.

Model A	β	*b*	*SE*	*P*
External knowledge → PACAP	**0.237**	0.113	0.051	0.000
KS → PACAP	**0.269**	0.419	0.071	0.000
NIH → PACAP	**0.166**	0.206	0.064	0.010
NIH → KS	**0.293**	0.233	0.067	0.000
PACAP → TI	**0.640**	0.527	0.054	0.000

Note: PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness; β: standardised regression coefficient; *b*: unstandardised regression coefficient; SE of standardised regression coefficients.
Bold values: significant for $P < 0.05$.

significantly correlated (r between 0.227 and 0.634, $P < 0.001$); however, the correlation coefficients supported that the applied scales measured distinct constructs.

The CFAs of PACAP and TI confirmed good measurement quality (PACAP: $\chi^2(9) = 49.566$, CFI = 0.974, SRMR = 0.041; TI: $\chi^2(2) = 2.631$, CFI = 0.99, SRMR = 0.028). The CFA of all four model constructs confirmed a good model fit ($\chi^2(98) = 147.222$, CFI = 0.974, SRMR = 0.038). The total variance of the dependent variable TI, based on unstandardised results, was 0.203. All unstandardised factor loadings of the indicators were statistically significant ($P < 0.001$), and the standardised factor loadings exceeded the threshold value of 0.40 (Ford et al., 1986).

Structural equation model

Model A (Table 2) provided a good fit to the data ($\chi^2(115) = 164.267$, CFI = 0.97, SRMR = 0.042), revealing that external knowledge significantly positively impacts PACAP ($\beta = 0.237$, $P < 0.001$). PACAP, in turn, had a significantly positive effect on TI ($\beta = 0.640$, $P < 0.001$). NIH significantly affected PACAP ($\beta = 0.166$, $P < 0.05$) and KS ($\beta = 0.293$, $P < 0.001$). Furthermore, KS had a significantly positive effect on PACAP ($\beta = 0.269$, $P < 0.001$). Accordingly, hypotheses H1–H4 were accepted. Model A accounted for 40.9%, 18.2% and 8.6% of the variance in TI, PACAP and KS, respectively. For the subsequent comparison between models A and C, the model's log-likelihood value (H0 = −4763.028) and the scaling correction factor (1.1336, $df = 53$) were assessed.

Table 3. Mediation analysis.

Model B	*b*	*SE*	*P*	95% CI	Partially standardised	Fully standardised
External knowledge → PACAP → TI	**0.053**	**0.015**	**0.000**	**0.028–0.088**	**0.118**	**0.176**
KS → PACAP → TI	**0.197**	**0.053**	**0.000**	**0.105–0.315**	**0.438**	**0.190**
NIH → PACAP → TI	**0.096**	**0.040**	**0.016**	**0.025–0.186**	**0.212**	**0.122**
NIH → KS → TI	0.021	0.022	0.332	−0.013 to 0.075	0.047	0.027
NIH → KS → PACAP → TI	**0.046**	**0.019**	**0.014**	**0.020–0.090**	**0.102**	**0.059**
NIH → KS → PACAP	**0.095**	**0.037**	**0.009**	**0.040–0.190**	**0.175**	**0.085**

Note: PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness; MLR: maximum-likelihood and robust standard error; ML: maximum-likelihood; 95% CI: 95% confidence interval.

Bold values: significant for $P < 0.05$.

The values of *b*, *SE*, *P*-values, and partially and fully standardised solutions were calculated based on the MLR estimator. 95% CI was calculated based on unstandardised ML estimation. The unstandardised estimates (*b*) were identical in both estimations with MLR and ML.

Mediation analysis

All indirect effects of model B were tested by calculating the indirect effects and total indirect effects. The model fit indices confirmed a good fit to the data ($\chi^2(112) = 170.694$, CFI = 0.97, SRMR = 0.039). The mediation analysis results (Table 3) showed that PACAP mediates the relationship between external knowledge and TI, with a specific indirect effect of $b = 0.053$ ($P < 0.001$, 95% CI [0.028–0.088]). The indirect effect of KS on TI mediated by PACAP was significantly positive ($b = 0.197$, $P < 0.001$, 95% CI [0.105–0.315]), and the indirect effect of NIH on TI mediated by PACAP was significantly positive ($b = 0.096$, $P < 0.05$, 95% CI [0.025–0.186]). Furthermore, the indirect effect of NIH on TI was significant when mediated by KS and PACAP ($b = 0.046$, $P < 0.05$, 95% CI [0.020–0.090]); however, it is not statistically significant when mediated by *KS* ($b = 0.021$, $P = 0.332$, 95% CI [−0.013 to 0.075]). In addition, the analysis revealed that NIH indirectly affected PACAP via KS ($b = 0.095$, $P < 0.005$, 95% CI [0.040–0.190]). Thus, hypotheses H2a, H3a, H4a and H4b were confirmed. The partially- and fully-standardised results are provided in Table 3.

Moderation analysis

The LMS held a log-likelihood value of H0 = −4756.808, a scaling correction factor of 1.1529, $df = 59$. The inclusion of interaction terms in the model significantly increases the model fit $D = 12.44$, $df = 6$, $P < 0.05$. The results of the LMS (Table 4) showed that only the regression coefficient of NIH × PACAP on TI was statistically significant ($b = 0.325$, $P < 0.05$, 95% CI [0.054–0.763]); the standardised coefficients are provided in Table 4. As NIH only moderates the relationship between PACAP and TI, hypothesis H3b was rejected, and H4c was partially supported. With an R^2 of 0.438, the LMS explained 43.8% of the variance in TI. The change in the R^2 from model A to model C (0.438 − 0.409) was 0.029, explaining an additional variance of 2.9% in TI. The effect size of the interaction was Cohen's $f^2 = (0.029/1 - 0.438) = 0.051$, which represented a small effect, as f^2 was greater than 0.02 (Cohen, 2013). The unstandardised effect of PACAP

Table 4. Interaction effects.

Model C	MLR-estimation			ML-estimation				Fully standardised
	b	*SE*	*P*	*b*	*SE*	*P*	95% CI	
KS × NIH → PACAP	−0.354	0.268	0.186	−0.354	0.297	0.234	−0.983 to 0.243	−0.099
External knowledge × NIH → PACAP	0.011	0.074	0.887	0.011	0.075	0.889	−0.126 to 0.169	0.009
KS × PACAP → TI	−0.183	0.145	0.209	−0.183	0.245	0.455	−0.473 to 0.336	−0.089
NIH × PACAP → TI	**0.325**	**0.162**	**0.045**	**0.325**	**0.169**	**0.054**	**0.054–0.763**	**0.201**

Note: PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness; MLR: maximum-likelihood and robust standard error; ML: maximum-likelihood; 95% CI: 95% confidence interval.
Fully standardised solutions were calculated based on the MLR estimator, 95% CI was calculated based on unstandardised ML estimation. The unstandardised estimates (*b*) were identical in both estimations with MLR and ML.
Bold values: significant for $P < 0.05$.

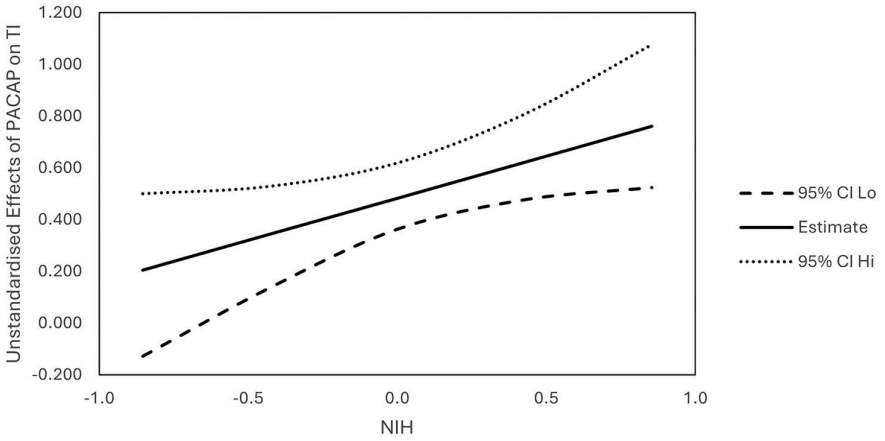

Figure 5. Unstandardised moderation effect.
Note: PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness. Unstandardised effects of PACAP on TI conditional on NIH.

on TI at various levels of NIH is shown in Figure 5, revealing that the effect of PACAP on TI increases with an increase in the level of NIH. Figure 6 shows the standardised effect of PACAP on TI when NIH was at one *SD* above and below the mean.

Discussion

This study investigated the relationship between external knowledge sources and collaborative TI in German schools while examining the impact of school leaders' NIH, PACAP and KS on this relationship. Several main findings can be drawn from these results.

