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DEVELOPMENT ARTICLE

Leading the AI transformation in schools: it starts with a digital mindset

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Abstract
Rapid developments in artificial intelligence (AI) require dynamic adaptation in education to integrate new technologies timely and sustainably. In particular, the rise of generative AI requires leadership to implement it in a meaningful way for teaching and learning. School leaders have a special role to play in driving digital transformation. Based on a sample of German school leaders, this article explores how school leadership approaches and a digital mindset influence the implementation of AI in schools. Our findings provide initial and preliminary evidence that school leaders' digital mindsets, particularly proactive agility and empathy, understood as perspective taking, influence the implementation of AI in schools. Furthermore, the findings highlight the effectiveness of ambidextrous leadership in driving AI implementation. As a consequence, our study paves the way for future explorations of the evolving landscape of AI in education and highlights the need for adaptive, empathetic, and proactive leadership in the digital age.

Keywords Ambidextrous leadership · Artificial intelligence · Digital mindset · Innovation · Technology integration

Introduction

The rapid development of artificial intelligence (AI) requires dynamic adaptation in education and a systematic digital transformation of schools to integrate new technologies in a timely and sustainable manner. It has been suggested that school leaders play a special role in driving digital transformation (Berkovich & Hassan, 2023; Christensen et al., 2018; Dexter & Richardson, 2020; Schmitz et al., 2023) because they have a significant impact on the design and improvement of school organization, processes, and functioning (Grissom et al., 2021; Leithwood & Jantzi, 2006). For digital transformation to be successful, schools, like other organizations, need skilled and digitally literate leaders (Schwarzmüller et al., 2018) who act on a specific digital mindset (Allen, 2020; Ghosh et al., 2022; Kane, 2019; McCarthy et al., 2023; Witthöft et al., 2024). In essence, a mindset is a set of beliefs or implicit theories that are domain- (Hughes, 2015) and context-specific (Solberg

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et al., 2020) as well as multidimensional (Rauch, 2022), which influence emotions, motivations, volitions, and behaviors (Achtziger & Gollwitzer, 2018), ultimately impacting distal outcomes (Burnette et al., 2013). Accordingly, a school leader's digital mindset is considered core to a school's successful transformation in the age of digitalization, as it sets the frame for how leaders think about and lead their organization, resulting in opportunities and possibilities being opened or closed (Allen, 2020; McCarthy et al., 2023). Kane (2019, p. 48) states: "The most successful digital transformations start with a shift in mindset at the employee, leadership, and organization levels. This shift produces a culture change that allows the company to be more agile, risk tolerant, experimental, and collaborative."

However, empirical research on what constitutes a digital mindset, how to measure it, and how it impacts digital transformation is scarce (Hildebrandt et al., 2022; Rauch, 2022; Solberg et al., 2020). Notwithstanding, some personal characteristics and how leaders think about them appear to be particularly relevant to successfully transforming organizations in the digital age: empathy, innovativeness, openness, and agility (Pabst von Ohain, 2023). This is particularly relevant for AI integration, which is usually associated with a high degree of uncertainty (Kaplan-Rakowski et al., 2023; Nordström, 2022) and requires leaders to dynamically deal with unprecedented paradoxical challenges (Nguyen et al., 2023; Singh et al., 2024; Waldman et al., 2019), namely: (1) AI is a large, interdisciplinary field that includes subfields such as machine learning, natural language processing, and computer vision (Russell & Norvig, 2016), and without in-depth knowledge, the field can be correspondingly confusing (Bewersdorff et al., 2023; Long & Magerko, 2020); (2) generative AI is currently developing rapidly (Fengchun & Homes, 2023; Kasneci et al., 2023; Yusuf et al., 2024), and schools are faced with constant and dynamic change, something they have not traditionally been prepared for (Dedering & Pietsch, 2023; Pietsch et al., 2023); (3) many questions about AI ethics and privacy remain unanswered (Celik, 2023; Holmes et al., 2022; Shin & Park, 2019) and require decisions under extreme uncertainty; (4) leaders, teachers, and learners need to think critically and be competent users of AI technology (Ng et al., Mah & Groß, 2024; UNESCO, 2024a, 2024b), especially to allay fears and anxieties about the future of AI (Hopcan, 2023; Velander et al., 2023); and (5) processes and structures for systematic and agile change management to adopt and integrate new AI technologies need to be established in schools (Ifenthaler & Egloffstein, 2020; McCarthy et al., 2023).

Today's school leaders must meet all of these challenges while ensuring that the day-to-day operations of the school continue (Dedering & Pietsch, 2023; Pietsch et al., 2022, 2023). For them, this means encouraging experimentation, creativity, and challenging the status quo (opening behavior) while adhering to policies and guidelines, taking governing action, and monitoring the achievement of school goals (closing behavior) at the same time. Outside of educational research, in general innovation and organizational research, this is referred to as paradoxical (Lewis et al., 2014) or ambidextrous leadership (Rosing & Zacher, 2023; Rosing et al., 2011), and it is assumed that such leadership helps leaders to counter paradoxes (Guo et al., 2020), fosters innovation at all levels of an organization (Zacher & Rosing, 2015; Zacher et al., 2016), and helps employees cope with rapid technological change (Gouda et al., 2023). As outlined by Zacher and Rosing (2015), the fundamental premise of ambidextrous leadership is that the intricacy of innovation processes necessitates a parallel complexity in leadership strategies. Consequently, this leadership model is primarily defined by its impact on the innovation performance of followers and organizations (Klonek et al., 2023). It has been hypothesized and empirically proven that the opening and closing behavior of leaders, when interacting at a high level, leads to positive joint effects that go beyond individual effects (Rosing & Zacher, 2023). As a

result, ambidextrous leadership is considered essential for leading a digital transformation (Duwe, 2021). This discourse is very similar to that of integrated leadership in schools, which assumes that complex change in schools requires a combination of transformational and instructional leadership (Bellibas et al., 2021; Kwan, 2020; Marks & Printy, 2003), thus simultaneously promoting bottom-up and top-down innovation strategies as well as first- and second-order change. However, while the educational discourse on integrated leadership is primarily concerned with effectiveness in more or less stable contexts (Kwan, 2020), the discourse on ambidextrous leadership explicitly focuses on innovation and change in dynamic and ever-evolving environments (Duwe, 2021).

In this regard, it is striking that empirical studies in education have not yet examined the relationship between school leaders' digital mindsets and the implementation of AI nor the impact of integrated leadership on technology integration in schools. Further, a discourse on paradoxical or ambidextrous leadership and its effects in the context of digitalization has so far only taken place outside the field of educational research. Our article addresses these desiderata. Specifically, we investigate whether and to what extent two different leadership approaches (transformational leadership and digital instructional leadership) and ambidextrous leadership (that is, the interaction of both leadership approaches, hence, transformational-digital-instructional leadership) affect AI integration in schools. In addition, we examine whether and to what extent school leaders' digital mindsets influence their transformational leadership practices, their digital instructional leadership practices, and, specifically, the mediated effect of a digital mindset on AI implementation in schools. Against this background, the three following research questions guide our study:

RQ1: Does a digital mindset positively affect school leadership and AI integration in schools?

RQ2: Do transformational and digital instructional leadership positively affect AI integration in schools?

RQ3: Does ambidextrous leadership positively affect AI integration in schools?