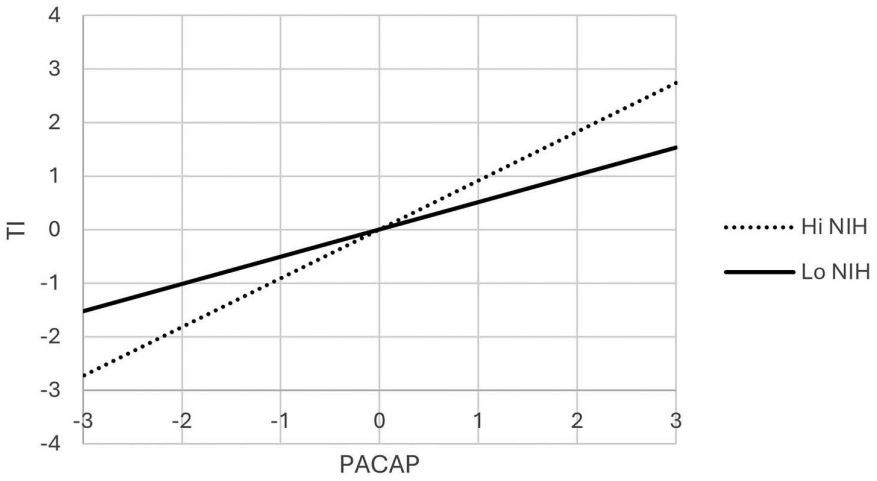

Figure 6. Standardised moderation effects.
Note: PACAP: pedagogical knowledge absorptive capacity; KS: knowledge-sharing; NIH: not-invented-here syndrome; TI: collective teacher innovativeness. Unstandardised effects of PACAP on TI conditional on NIH.

First, schools lacking PACAP are less likely to use external knowledge to increase TI. Organisational PACAP in schools allows collaborative innovation processes and functions as an intermediary to implement external knowledge successfully. Furthermore, PACAP mediates the relationship between school leaders' KS and TI and thus helps manage internal KS. School leaders' KS is necessary to enrich PACAP in schools (Zuckerman et al., 2018). These findings are in line with previous studies that highlighted the crucial role of ACAP in advancing from external knowledge and implementing it to enhance internally available expertise (Cohen and Levinthal, 1990; Lane et al., 2006; Tutida et al., 2023; Zahra and George, 2002).

Second, the results support the idea of school leaders' central role as knowledge brokers who need to ensure staff members' engagement and professionalisation to build learning communities and foster TI (Anderson and Weiner, 2023; Benoliel and Schechter, 2017; Schechter and Qadach, 2016).

Third, direct, indirect and moderating effects of NIH underlined that school leaders' attitudes are pivotal antecedents that impact their leadership behaviours (Murphy et al., 2006). Accordingly, school leaders with a positive attitude towards external knowledge are more likely to build the schools' PACAP, actively share knowledge within the school and enhance TI. These findings highlight the need for school leaders' openness to draw on multiple knowledge sources and engage with the community to lead change effectively (Fullan, 2010; Holmes et al., 2013). In general, NIH is a barrier to external knowledge acquisition, especially in the context of innovation implementation and organisational change (Antons and Piller, 2015). The findings of this study support the impact of individual attitudes towards external knowledge in terms of knowledge creation and collaborative innovation processes (Bohner and Dickel, 2011; Spithoven et al., 2010). Overall, these findings align with those of previous studies, highlighting the facilitating role of school leaders in creating a culture of trust, knowledge exchange and innovation (Dedering and Pietsch, 2023; Hallinger, 2011; Leithwood, 2021; Polatcan et al., 2024). Furthermore, empirical evidence

was observed in terms of the positive effect of schools' PACAP in implementing external knowledge for developing innovation, thus contributing to the research base on ACAP in education (Da'as et al., 2020; Da'as and Qadach, 2019; Zuckerman et al., 2018). Investigating school leaders' NIH opened a new perspective on individuals' unconscious decision biases that impact openness towards external knowledge and innovation processes in education. The positive reverse of the construct allowed us to shed light on the impact of school leaders' positive attitudes towards external knowledge in innovation, proposing positive attitudes and beliefs as a solution to the lack of knowledge exchange in educational settings.

When interpreting these findings, considering the contextual factors of the study is important. The infrequent use of external knowledge sources can result from organisational structures, decision-making policies (Lane and Lubatkin, 1998; Lichtenthaler and Lichtenthaler, 2010; Rezaei-Zadeh and Darwish, 2016), school leaders' limited autonomy in the German educational system and lack of experience in knowledge exploration (Pietsch et al., 2022). Although the school leaders in this study had highly pronounced KS and NIH, contextual factors and highly demanding tasks, such as implementing reform strategies and developing innovations while running the school (Huber, 2008), might hinder the active search for and successful acquisition of external knowledge sources.

Limitations

While this study provides valuable insights into the impact of school leaders' NIH and schools' PACAP on collaborative knowledge creation and TI, the following limitations need to be considered. This study relied on cross-sectional data, which is why causality can only be assumed, and the results are not generalisable. In particular, in the context of growing digitisation, artificial intelligence and easily accessible communication and knowledge exchange channels, longitudinal data could offer crucial insights into the development of knowledge exchange. Furthermore, the analysis was performed based on school leaders' self-reports from Germany only, allowing for no comparison with other stakeholders' perceptions (e.g. teachers, students or other contexts). NIH can lead to serious rejection of knowledge exchange and decreased organisational development and performance (Katz and Allen, 1982); however, investigating all stakeholders' attitudes, their origins/ and the resulting impact on innovativeness within and across schools remains necessary.

Due to the novelty of this study, control variables were not incorporated into the analysis because even valid controls may be endogenous, representing a combination of multiple causal mechanisms (Hünermund and Louw, 2025). Hence, it is recommended that control variables should always be chosen based on theory (Hünermund et al., 2025), with transparent selection processes and rationales (Becker et al., 2016). Furthermore, control variables should be used sparsely in management research (Mändli and Rönkkö, 2025). Bernerth et al. (2018: 131) stated that 'control variable usage in existing leadership studies is rarely grounded in theory but instead frequently relies on outdated misconceptions'. Therefore, this limitation was avoided in the present study. However, the implementation of well-founded theoretical control variables (Hünermund et al., 2025) has the potential to offer a profound understanding of the relationships and varying effects concerning different organisational contexts or individual characteristics and should be given due consideration in future investigations.

Conclusion

The findings of this study provide insights into the complex processes and antecedents required to absorb and utilise external knowledge to enhance collaborative TI successfully. Notably, external

knowledge sources serve as resources for collaborative knowledge creation and increase TI. However, accessing the benefits of knowledge sources depends on schools' capabilities to absorb, transform, adapt and apply new knowledge strategically. Thus, schools' PACAP enables teachers to access and utilise external knowledge to develop innovative teaching practices. As knowledge brokers, school leaders are responsible for facilitating learning opportunities, establishing KS practices and creating a culture of change in their schools (Dedering and Pietsch, 2023; Farrell et al., 2019). Considering these responsibilities and the broader context in which school leaders act, fostering their knowledge on leading change and innovation processes is essential (Acton, 2021; Bros and Schechter, 2022).

By investigating the impact of school leaders' NIH as a potential barrier to knowledge flow and external knowledge absorption, this study adopted a novel perspective on how school leaders' attitudes impact TI. The findings show that school leaders' positive attitudes and beliefs can enhance knowledge acquisition and transfer and increase teachers' opportunities to learn collaboratively in schools. Teachers' collaborative innovation can be strengthened through a responsive culture characterised by school leaders' behaviours. With school leaders as facilitators of learning, a positive culture of KS and sensing affects not only teachers' professionalisation but also students' learning processes (Hallinger, 2011; Leithwood, 2021; Mulford, 2008).

Although implementing external knowledge is essential for constantly developing adequate and innovative teaching and learning opportunities (Pietsch et al., 2023b), several practical and policy implications can be suggested. School leaders and teachers need to be prepared and educated about the impact of negative attitudes, i.e. NIH, on knowledge-creation and innovation processes. To overcome these barriers, their openness to external knowledge and knowledge exchange must be strengthened. School leaders, especially in their facilitating and steering roles (Benoliel and Schechter, 2017; Dedering and Pietsch, 2023), must be open and value external knowledge as a resource for innovation. Professionalisation programmes should address school leaders' responsibility for creating a climate of change and development and the need for organisational KS and transfer to support organisational learning and TI (Anderson and Weiner, 2023; Schechter and Qadach, 2016). An open culture in school communities in which experimentation is supported and failures are accepted can be the basis for overcoming the fear of negative consequences when implementing external knowledge and help school leaders lower the degrees of their NIH, which often has an ego-defensive and self-protective function (Antons and Piller, 2015). In addition, socialisation practices and opportunities to engage in organisational collaborative and creative thinking processes are essential (Burcharth and Fosfuri, 2015). In general, school leaders need to understand the roots and origins of their attitudes, and strategies of cognitive debiasing (e.g. perspective taking) were especially found to effectively mitigate the effects of NIH on innovation processes (Hannen et al., 2019) and could be a helpful strategy for school leaders to change their negative attitudes.

Furthermore, the development of PACAP helps overcome attitude-based biases and enables the implementation of external knowledge; hence, this dynamic capacity needs to be strengthened in educational contexts (Cohen and Levinthal, 1990; West and Bogers, 2014). Moreover, research highlights that building professional autonomy in schools is a prerequisite for success (Caldwell, 2018). Considering the low autonomy of schools in Germany in comparison to other Organisation for Economic Cooperation and Development states (OECD, 2016), increasing school leaders' autonomy and decision-making power could be a first step towards fostering knowledge exploration activities and bottom-up innovation processes. Overall, this study demonstrates the impact of school leaders' attitudes on collaborative knowledge creation and TI, highlighting

the need for their positive attitudes, willingness and openness towards external knowledge sourcing, internal knowledge management and PACAP for utilising and implementing new knowledge in more targeted ways.

Although this study was able to transfer the concept of NIH into the educational context and gain essential insights into school leaders' NIH, the need to extend the research on factors supporting successful pedagogical innovation remains necessary. It would be prudent to adopt models that have been previously developed and empirically tested in other disciplines. Typically, three contingency factors are considered particularly relevant in the context of ACAP (Todorova and Durisin, 2007; Zahra and George, 2002): activation triggers, social integration mechanisms and regimes of appropriability. Future research should investigate the antecedents and conditions that shape the negative attitudes and beliefs of all pedagogical stakeholders while developing strategies that foster positive cultures of knowledge flow. Due to ACAP's domain-specific nature, more research is warranted on various types of ACAP and their impact on collaborative learning and collective innovativeness in schools. In addition, investigating the impact of different leadership styles and cultural phenomena in schools, e.g. distributed or transformational leadership, on different stakeholders' NIH and schools' ACAP can help develop an understanding of how power relationships impact collaborative cultures, knowledge transfer and innovation within and beyond school.

Data availability

To protect the study's participants' privacy, it is impossible to share our data.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval and informed consent

Participants for the study were recruited by the field service provider Forsa (forsa.de), based in Germany. This institute specialises in conducting surveys for research, political and state institutions, as well as private companies. Forsa is a member of ESOMAR (esomar.org). Consequently, the process adhered entirely to the ESOMAR code of ethics. The study was conducted with informed consent and in accordance with the applicable rights under the general data protection regulation. All participants were informed that participation was voluntary and that their anonymised data would be protected in accordance with the legal requirements. Additionally, they were made aware that the survey results might be used for academic publications. All data were fully anonymised by Forsa before being made accessible to the authors.

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Appendix

Items and scales

Measurement of innovation implementation. Introduction: We would now like to know whether, and if so, to what extent process innovations, i.e. innovations or changes in the pedagogical work of the school that did not previously exist, have been introduced at your school within the last 12 months.

Have any process innovations, i.e. innovations or noticeable changes that affect the pedagogical work of the school, been introduced at your school in the last 12 months?

Item measured on a binary scale (0 = no; 1 = yes).

Measurement of external knowledge. Base question: Now we would like to know where the knowledge came from for pedagogical innovations introduced at your school in the last 12 months.

The knowledge that we used for the innovations came…

- …from parents and guardians.
- …from other schools.
- …from school authorities, other authorities or official institutions, e.g. state institutes.
- …from academic institutions, e.g. universities.
- …from freelance or independent school improvement consultants.
- …from commercial enterprises.
- …from professional trainings and/or conventions.
- …from professional literature.

Items measured on a six-point scale (1 = not at all to 6 = to an exceptionally high degree).

Measurement of teacher innovativeness. When you think about the teachers at your school, how much do you agree with the following statements?

- Most teachers at my school try to develop new ideas for teaching.
- Most teachers at my school are open to change.
- Most teachers at my school look for new ways of solving problems.
- Most teachers at my school support each other when implementing new ideas.

Items measured on a four-point scale (1 = strongly disagree; 2 = somewhat disagree; 3 = somewhat agree; 4 = strongly agree).

Measurement of pedagogical absorptive capacity. Introduction:

In order for external knowledge to be effective in a school setting, it must be adapted to align with the institution's requirements and those of its teaching staff. With the increasing adoption of distance learning by numerous schools in recent months, two types of knowledge are particularly

relevant: pedagogical knowledge and information and communication technology (ICT) knowledge.

Definition of pedagogical knowledge:

Pedagogical knowledge comprises knowledge about learning and teaching that relates to the organisation of teaching situations and can be applied independently of the subject, i.e. to different subjects and areas of education.

To what extent does the following apply to your school?

- We are constantly looking for new pedagogical knowledge to innovate teaching.
- We can easily identify the pedagogical knowledge that is particularly important to us.
- We are able to translate new pedagogical knowledge into a language that all members of staff understand.
- We create new ideas for teaching from existing pedagogical knowledge.
- We use newly acquired pedagogical knowledge to rethink teaching.
- We constantly consider how we can use new pedagogical knowledge to improve teaching.

Items measured on a four-point scale (1 = strongly disagree; 2 = somewhat disagree; 3 = somewhat agree; 4 = strongly agree).

Measurement of not-invented-here syndrome. Now, we would like to know how you perceive yourself with regards to your own innovativeness, creativity and willingness to take risks. Please answer all the questions quickly and trust your spontaneous judgment. How much do you agree with the following statements?

- I think it's good when other people draw on my knowledge.
- I think that different knowledge backgrounds may be helpful for the progress of a project.
- I look for opportunities to exchange with persons having a different knowledge background.

Items measured on (1 = strongly disagree; 2 = somewhat disagree; 3 = somewhat agree; 4 = strongly agree).

Measurement of knowledge sharing. Now we would like to find out how the exchange of newly acquired knowledge and information between you and the school's teaching staff is organised. How would you rate the exchange of knowledge between you and the school's teaching staff?

- When I learn something new, I make sure that the teachers at my school know about it.
- I share the information I have with the teachers at my school.
- I share my knowledge with the teachers at my school.

Items measured on a four-point scale (1 = very rarely or never; 2 = rarely; 3 = often; 4 = very often).

3. Research Article: Microfoundations of Open Innovation in Schools: Overcoming Teachers' Not-Invented-Here Syndrome with Transformational Leadership and Leader-Member Exchange

Witthöft, J., Adams, D., Aydin, B., Muniandy, V. & Pietsch, M. (2025). Microfoundations of Open Innovation in Schools: Overcoming Teachers' Not-Invented-Here Syndrome with Transformational Leadership and Leader-Member-Exchange. *School Leadership & Management CSLM*. https://doi.org/10.1080/13632434.2025.2580641

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Microfoundations of open innovation in schools: overcoming teachers' not-invented-here syndrome with transformational leadership and leader-member-exchange

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ABSTRACT

Open innovation (OI) offers new strategies for educational innovation and change. Whereas collective knowledge creation and external knowledge inputs are essential to OI, schools must embrace knowledge sourcing and exchange. Especially leadership and social interactions are key to OI. A microfoundational perspective on OI posits that micro-level organisational actions and interactions mediate macro-level associations. On this behalf, individuals' negative attitudes toward external knowledge, such as the Not Invented Here Syndrome (NIH), can hinder knowledge exchange and disrupt OI. This study uses multilevel structural equation modelling to investigate the microfoundations of OI in schools. Following microfoundational research principles, Coleman's bathtub model is employed to analyse the relationship between transformational leadership (TL), leader-member-exchange (LMX), teachers not invented here syndrome (NIH), and OI. Data from 1,178 Malaysian teachers and 54 school leaders is analysed. The results offer new insights into the underlying social mechanism influencing OI in schools and demonstrate the impact of micro-level interactions. Teachers' NIH and positive teacher-principal relationships (LMX) are pivotal to fostering OI and mitigating NIH.

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Leader-member-exchange; microfoundations; not invented here syndrome; open innovation; transformational leadership

Introduction

Innovation has become a central topic in educational research (Fuad, Musa, and Hashim 2022). Especially in the fast-changing environments of the twenty-first century, schools need to adapt and develop innovations to meet current

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challenges and to ensure adequate and effective teaching and learning (Dedering and Pietsch 2025; Schwabsky, Erdogan, and Tschannen-Moran 2019). As social institutions, schools operate in dynamic contexts and must become adaptive organisations that continuously learn and improve (Adams et al. 2025). Following McGeown (1980), innovation in schools is a 'complex socio-political process, involving the interaction of individual, group, organisational and environmental characteristics and perceived innovation characteristic.' (148–149). Confronted with these complex internal processes and external environments, schools require strategic innovation and knowledge management, which creates the conditions for collaborative knowledge creation (Cheng 2021).