Theoretical background and hypotheses

Implementing artificial intelligence in schools

AI in education has tremendous potential to improve learning, teaching, and educational administration (Bond et al., 2023; Pelletier et al., 2021a, 2021b) and, consequently, has been evolving as a field in educational research for several years (Baker, 2000). AI applications in education can be categorized into four distinct areas: profiling and prediction (e.g., student retention, academic achievement), intelligent tutoring systems (e.g., diagnosing strengths, automated feedback), assessment and evaluation (e.g., automated grading, evaluation of feedback), and adaptive systems and personalization (e.g., recommending personalized content, supporting teachers and learning design) (Zawacki-Richter et al., 2019). The benefits of AI in education are manifold, including personalized learning, greater insight into student understanding, positive impact on learning outcomes, and reduced planning and administrative time for teachers as key opportunities (Bond et al., 2023; Kasneci et al., 2023). For example, learning analytics provides deeper insights into student understanding, allowing educators to more effectively identify and address learning gaps and positively impact student retention (Arnold & Pistilli, 2012; Mah, 2016; Tsai et al., 2020). Key challenges related to AI in education include ethical considerations (Holmes et al., 2022) such

as concerns about honesty and plagiarism (Cotton et al., 2023), curriculum development (Bellas et al., 2023; Chiu, 2021; Touretzky et al., 2019), infrastructure, and digital literacy and AI literacy (Fraillon et al., 2020; Ifenthaler, 2017). With a focus on digital literacy and AI literacy for teaching and learning, conceptual frameworks, self-assessments, and empirical research are being developed (Lintner, 2024; Long & Magerko, 2020; Lorenz & Romeike, 2023; Ng et al., 2021; Punie & Redecker, 2017; Wang et al., 2023). Teachers play a central role in equipping their students with twenty-first century skills, including AI (Markauskaite et al., 2022; Punie & Redecker, 2017). Recently, UNESCO (2024b) has published an AI competence framework for teachers, which aims to serves as a guide for professional development and to empower teachers to utilize AI in informed, secure, and ethical ways within the context of their teaching practices (UNESCO, 2024b). Furthermore, in light of the evolving competencies that may be required for the transition to AI-enhanced education, the framework's target audience includes policy-makers and school leaders. This is with a view to supporting the design and planning of training courses on AI, continuous professional learning regarding the use of AI, and other enabling factors that can support teachers' effective use and systematic integration of AI in education (Pratschke, 2024; UNESCO, 2024a, 2024b).

Therefore, it is important to provide teachers with professional development to become digitally and AI literate and to incorporate technology into their teaching practices (Celik et al., 2022; Seufert et al., 2021). Despite the growing body of research on AI in education, more empirical research and evidence is needed (Bond et al., 2023; Ferguson & Clow, 2017). This is even more important given the dynamic developments in generative AI and its competent, constructive adoption in educational settings (Kasneci et al., 2023; Kohnke et al., 2023; Mao et al., 2023; Yusuf et al., 2024). In this regard, the role of school leaders and their leadership practices are regarded as being of central importance, as school leaders are uniquely positioned at the boundary of environment and organization and exert a major influence on the design and development of organizational structures, processes, and functions (Cheng & Wang, 2023; Dedering & Pietsch, 2023; Dexter & Richardson, 2020; Fullan et al., 2023; McCarthy et al., 2023). As technology leaders in schools (Arslan & Sumuer, 2024; Dexter & Richardson, 2020; Kaya-Kasikci et al., 2023) they have the function (McLeod & Richardson, 2013, p. 255) "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". In this regard, studies indicate that school leadership plays an important role in teachers' intentions to participate in technology-related professional development in order to integrate technology into the classroom in a meaningful and instructional way (Fütterer et al., 2023; Krille, 2020). Consequently, Fullan et al. (2023) suggest that school leaders are pivotal to the successful integration of AI in schools and must establish a long-term vision for integrating AI-based technology into their schools in a thoughtful and ethical manner.