In this regard, Pietsch et al. (2023) adapted the concept of Open Innovation (OI) to the educational context. They found that incorporating external knowledge increases schools' innovations in digital and traditional teaching and learning methods. Originally developed as a new approach to knowledge generation for commercial enterprises to overcome rigid and limited innovation practices (Chesbrough 2003b), OI is characterised by strategically managed knowledge flows that go beyond organisational boundaries and allow external knowledge to get inside and internal knowledge to get outside an organisation (Chesbrough and Bogers 2014). Whereas external knowledge is a crucial source for schools' knowledge creation and can enhance teacher innovativeness (Witthöft, Aydin, and Pietsch 2025), OI in education offers an effective approach to organise knowledge flows for successful innovation.

Recently, the microfoundational conceptualisation of OI has gained relevance in research, aiming to extend the understanding of how a macro-level phenomenon like OI arises from underlying social micro-level mechanisms (Felin and Foss 2006). As leadership and social interactions are key to OI (McGahan et al. 2021), a microfoundational perspective on OI posits that macro-level associations, e.g. between leadership and innovation at the organisational level, are mediated by micro-level processes, interactional and individual components (Coleman 1990; Felin, Foss, and Ployhart 2015). Accordingly, leadership and management that create the context and conditions for interactions and exchange, and positively impact the development of relationships between organisational members, e.g. leader-member-exchange (LMX), are essential (Vermeulen, Kreijns, and Evers 2022). Nonetheless, individuals' characteristics, beliefs and attitudes toward external knowledge, such as the not invented here syndrome (NIH), can influence knowledge exchange and OI (Figure 1) (Burcharth, Knudsen, and Søndergaard 2014; Fernandes et al. 2023).

Although, research on the microfoundations of OI is increasing (Pietsch et al. 2025), little research has been conducted on the social mechanisms in schools and teachers' attitudes influencing the processes of OI in education (Pietsch et al. 2024). However, there is a great amount of research highlighting the impact of principal leadership on teachers' attitudes and behaviour (Gumus, Bulut, and Bellibas 2013; Leithwood and Jantzi 2006). Especially transformational

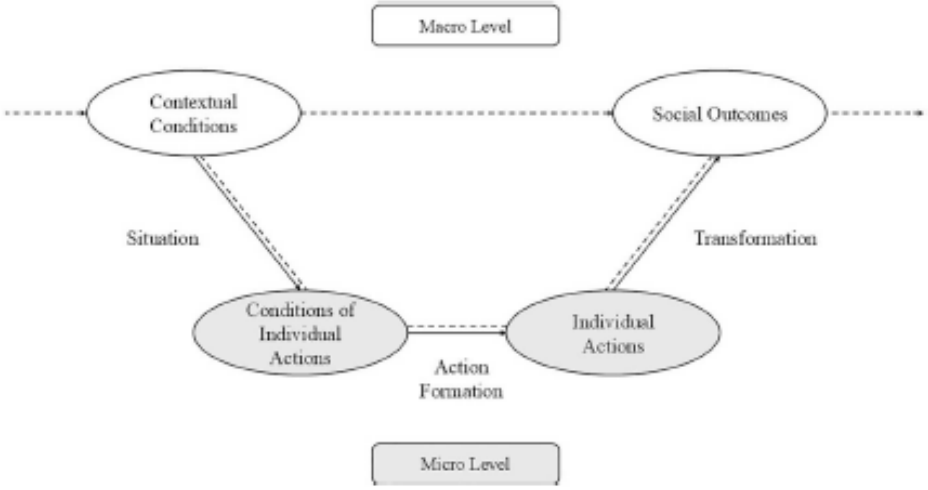

Figure 1. Theoretical model of microfoundations.
Note: Figure is based on Coleman (1990) and adapted from Felin and Foss (2019).

leadership (TL) was found to positively affect teachers' willingness to participate in collaboration and increase teachers' job satisfaction and their capacity for instructional improvement (Bellibaş, Gümüş, and Liu 2021). More generally, TL was found to affect change and innovation processes in education (Hallinger 2003; Khalili 2016), as it enhances a culture of change, professional development, and the quality of relationships (Day, Gu, and Sammons 2016; Vermeulen, Kreijns, and Evers 2022). Furthermore, (Özdemir et al. 2024) found that higher levels of perceived TL enhance teachers' LMX and, consequently, their exploration behaviour. Therefore, TL can be considered an organisational macro-level factor. LMX, on the other hand, functions as a mediator between organisational factors and teachers' innovative behaviour (Ng 2017; Vermeulen, Kreijns, and Evers 2022). At the micro-level, LMX is expected to influence teachers' NIH, which, in turn, triggers OI (Chesbrough 2012; Santoro et al. 2020).

Considering the above, this study aims to address the identified research gap by examining microfoundations of OI in schools. Building on the social theory of microfoundations and employing Coleman's bathtub model (Yantai Chen et al. 2023; Felin & Foss 2006), the study examines the interplay between TL, as a macro-level factor, LMX and teachers' NIH as micro-level factors, and how these dynamics contribute to schools' OI practices. Thereby, this study advances the understanding of underlying social mechanisms that determine OI in education and provides novel insights into diverse factors determining the implementation of OI.

Theoretical background

Open innovation and microfoundations (Social outcome)

OI is known for being the imperative for organising innovation (Bogers et al. 2019). Through 'purposively managed knowledge flows across organisational boundaries

[…]' (Chesbrough and Bogers 2014, 17), innovations can emerge cooperatively despite organisations' limited resources (Chesbrough 2003b). Especially, sustained knowledge flows allow dynamic developments in accordance with changing environments and trends (Bigliardi et al. 2021). OI not only helps to develop new ideas for innovation internally but also paves the way for sharing innovative ideas and making them accessible to others. Therefore, organisations must embrace external inputs and share internal knowledge to maximise potential (Chesbrough 2012). Incorporating external knowledge has been demonstrated to positively influence the implementation of innovations in educational institutions (Pietsch et al. 2024). Conversely, the exclusive reliance on internal knowledge has been shown to be inadequate in ensuring the capacity to respond to social and technological advancements (Pietsch et al. 2023). Thus, OI can be concluded to be 'a lever for change in schools' (Pietsch et al. 2024, 1070).

Research on the antecedents and predictors of OI highlights social interactions and leadership as key to OI. Interactions between different stakeholders foster collective knowledge creation, and specific styles of leadership help leaders to bind communities and foster integration and collaborative relationships (McGahan et al. 2021). Furthermore, leaders have a central role in supporting employees' capability development and fostering their motivation to engage in change processes, as well as developing personal contact and individual ties to increase employees' openness and willingness to contribute to OI (Burcharth, Knudsen, and Søndergaard 2014; Chesbrough 2003a; Lowik, Kraaijenbrink, and Groen 2017; Santoro et al. 2020). Generally, OI emerges in dynamic organisational contexts, and is decisively influenced by individual-level factors, such as mindsets, attitudes, behaviours and motivation (Ahn, Minshall, and Mortara 2018; Slavec Gomezel and Rangus 2019; Xia et al. 2023).

A microfoundational investigation of OI allows to shed further light into the underlying individual – and social interactional factors that aggregate effects and impact macro-level phenomena OI (Aleksić, Rangus, and Slavec Gomezel 2022). Following Felin and Foss, microfoundational research allows to reveal where macro-level factors originate from (Figure 1). Especially organisational contexts and individuals' characteristics define interactions and conditions in organisations and thereby organisational phenomena (Felin et al. 2012). Previous research on the microfoundations of OI stems from outside of educational research and highlights that, employees' capacities to recognise and integrate external knowledge is an essential microfoundation of OI (Santoro et al. 2020). Furthermore, individuals' motivation was found to significantly impact knowledge sharing processes and openness to transfer knowledge and consequently promoting OI (Aleksić, Rangus, and Slavec Gomezel 2022).

The perspective of microfoundations is in line with research findings on the mechanisms of TL. Accordingly, leaders and their leadership behaviour influence followers, who develop and change and consequently enact the

effects of TL at the organisational level (Siangchokyoo, Klinger, and Campion 2020; Yammarino and Dansereau 2011).

Not invented here syndrome (Individual action)

Whereas individuals' capacities to recognise and integrate external knowledge and organisations' openness towards knowledge exchange determine the success of OI (Chesbrough 2012; Santoro et al. 2020), the NIH has been identified as a significant barrier to successful OI (Burcharth, Knudsen, and Søndergaard 2014; Chesbrough 2003a; Lichtenthaler and Ernst 2006).

The NIH is an individual's attitude-based bias stemming from negative attitudes toward knowledge from external sources that leads to an irrational rejection of knowledge despite its potential benefits (Antons and Piller 2015). Following the theory of microfoundations, the NIH can be categorised as an individual-level factor (Felin et al. 2012), functioning as a perception filter to protect or defend individual values and guiding information processing (Antons and Piller 2015; Vanska and Hurmelinna-Laukkanen 2023). Nevertheless, NIH is also a social phenomenon, which is embedded in organisational cultures and develops within structures, group dynamics and social contexts (Burcharth, Knudsen, and Søndergaard 2014; Lichtenthaler and Ernst 2006). On the one hand, organisational beliefs, values, shared experiences, and relationships can lead to a collectively biased interpretation of knowledge (Burcharth and Fosfuri 2015). Consequently, limited external knowledge acquisition and sharing impact organisational-level outcomes (macro-level), e.g. OI (Katz and Allen 1982; Lichtenthaler and Ernst 2006). On the other hand, an organisational context with a culture of knowledge sharing that creates positive experiences, debiasing practices and relationships can effectively help to overcome NIH (Burcharth and Fosfuri 2015; West and Bogers 2014). Furthermore, continuous professionalisation, training and management that foster the development of dynamic capabilities are crucial to successfully implementing external knowledge for innovation (Cohen and Levinthal 1990).

A positively reserved scale following Antons et al. (2017) was applied to assess the NIH measuring teachers' positive attitude towards external knowledge sourcing and sharing within this research study. Considering previous research findings on the NIH as an individuals' attitude that changes within social contexts and relationships and that has a direct impact on individuals' behaviours and, therefore, on organisations' innovation development and implementation, the following hypothesis was developed:

H1: Teachers' NIH positively impacts OI in schools.

Leader-Member-Exchange (Conditions of individual actions)

Interpersonal interactions among employees can influence the development of positive work attitudes and behaviours in organisations (Sparrowe and Liden

2005). These interactions can evolve into relationships through diverse styles and qualities of social exchange (Colquitt et al. 2013; Uhl-Bien et al. 2014). Though empirical research has shown that in these interactions, the leader is often portrayed as an active agent and the employee as a passive participant, their dyadic work-related exchanges can develop into meaningful relationships over time (Götz, Donzallaz, and Jonas 2020). In general terms, LMX refers to the quality of the relationship developed between an employee and their manager through ongoing two-way social interactions (Feng and Adams 2023). However, high quality relationships are characterised by mutual trust and benefits for both parties, whereas low-quality relationships as more formal in nature, marked by high levels of distrust and minimal mutual benefits (G. Graen, Canedo, and Grace 2018). Specifically, employees engaged in high quality exchanges with their superiors are more inclined to show extra-role behaviours as compared to those with low-quality exchanges (Feng & Adams 2023; Mascareño, Rietzschel, and Wisse 2020).

Thus, LMX may shape teachers' characteristics, beliefs and attitudes toward external knowledge, particularly the NIH syndrome. A high-quality relationship with school principals that fosters trust, psychological safety, and a shared commitment to learning can make teachers more willing to adopt knowledge from outside the school. In contrast, when leader – teacher interactions are marked by distrust, teachers are more inclined to reject external knowledge, perceiving it as a threat (G. Graen, Canedo, and Grace 2018). Therefore, LMX can become a key enabler of knowledge exchange in schools (Burcharth, Knudsen, and Søndergaard 2014; Fernandes et al. 2023). Based on the above arguments, the following hypothesis is proposed:

H2: LMX positively affects teachers' NIH.

Transformational leadership (Contextual conditions)

TL is known for being the leadership for change and innovation in various research fields (Choi et al. 2016; Mumford et al. 2002; Ng 2017). In educational research, TL has been investigated intensively and has been found to significantly affect change and innovation processes (Hallinger 2003; Khalili 2016). With a distributed leadership approach, TL aims to enable second-order effects and bottom-up school development processes (Hallinger 2003). Empirical evidence supports that TL positively affects the culture, learning climate and teachers' professional development in schools (Day, Gu, and Sammons 2016; Vermeulen et al. 2015; Vermeulen, Kreijns, and Evers 2022). Fostering capacities, commitment and communication among the school stakeholders are essential characteristics of TL that help achieve organisational goals and visions (Leithwood and Jantzi 2006).

Following the concept of TL (Bass and Riggio 2010), school leaders have a supportive, encouraging and empowering role. They help their followers to

grow and develop individually while engaging in organisational goal achievement and development. At the same time, leaders are role models who are responsible for spanning bridges of knowledge exchange and collaboration and need to be connected with all members of the organisation to communicate the schools' visions and goals (Den Hartog and Belschak 2012; Leithwood and Jantzi 2006; Sauer and Kauffeld 2015). Furthermore, TL is an antecedent of social capital that impacts how relationships within organisations are built (L. Chen et al. 2016). Vermeulen, Kreijns, and Evers (2022) highlight that the organisational climate created through TL increases the perceived quality of relationships between school leaders and teachers, thereby influencing how individuals make sense of situations and how they behave. Özdemir et al. (2024) confirmed the relevance of TL as it leads to greater LMX, which impacts teachers' exploration activities and fosters their social exchange. Following the social theory of microfoundations (Coleman 1990; Felin & Foss 2006), TL can be considered an organisational macro-level condition that influences macro-level outcomes (OI) only indirectly through micro-level factors, such as LMX and teachers' NIH. In this background, hypotheses H3 and H4 were developed:

H3: TL positively affects LMX.

H4: TL indirectly affects OI through LMX and teachers' NIH.

Conceptual model

The conceptual model was developed by combining previous findings on the antecedents and microfoundations of OI and applying Coleman's bathtub model (1990) (Figure 2). With data measured at different levels, a multilevel approach allows the analysis of effects at different levels while considering that individuals are nested in higher organisational collectives (Aguinis and Molina-Azorín 2015). Accordingly, TL, as a macro-level factor, is the starting point for establishing trustful conditions and an innovative school culture. However, relationships and exchange in schools, i.e. LMX and teachers' NIH, are regarded as micro-level factors that are expected to aggregate and impact OI in schools.

Methodology

Sample and data collection

The study was conducted in Malaysia. The Malaysian education system is a highly centralised education system as all aspects of education (e.g. curriculum, budgets, and the hiring of principals and teachers) are managed and regulated by its Ministry of Education (Adams and Tan 2022). School leaders are accorded with autonomy in decision-making in leadership matters such as school improvement, curriculum, and co-curricular planning and the utilisation of school funds (Harris et al. 2017). Meanwhile, teachers are implementers of a

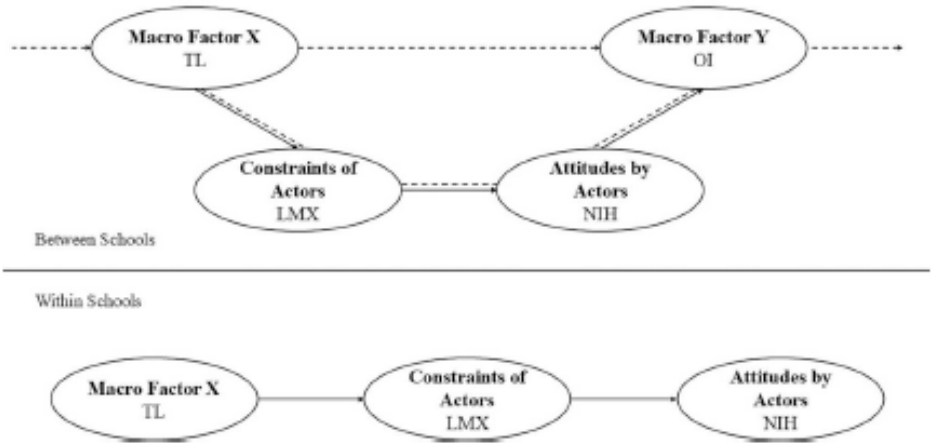

Figure 2. Conceptual model.

Note: TL= *T*ransformational Leadership, LMX= *L*eader-Member-Exchange, NIH= *N*ot Invented Here Syndrome, OI = Open Innovation, figure is based on Coleman (1990).

predetermined curriculum. Malaysia has high ambitions as reflected in its Education Blueprint 2013–2025 (Ministry of Education Malaysia 2012) in which it aims to transform the quality of its education on par to international standards. The blueprints set high targets such as positioning Malaysia within the top one-third of nations in global assessments such as the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA).