Leadership for digital transformation

Transformational leadership

Transformational leadership is seen as essential for organizational transformation, especially when it comes to bringing about significant change in others. Theory suggests (Yammarino & Dansereau, 2011) and empirical studies show (Siangchokyoo et al., 2020) that

these aspects are closely related: first, leaders affect followers; second, followers change in a specific way; and third, the alteration of followers is responsible for transformational leadership effects at the organizational level. Transformational leaders provide their followers with an inspiring mission and vision and give meaning to their work (Bass, 1990). More specifically, such leaders transform and motivate their followers through their charisma; intellectual stimulation—that is, by actively soliciting new ideas and ways of doing things differently; and the individual consideration of a followers ' motives and needs (Bass & Riggio, 2010). In this regard, transformational leaders activate an organizational structure by initiating a process of change in accordance with dynamic environmental conditions, influencing followers' beliefs, attitudes, and values with personality traits that evoke prestige, confidence, and courage, and embracing the school's mission and goals (Bass & Avolio, 1993; Bass & Riggio, 2010). In sum, transformational leaders are considered as change agents who communicate a new vision that challenges the status quo, inspire followers to embrace new ideas and prioritize the success of the organization, and motivate them to recognize the importance of achieving future organizational goals.

In educational research, transformational leadership became an increasingly important topic when extensive initiatives were undertaken to redesign schools to meet the needs of 21st-century students (Leithwood & Jantzi, 2000) and has been suggested as the most relevant leadership style for school leaders considering substantial reform and change (Leithwood & Jantzi, 2006). Although the general discussion of transformational leadership is often about bottom-up processes (Daniels et al., 2019), the school leader as a person plays a much more important role in educational research (Kovačević & Hallinger, 2019). Consequently, in this field of research, transformational leadership is primarily seen as a school leader's ability to create a school climate that is conducive to motivating and sustaining school improvement and promoting educational change in order to create an effective school (Kovačević & Hallinger, 2019; Muijs et al., 2006). It should be noted that this type of leadership is expected to produce indirect second-order effects by empowering teachers to work toward school improvement, which, in turn, produces first-order effects on learning (Hallinger, 2003). Accordingly, a large number of studies show that transformational leadership in schools influences variables at both school and teacher levels (Scheerens, 2012) but that the unique effect on student achievement is comparatively low (Robinson et al., 2008).

However, as Dexter and Richardson (2020) argue, successful integration of new, digital technologies in schools requires leadership that establishes a vision, provides high-quality learning opportunities, builds professional capacity, creates a supportive climate for learning, and connects with external partners. Consequently, when it comes to integrating emerging technologies into schools and classrooms, transformational leadership practices are considered essential (Schmitz et al., 2023). One of the main reasons for this is that digital transformation in schools is not just about installing new technologies but rather about changing mindsets and organizing and developing the capacity of teachers to adapt to a potential digital future (McCarthy et al., 2023; Timotheou et al., 2023). Philip (2021) argues that transformational leadership is expected to facilitate digital transformation in organizations by encouraging divergent thinking and creativity, supporting structural change toward agility, and providing individual attention and support to organizational members to adapt to comprehensive change. Consequentially, transformational leaders are expected to both anticipate and initiate change in the digital world to drive innovation (Karakose et al., 2023). Although not extensively empirically researched, several studies suggest that these assumptions are largely accurate and that transformational leadership in schools is associated with a climate conducive to digital innovation (Berkovich & Hassan,

2023; Ruloff & Petko, 2022) and sustainable integration of new technologies in schools (Schmitz et al., 2023).

H1 Transformational leadership positively affects AI implementation in schools.

Digital instructional leadership

Instructional leadership is one of the most popular leadership approaches in educational research and is considered to be particularly relevant when it comes to school effectiveness (Gümüs et al., 2018; Pietsch et al., 2023). Based on the initial empirical finding that effective schools almost always had strong instructional leadership (Edmonds, 1979) and that in several studies no evidence of effective schools with weak instructional leadership was detectable (Sammons et al., 1995), during the 1980s the idea developed that schools need strong instructional leaders who prioritize improvements in the quality of teaching and learning activities (Bellibas et al., 2021) to successfully realize the potential of all students, regardless of their social backgrounds (Neumerski, 2013). However, what exactly was meant by instructional leadership was more or less unclear until the mid-1980s, when scholars began to develop models describing what it entails (Hallinger et al., 2020; Pietsch et al., 2023).

In particular, the model developed by Hallinger and Murphy (1985), which proposes three dimensions of instructional leadership practices, is now well established. According to this approach, an instructional leader is a person who sets and communicates the school's academic goals, supervises instruction and monitors student progress, provides incentives for teaching and learning, protects instructional time, and creates opportunities for teacher professional development (Hallinger & Wang, 2015). This approach heavily focuses on those people in formal leadership positions and primarily pursues a top-down perspective (Bellibas et al., 2021; Hallinger et al., 2020). Instructional leadership is thought to produce primarily first-order change (Hallinger, 2003)—that is, an instructional leader influences conditions that directly affect the quality of teaching and instruction provided by teachers to students in the classroom. In principle, the goal of such leadership is to guide and shape instruction and the conditions in which it takes place so that it is as effective as possible for the learning of all students (Boyce & Bowers, 2018; Hallinger, 2020; Neumerski, 2013). Consequently, instructional leadership is considered one of the most important and effective determinants at the individual school level when it comes to successful student learning (Robinson et al., 2008).

Recently, scholars have developed the idea of digital instructional leadership (Berkovich & Hassan, 2022; Sanchez Corona, 2019; Shepherd & Taylor, 2019)—that is, a school leader's ability to (a) use information technology, (b) understand and communicate the accompanying changes in teaching and instruction, (c) promote a vision of the role of technology integration and its added value in the school, and (d) create opportunities to learn for all those involved in a school for technology integration (Berkovich & Hassan, 2022; Dexter & Richardson, 2020). It is argued that the technology-oriented transformation of schools requires strong instructional leadership with an appealing vision of technology integration (Dexter & Richardson, 2020; MacLeod, 2015) to empower and encourage teachers to use new technologies for the greater good of their students (Navaridas-Nalda et al., 2020). The goal of such leadership then is to promote and ensure the coherence of the teaching and learning process in a hybrid or distance learning environment (Berkovich, 2023; Hassan & Berkovich, 2023). Empirical studies of whether and how digital instructional leadership

works in schools are scarce. Nevertheless, early results show that such leadership can influence teachers' attitudes toward digital learning and teaching (Berkovich, 2023) as well as students' learning (Hassan & Berkovich, 2023).

H2 Digital instructional leadership positively affects AI implementation in schools.

Ambidextrous leadership

For a long time, transformational and (traditional) instructional leadership in schools were seen as two separate, distinct approaches to leadership that require an either/or choice (Bellibas et al., 2021). In recent years, however, it has become increasingly clear that comprehensive educational innovation and change requires leadership that follows a both/and approach and addresses learning at all levels of a given school while simultaneously focusing on student learning and success (Boyce & Bowers, 2018; Day et al., 2016; Kwan, 2020; Marks & Printy, 2003). Accordingly, integrative leadership approaches have recently become more prevalent in educational research, emphasizing the importance of addressing first- and second-order change simultaneously to transform schools while ensuring a high quality of instruction (i.e., integrative leadership [Marks & Printy, 2003], learning-centered leadership [Goldenring et al., 2009], and leadership for learning [Daniels et al., 2019]). The assumption here is that instructional and transformational leadership coexist and can complement and reinforce each other (Bellibas et al., 2021; Kwan, 2020).