A three-stage stratified random sampling procedure was adopted for this study. First, eight states in Malaysia's north, south, eastern, central and western regions were identified. Next, 148 schools within each state were randomly selected to ensure data representativeness. In our study, we followed the best-practice recommendations of Podsakoff et al. (2024) and, hence, collected multi-source data. Thus, in the final stage, teachers and school leaders within these schools were invited to participate in the study. Only teachers who have at least one year of teaching experience were selected as to ensure familiarity with school functions, processes and leadership dynamics. To ensure ethical compliance, permission was obtained from the Ministry of Education to conduct the study. Teachers then consented to participate by answering the survey. The survey administered between February to May 2024. Out of 8736 teachers that were invited to participate, 3016 teachers answered the survey. This resulted in a response rate of 35%. As for demographics, 83.2% ($n = 2508$) were female teachers and the remaining 16.8% ($n = 508$) were male teachers. As for school leaders, 73.2% of the principals were female and 26.8% male; on average, they had held their position for 6.6 years.

For the multilevel analysis, data of school leaders and teachers from the same schools was matched leading to data set with teacher reports ($n = 1,178$) on TL, LMX, and NIH and principal reports ($n = 54$) on OI.

Measures

The variables TL, LMX, and NIH were measured by the teacher questionnaire and the dependent variable OI was measured by the principal questionnaire. To assess teachers' opinions on their school principals TL behaviour, four items covering the dimensions: idealised influence, inspirational motivation, intellectual stimulation, and individualised consideration were used (Avolio and Bass 1991). An example of the scale is: My principal talks optimistically about the future. The answers were given on a four-point Likert scale the from 1; very rarely to never to 4; very often. LMX was measured by an adapted scale based on G. B. Graen and Uhl-Bien (1995), as this scale was proven to being a high-quality measurement to assess LMX in various contexts and cultures (Rockstuhl et al. 2012). By answering seven items, on a five-point Likert scale, teachers provided information on their relationships with their principals. An example item of the scale is: I have enough confidence in my principal that I would defend and justify his or her decision if he or she were not present to do so. With items coded as 1; strongly disagree to 5; strongly agree. Following (Antons et al. 2017), three items were used to measure the models' variable NIH. The scale is positively reversed, accordingly the items measured teachers' positive attitudes towards knowledge sharing and sourcing. An example item of the scale is: I look for opportunities to exchange with persons having a different knowledge background. Answers were given on a four-point Likert scale with 1: strongly disagree to 5: strongly agree. The dependent variable OI was measured in a stepwise procedure. In a filter question school principals were asked if process innovations, i.e. innovations or changes affecting their pedagogical work that did not previously exist at their school, have been introduced in the last 12 months. If they answered with 'yes, have been introduced', a scale with nine items based on Laursen and Salter (2006), referring to the different source and intensity of usage of information for the development of innovation followed: Where did the knowledge come from for pedagogical innovations introduced at your school in the last 12 months? For the following analysis five items were used and rated on a six-point Likert scale, 1; not at all and 6; to an extraordinarily high degree. Two example items are: from the school authorities, other authorities or official institutions, e.g. state institutes; from scientific institutions, e.g. universities. Accordingly, OI refers to the intensity of usage of external knowledge sources, the OI depth (Laursen and Salter 2006). Reliability statistics of all variables can be obtained from Table 2.

Analytical strategy

The present study applied doubly latent multilevel structural equation modelling (DL-MLSEM) as the most complex model following Marsh et al. and Morin, Blais, and Chénard-Poirier (2022). DL-MLSEM allows the assessment of

relations that occur across different levels of analysis while controlling for item-level unreliability, as latent variables are estimated directly at individual-level (L1) and group-level (L2) and are latently aggregated (Morin, Blais, and Chénard-Poirier 2022). The data analysis was performed in Mplus version 8.3 (Muthén and Muthén 2017), with maximum likelihood and robust standard error (MLR) ensuring robustness to nonnormality and nested data structure (Cheung et al. 2021). All variables were centred based on the group (school) to differentiate between within-group and between-group variation.

The descriptive sample statistics mean values (M), standard deviations (SD), and correlations between the latent constructs were calculated across teacher and school-level variables. Previously to the DL-MLSEM, all measurement models of the latent constructs were evaluated through single-level confirmatory factor analysis (CFA) and, if aggregated to L2 in the multilevel analysis, as multilevel-CFA (ML-CFA). Furthermore, ML-CFAs and the DL-MLSEM were set to have measurement isomorphism to allow a meaningful interpretation and direct comparison of the constructs at L1 and L2. Accordingly, the latent constructs have the same measurement structure and factor loadings at both levels (Tay, Woo, and Vermunt 2014). The models' goodness of fit was assessed based on the following fit indices and ranges: standardised root mean square residual (SRMR, < 0.08), the comparative fit index (CFI, > 0.95), and the standardised factor loadings (>0.4) (Kline 2016; Schermelleh-Engel and Moosbrugger 2003).

Due to the small sample size of school leaders (n = 54) and following Hu and Bentler (1999), the RMSEA was not considered, instead a combination of the CFI and SRMR was used to evaluate the model fit. Reliability tests were estimated based on standardised single-level and ML-CFA factor loadings with measurement isomorphism. McDonald's omega coefficients of composite reliability were estimated for the single-level models (ω) and ML models (ωL1, ωL2). Furthermore, two intra-class correlation coefficients were estimated. The ICC1 is used to assess the total variance in ratings at L2, and the ICC2 to assess the reliability of the group aggregate (L2) (Morin, Blais, and Chénard-Poirier 2022). For the within-group agreement of the group-level constructs, the rWG(j) values were estimated (Bliese 2000; James, Demaree, and Wolf 1984). Following Bliese (2000), ICC1 values should exceed .05, and ICC2 values should exceed .70 to ensure that a given construct is a group-level construct. The rWG(j) values were interpreted based on Brown and Hauenstein (2005). Accordingly, values between 0 and .59 suggest an unacceptable level of rater agreement; values between .60 and .69 are weak; values between .70 and .79 are moderate; and values between .80 and .89 are a strong level of rater agreement.

As three of the four scales were administered by teachers, the common method bias was assessed by loading all items on a single unrotated factor (Harman 1960). With a total variance extracted of 18.73%, the threshold of 50% was not exceeded, and a common method bias was rejected.

Results

Descriptive statistics

The descriptive statistics and correlations of the models' variables can be obtained from Table 1. At the teacher level, the mean value of TL was 3.30 (SD = 0.63), and of LMX, M = 3.72 (SD = 0.74), suggesting that teachers perceive TL practices positively, with slightly stronger perceptions reported for LMX. Whereas the mean value of NIH was 3.31 (SD = 0.48), the surveyed teachers' attitudes towards knowledge sharing and sourcing are have positively pronounced. The correlations between the constructs show that LMX and TL were positively related ($r = 0.65$, $p < 0.01$), and that NIH was positively related with TL ($r = 0.34$, $p < 0.01$) and LMX ($r = 0.31$, $p < 0.01$). At the school level, TL (M = 3.29, SD = 0.63) and LMX (M = 3.73, SD = 0.74) were strongly correlated ($r = 0.84$, $p < 0.01$). NIH (M = 3.29, SD = 0.63) was positively correlated with TL ($r = 0.78$, $p < 0.01$) and LMX ($r = 0.91$, $p < 0.01$). Furthermore, the mean value of OI 2.78 (SD = 1.38) suggested that schools moderately engage with external knowledge sources to develop innovation. Even though OI was not statistically correlated with TL and LMX, the correlation between NIH and OI was statistically significant ($r = 0.49$, $p < 0.01$), emphasising the relationship between teachers' positive attitudes towards knowledge sharing and sourcing and utilising external knowledge sources for innovation.

Multilevel structural equation models

Prior to the DL-MLSEM, all latent constructs measured by more than three items were evaluated through CFA. The results of the CFA and ML-CFA indicated a good fit to the data for TL (CFA: CFI = 0.991, SRMR = 0.012; ML-CFA: CFI = 0.976, SRMR within = 0.016, SRMR between = 0.004), and LMX (CFA: CFI = 0.980, SRMR = 0.032; ML-CFA: CFI = 0.968, SRMR within = 0.038, SRMR between = 0.094). The measurement model of OI showed a moderate fit to the data (CFI = 0.908, SRMR = 0.066). Reliability statistics of the constructs at the single – and multilevel can be obtained from Table 2. The omega coefficients support the

Table 1 Descriptive statistics.

Construct	M	SD	1.	2.	3.	4.	5.	6.	7.
Teacher level (L1) (n = 1178)									
1. TL	3.305	0.630	I						
2. LMX	3.728	0.741	**0.654**	I					
3. NIH	3.310	0.482	**0.364**	**0.317**	I				
School level (L2) (n = 54)									
4. TL	3.298	0.630				I			
5. LMX	3.725	0.741				**0.845**	I		
6. NIH	3.308	0.482				**0.786**	**0.912**	I	
7. OI	2.780	1.384				−0.005	0.150	**0.492**	I

Note: *TL = Transformational Leadership; LMX = Leader-Member-Exchange; NIH = Not invented Here Syndrome; OI = Open Innovation; bold = statistically significant at p < 0.01*

Table 2. Reliability information.