This idea partly overlaps with the concept of ambidextrous leadership, which is widely used in general organizational and innovation research which is considered to be one of the most important drivers for the digital transformation of companies (Duwe, 2021). Scholars suggest that two types of leadership behaviors are needed simultaneously in the context of organizational transformation processes (Rosing et al., 2011; Trong Tuan, 2017): opening and closing leadership behavior. While opening leadership behavior ensures that creativity is unleashed and new things are tried, closing leadership ensures that innovations and routines are implemented effectively (Zacher & Rosing, 2015). Rosing and Zacher (2023, p. 55) describe these two aspects of leadership as follows: "Opening leader behavior comprises, for example, to encourage followers to experiment with new ideas, to give room for independent thinking and acting, and to allow for learning from errors. In contrast, the aim of closing leader behavior is to reduce variance in follower behavior in order to promote implementation. Closing leader behavior encompasses, for example, establishing routines, monitoring goal achievement, and controlling the adherence to rules." In the school context, this may, for instance, mean that a school leader gives teachers the freedom to experiment with different digital tools (opening leadership) while monitoring whether these tools and their use are having the desired effect (closing leadership), namely, whether they are reflected in the quality of instruction or student learning and achievement. In this understanding, transformational leadership primarily addresses opening behavior and digital instructional leadership addresses closing behavior.

H3 Ambidextrous (that is, integrated transformational-digital-instructional) leadership positively affects AI implementation in schools.

To achieve a high level of ambidextrous leadership, leaders must demonstrate a high level of both opening and closing leadership behaviors; methodically, this is an interaction of both aspects of leadership (Rosing & Zacher, 2017, 2023). This is perfectly in line

with the idea of integrative leadership which is widely used in educational research and which "focuses … on demonstrating two leadership types at the highest level" (Bellibas et al., 2021, p. 781). Although there is a paucity of studies that empirically investigate such integrative leadership approaches in schools, the available evidence suggests that the interplay or interaction of transformational and instructional leadership entails a unique effect that goes beyond the specific effects of instructional and transformational leadership. Corresponding effects on learning have been observed at all levels of schools—the school as an organization, the professional development of teachers, the improvement of instruction, and the learning of students. For instance, Day et al. (2016) demonstrated that both transformational and instructional leadership alone are not sufficient to promote school improvement and educational change, and that only the combination of both aspects of leadership leads to sustainable change in schools. Bellibas et al. (2021) showed that teachers' professional learning and development strongly benefits from integrated leadership. Pietsch and Tulowitzki (2017) were able to show that the implementation of innovative and challenging teaching practices requires a coordinated integration of both aspects of leadership. Finally, Marks and Printy (2003) demonstrated that transformational leadership is a necessary but not sufficient condition for effective instructional leadership, and the effect of integrated leadership on student achievement is substantial. Whether such effects can also be demonstrated with regard to the implementation of new learning technologies and digital transformation in schools and classrooms has not yet been investigated.

Digital mindset as antecedent

While both the effects of digital instructional leadership on teachers' attitudes and students' learning and the effects of transformational leadership on educational innovation and change have been explored empirically, research on their antecedents has rarely been conducted so far (Berkovich, 2023; Berkovich & Hassan, 2022; Leithwood & Jantzi, 2006; Sun et al., 2017). However, theory suggests, and scholars make a strong case, that leading the digital transformation requires a specific digital mindset (Allen, 2020; Ghosh et al., 2022; Kane, 2019; McCarthy et al., 2023), namely, a leader's context-specific dynamic traits that determine how they perceive the environment and decide how to act and solve tasks in the context of digitalization (Hildebrandt et al., 2022). As Allen (2020) notes, a leader's digital mindset is the foundation for organizational success in the age of digitalization because it frames how leaders think about and manage their business, resulting in the opening or closing of opportunities and possibilities. Accordingly, there seems to be a consensus that the digital mindset of leaders should be characterized by a "change-as-usual" rather than a "business-as-usual" orientation (Eden et al., 2019) and a "both/and" rather than an "either/or" thinking (Vopentesta et al., 2023) that will enable them to lead positive digital change (Connolly et al., 2023).