Construct	ω	ωL1	ωL2	ICC1	ICC2	rWG(j)
TL	0.95	0.94	0.99	0.12	0.74	0.94
LMX	0.91	0.91	0.99	0.1	0.71	0.91
NIH	0.82	0.81	0.99	0.03	0.40	0.94
OI	0.95	–	–	–	–	–

Note: TL = Transformational Leadership; LMX = Leader-Member-Exchange; NIH = Not invented Here Syndrome; OI = Open Innovation; ω = omega coefficient estimated from a single-level model; ωL1 = omega coefficient estimated at L1 from a multilevel model; ωL2 = omega coefficient at L2 from a multilevel model; ICC1 = intraclass correlation; ICC2 = reliability of unit-level aggregations; rWG(j) = within group agreement for multiple item measures

high reliability of factors across levels and model (ω = 0.82–0.95, ωL1 = 0.81–0.94, and ωL2 = 0.99). The inter-rater agreement, ICC1 and ICC2, showed a sufficient level of between group variance for TL (ICC1 = 0.12, ICC2 = 0.74) and LMX (ICC1 = 0.1, 0.71), yet a lower value of NIH (ICC1 = 0.03, ICC2 = 0.40), indicating that NIH is mainly an individual teacher level construct. However, even minimal group variance (ICC1 = 0.01) can reveal strong group-level relationships (Bliese 1998, 2000). This was also supported by the rWG(j) values ranging from 0.91–0.94, demonstrating high group agreement and reliability.

The model fit indices of the proposed DL-MLSEM (χ^2 = 840.432 (235), p < 0.001, SRMR: within = 0.048, between = 0.095; CFI = 0.960; RMSEA = 0.047) support the model's fit to the data (Kline 2016; Schermelleh-Engel and Moosbrugger 2003). However, due to the relatively small sample size at L2 (n = 54) in conjunction with the low ICC1 of the NIH construct (Lüdtke et al. 2011), convergence problems were observed for the doubly latent approach, i.e. an overestimation of the relationship between NIH and OI at the L2 with the regression coefficient exceeding one (see appendix Table 5). In such cases, the most appropriate approach is to apply partial correction models (Marsh et al., 2009; Morin, Blais, and Chénard-Poirier 2022). Consequently, five alternative models (Doubly Manifest, Manifest-Latent, Latent-Manifest, Manifest-Factor Score, and Latent-Factor Score) were estimated and compared to eliminate possible estimation biases. A detailed description and results of the alternative models is listed in the appendix (Tables 4 and 5). Overall, the Manifest-Factor Score Model (FS-MLSEM) held the best fit to the data (χ^2 = 95.188 (20), p < 0.001, SRMR: within = 0.060; between = 0.052; CFI = 0.927), even though slightly diminished in comparison to the initial DL-MLSEM. However, no issues with unstable estimates or nonconvergence occurred. Accordingly, the results of the FS-MLSEM will be referred to as the final results of the analysis (Table 3). The factor scores (FS) of the FS-MLSEM were estimated based on a single level CFA allowing for control of L1 inter-item measurement errors while preserving the measurement structure of L1 variables (Moris, Blais, and Chénard-Poirier 2022). The L1 constructs were used with a group mean centreing function, L2 constructs as observed score school averages only, and OI, the dependent variable, was modelled

Table 3. Estimates, standard errors and confidence intervals for both models.

	Effects	Coefficient		95% Confidence Interval		*p*-value
		Estimate	SE	Lower	Upper	
Direct effects (within)	TL → LMX	**0.692**	0.020	0.653	0.731	**0.000**
	LMX → NIH	**0.363**	0.029	0.306	0.419	**0.000**
Direct effects (between)	TL→ LMX	**0.802**	0.045	0.714	0.890	**0.000**
	LMX → NIH	**0.718**	0.059	0.603	0.833	**0.000**
	TL → OI	**−0.356**	0.142	−0.633	−0.078	**0.012**
	NIH → OI	**0.578**	0.155	0.275	0.882	**0.000**
Indirect effect	TL → LMX → NIH→ OI	**0.333**	**0.103**	**0.131**	**0.535**	**0.001**

Note: *Model = FS-MLSEM (Factor Score Multilevel Structural Equation Model), TL = Transformational Leadership; LMX = Leader-Member-Exchange; NIH = Not invented Here Syndrome; OI = Open Innovation, SE = Standard Error.*

Table 4. Model fit indices of alternative model specifications.

Model	χ^2 (*df*)	CFI	SRMR within	SRMR between
(A) DL-MLSEM	840.432 (235)	0.960	0.048	0.095
Multiple indicators with latent aggregation				
(B) Doubly Manifest	52.730 (3)	0.929	0.064	0.037
Manifest indicators with manifest aggregation				
(C) Manifest-Latent	85.077 (20)	0.910	0.064	0.053
Manifest indicators with latent aggregation				
(D) Latent-Manifest	618.184 (234)	0.963	0.045	0.334
Multiple indicators with manifest aggregation				
(E) Manifest-FS	95.188 (20)	0.927	0.060	0.052
FS with declared clusters				
(F) Latent-FS	99.835 (20)	0.926	0.071	0.055
FS without declared clusters and latent decomposition				

latently. In the following, the results of the FS-MLSEM are reported. The direct and indirect effects are displayed in Figure 3.

At the individual level, TL as a macro factor variable is a significant predictor of LMX (β = 0.692, 95% CI = 0.653–0.731) and LMX significantly predicts teachers' NIH (β = 0.363, 95% CI = 0.306–0.419). Similar effects were found at the school level, with TL predicting LMX (γ = 0.802, 95% CI = 0.714–0.890) and LMX predicting NIH (γ = 0.718, 95% CI = 0.603–0.833). Furthermore, teachers' NIH significantly positively affects schools' OI as a macro factor (γ = 0.578, 95% CI = 0.275–0.882). Accordingly, hypotheses 1–3 were supported by the data. In contrast, TL was identified as a negative factor influencing the dependent variable OI (γ = − 0.356, 95% CI = −0.633 – − 0.078). However, if TL was mediated by LMX and NIH, the indirect effect on OI was significantly positive (γ = 0.333, 95% CI = 0.131–0.535), supporting hypothesis 4. Consequently, this study reveals the relevance of leader-member-exchange between school leaders and teachers and teachers' NIH, as facilitating microfoundations of OI in schools.

Discussion

This study revealed that OI in schools is a macro-level phenomenon that is influenced by several micro-level factors. The direct negative effect of the

Table 5. Results of alternative model specifications.

		DL-MLSEM Est. [CI]	Doubly Manifest Est. [CI]	Manifest-Latent Est. [CI]	Latent-Manifest Est. [CI]	Manifest-FS Est. [CI]	Latent-FS Est. [CI]
Direct effects within (L1)	TL → LMX	0.656 [.607-0.704] **	0.588 [0.539-0.636] **	0.588 [0.539- 0.636] **	0.658 [0.611-0.706] **	0.692 [0.653- 0.731] **	0.690 [0.650-0.729] **
	LMX → NIH	0.331 [0.264-0.398] **	0.249 [0.187-0.310] **	0.249 [0.187- 0.310] **	0.328 [0.259-0.397] **	0.363 [0.306-0.419] **	0.365 [0.310-0.420] **
Directs effects between (L2)	TL→ LMX	0.875 [0.714-1.037] **	0.744 [0.631-0.857] **	0.744 [0.631- 0.857] **	0.775 [0.633-0.917] **	0.802 [0.714-0.890] **	0.903 [0.810-0.996] **
	LMX→ NIH	0.838 [0.655-1.020] **	0.637 [0.500-0.773] **	0.637 [0.500- 0.773] **	0.699 [0.549- 0.849] **	0.718 [0.603 −0.833] **	0.874 [0.745- 1.004] **
	TL → OI	−0.847 [−1.753-0.058]	−0.293 [−0.546 — 0.040] *	−0.281 [−0.537 − −0.025] *	−0.297 [−0.641-0.048]	−0.356 [−0.633 −0.078] *	−1.018 [−1.890–0.145] *
	NIH → OI	1.095 [0.256-1.935] *	0.531[0.246-0.817] **	0.511 [0.220- 0.802] **	0.561 [0.236-0.886] **	0.578 [0.275-0.882] **	1.239 [0.370- 2.109] *
Indirect effect (L2)	TL → LMX → NIH→ OI	0.803 [−0.008-1.615] *	0.252 [0.087 - 0.416]**	0.242 [0.076- 0.408] **	0.304 [0.080- 0.528] *	0.333 [0.131-0.535] **	0.575 [0.163 - 1.787] *

Note: * $p < 0.05$; ** $p < 0.01$, Est. = standardised coefficient; CI = 95% confidence interval; DL-MLSEM = Doubly Latent Multilevel Structural Equation Model; FS = Factor score, TL = Transformational Leadership; LMX = Leader Member Exchange; NIH = Not invented Here Syndrome; OI = Open Innovation

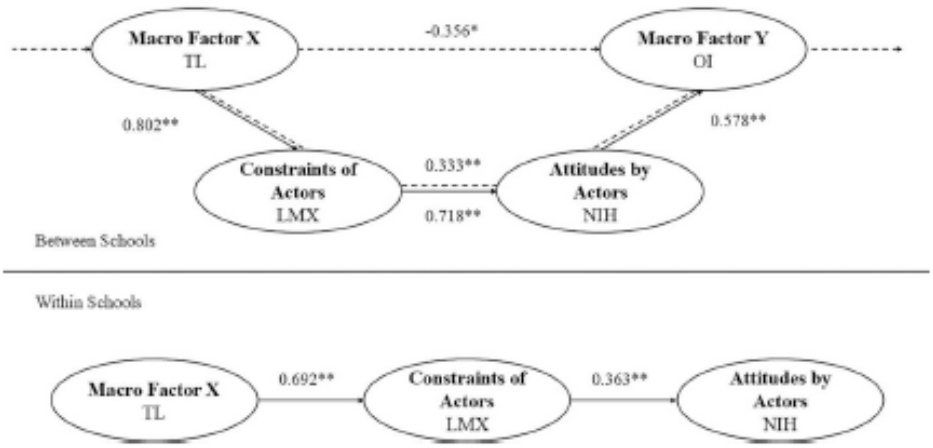

Figure 3. Regression coefficients of FS-MLSEM.

Note: TL= *T*ransformational Leadership; LMX= *L*eader Member Exchange; NIH= *N*ot invented Here Syndrome; OI= *O*pen Innovation; ** $p<0.001$, $p<0.05$.

macro-level factor TL on OI especially shows that solely TL is inadequate for implementing OI. Only when mediated by LMX and teachers' NIH was the effect of TL on OI positive. Like previous research, the negative direct effect reflects the inconsistent impact TL can have on innovation (Rosing, Frese, and Bausch 2011). Diverse organisational factors and individual characteristics impact the effects of TL and can result in negative outcomes (Chen et al. 2018; Rosing, Frese, and Bausch 2011). Thus, this finding highlights the complexity of innovation processes and demonstrates the relevance of including underlying micro-level factors, such as contextual-, individual – and social interactional aspects in the analysis (Aleksić, Rangus, and Slavec Gomezel 2022; Osborn and Marion 2009). Consequently, leading successful innovation processes in schools requires more integrated leadership approaches that address complex contexts and the interconnectedness of diverse stakeholders (Bryk 2010). A promising leadership style that stimulates innovation at different levels in schools could be ambidextrous leadership, which allows the integration of different leadership approaches to transform schools effectively (Pietsch and Mah 2025).

Nevertheless, the positive effect of TL on LMX at the individual and school level, which was revealed in this study, align with research suggesting that TL leads to greater LMX in schools (Özdemir et al., 2024). Accordingly, TL can be considered an essential macro-level factor that positively impacts schools' social capital and creates an organisational climate supporting the development of relationships and exchange between teachers and school leaders (L. Chen et al. 2016; Vermeulen, Kreijns, and Evers 2022). Thus, this study confirmed that TL facilitates change through second order and bottom-up processes (Hallinger 2003).

At the micro-level, the direct positive effect of LMX on teachers' NIH supports the relevance of high-quality relationships and exchange between school leaders and teachers (Götz, Donzallaz, and Jonas 2020; G. Graen, Canedo, and Grace 2018). Especially in the context of school innovation, teachers are one of the main stakeholders who play a fundamental role in collaborative innovation development (Anderson and West 1998; Fullan 2016). On this behalf, their attitudes, values and openness determine processes and the success of innovation (McGeown 1980). In line with Sparrowe and Liden (2005), the effect of LMX on teachers' NIH confirms that interpersonal interactions can influence teachers' attitudes. Thereby LMX is a decisive factor supporting knowledge sharing and exchange and sets a foundation for OI.

Furthermore, this result aligns with research on the NIH, claiming that this individual attitude is a social construct embedded in social structures and changes with organisational cultures and group dynamics (Burcharth, Knudsen, and Søndergaard 2014; Lichtenthaler and Ernst 2006). Whereas shared beliefs, experiences and the collective interpretation of knowledge help debias and overcome individuals' NIH (Burcharth and Fosfuri 2015), it can be concluded that LMX is crucial to overcoming teachers' negative attitudes. Beyond that, teachers' NIH significantly influenced OI at the school level. In previous research, the NIH has been identified as a barrier to OI as it leads to knowledge rejection (Burcharth, Knudsen, and Søndergaard 2014; Chesbrough 2003b; Lichtenthaler and Ernst 2006). However, by reversing the construct positively, this study revealed that teachers' positive attitudes towards external knowledge increase OI in schools.

Limitations and recommendations for future research

This study has several limitations that require attention when interpreting its results. First, the nature of cross-sectional data limits the ability to draw conclusions about causal relationships and the direction of relations. Future research could utilise longitudinal data to determine a causal relationship. Furthermore, many concepts, including LMX, NIH, and OI, are new to educational research. Future research could validate these results with other models and methods, possibly even replicating this study's model in order to provide further evidence of the findings. As this study was only situated in Malaysia, developing an understanding among the variables in this study requires extending the present research to other counties and contexts.

Furthermore, the analysis revealed a very low ICC1 value of teachers' NIH. School membership explains only 3% of the variance in individuals' teachers' NIH ratings, indicating that individual characteristics and experiences mainly influence this attitude. Future research should address this by investigating further individual-level factors that impact teachers' NIH. Beyond that, within the DL-MLSEM, convergence problems occurred, resulting in an overestimation

of a regression coefficient. This issue could result from the low sample size of school leaders ($n = 54$) and highlights the need for future investigations with larger sample sizes.

Conclusion

Grounded in a microfoundational perspective, this study uncovered new insights into the underlying social mechanisms that mediate OI at schools. Unique findings on the interplay between TL, LMX and teachers' NIH influencing OI were unveiled by applying multilevel analysis based on matching school leader and teacher data.

More precisely, the findings underline the complexity of innovation processes in schools that involve contextual and conditional factors as well as interactional and individual factors. Becoming adaptive organisations that continuously learn and innovate requires school leaders to create an environment with high-quality relationships and collaborative knowledge exchange. A leadership approach that fosters teachers' trust, commitment, empowerment and openness is essential. Considering the impact of teachers' NIH on OI, more attention is needed on teachers' individual and collective attitudes when implementing OI. As positive attitudes towards external knowledge help to obviate knowledge rejection and resistance to change and instead allow collaborative knowledge creation and enable innovation. Especially in the context of OI, external knowledge is a crucial resource that requires individuals' openness, strategic knowledge management and innovation management (Chesbrough and Bogers 2014).

Accordingly, several implications for policy and teacher training, both in the Malaysian context and internationally, can be derived. As other emerging nations, the current educational reformation in Malaysia aims to transform its quality to meet international standards such TIMSS and PISA. Thus, fostering positive attitudes and beliefs toward external knowledge, such as the NIH and encouraging positive principal-teacher relationships are critical as it influences knowledge exchange and OI in schools. This research highlights that principal TL enhances the quality of relationships between school leaders and teachers, influencing the processes of OI in schools. Therefore, insights from this study can inform policymakers in developing strategies or programmes to improve educational outcomes.

One key suggestion is the designing of teacher professional development programmes that strengthen openness to external knowledge and collaboration, such as inter-school networks, community partnerships, and action research. Additionally, leadership training for school leaders is pivotal to enable them to build high quality relationship with their teachers as this leads to relational trust, mutual respect, and open communication with teachers, all qualities that cultivates a culture conducive to educational innovation. Our findings also show the critical role of principals' TL

particularly in hierarchical and centralised contexts can unleash the full potential of teachers which is essential for successful innovation in educational settings.

Overall, this study demonstrates that schools are dynamic social organisations where diverse stakeholders interact and cooperate. Thereby, individual attitudes and social interactions influence change processes and need to be taken into consideration as a fundamental starting point when leading OI.

Disclosure statement

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Methodological Appendix

Alternative analysis

Five alternative model specifications were performed following Morin, Blais, and Chénard-Poirier (2022) and Marsh et al. (2009). The authors recommend comparing the results of all partial correction models to identify the most accurate solution to the data. For a detailed description of the alternative models B, C, D please see Marsh et al. (2009). The models based on factor scores (E and F) are described by Morin, Blais, and Chénard-Poirier (2022). Table 4 shows the model fit indices of all alternative specifications and Table 5 shows the results of the SEM.