Generally, a mindset can be defined as follows (Rauch, 2022, p. 16): "A mindset represents a combination of robust, pre-set beliefs activated in the interaction between a sensemaker's mind and his/her context. This combination of beliefs is perceived by the sensemaker as the correct logic for perceiving, understanding and acting within a given situation." Consequently, a digital mindset represents a multidimensional combination of beliefs that is activated in the context of digitalization (Rauch, 2022). According to Solberg et al. (2020), such beliefs can be divided into self-oriented and situation-oriented components, namely, individual beliefs about oneself in digitalization and beliefs about the context in which digitalization takes place. An individual's mindset exerts a

considerable influence on their motivation, volition, and behavior (Achtziger & Gollwitzer, 2018), which, in turn, shape outcomes (Burnett et al., 2013). To drive digitalization forward, a digital mindset is required at all levels of an organization to enable comprehensive and sustainable change (Kane, 2019; Pabst von Ohain, 2023). Although a digital mindset is regarded as a key driver of digitalization, little empirical research has been done on what constitutes a digital mindset and how to measure it (Hildebrandt & Beimborn, 2021). However, following Den Hartog et al. (1999) and based on several hundred expert ratings, Pabst von Ohain (2023) recently used a three-step process (Pratt et al., 2006) and applied a Gioia methodology (Gioia et al., 2013) to identify attributes that describe a prototypical digital leader, namely, an ideal leader for digital transformation. This research identified four clusters of individual traits that are associated with successfully leading digital transformation. According to the experts surveyed, such a prototypical digital transformation leader can be described in four dimensions: empathic, innovative, open, and agile.

Empathy, here, is the ability to experience and understand the emotions of others (Cuff et al., 2016) and is regarded as central for both educational improvement and change and leadership in schools (Berkovich & Eyal, 2015). *Innovativeness* generally refers to the degree to which a person is relatively quicker to adopt new ideas and solutions than other members of a system (Rogers, 1995). Being domain-specific (Goldsmith, 2001), innovativeness in the context of digitalization mainly revolves around technology orientation (Pabst von Ohain, 2023), which we define as a school leader's orientation and inclination to adopt and promote new technologies in the context of schooling. *Openness* or, more specifically, openness to change, in the context of digital transformation refers to a person's willingness to support change and their positive affect toward change (Wanberg & Banas, 2000) and is generally considered an essential quality that every successful leader must possess (Northouse, 2010). *Agility* is essentially the ability to respond quickly to rapidly changing circumstances (Brown & Agnew, 1982). In the context of constantly evolving environments and digital transformation, agility refers to the ability to identify and act on opportunities as they arise and to proactively build advantage from fast-changing environments (Verhoef et al., 2021); hence, it is also referred to as entrepreneurial or proactive agility (Chakravarty et al., 2013).

H4 School leaders' digital mindsets positively affect their transformational leadership practices.

H5 School leaders' digital mindsets positively affect their digital instructional leadership practices.

Although various strands of research have suggested that such personal traits and how leaders think about them influence leadership behavior and its effects (Deinert et al., 2015; Hogan & Kaiser, 2005), studies that have empirically examined this in the field of school leadership are scarce (Leithwood et al., 2020). In principle, however, a core assumption in (educational) leadership research is that traits and beliefs about them influence the leader's actions, which in turn influence various internal school factors and, consequentially, school performance, such as the integration of technology in the classroom and, consequently, student achievement (Christensen et al., 2018; Hsu & Sharma, 2008; Leithwood & Day, 2007; Zadok & Benoliel, 2023). Even though little evidence exists, cognitive empathy (i.e., mental perspective taking) in particular seems to be a relevant antecedent of transformational and instructional leadership (Berkovich & Eyal, 2015). While some empirical evidence

about teachers' innovativeness and its predictors is available (Blömeke et al., 2021; Dedering & Pietsch, 2023), little is known about school leaders' innovativeness and its implications for leadership (Davitt, 2008). In particular, nothing is known about whether and how the technological orientation of school leaders affects their leadership practices. At least initial findings are available for the aspects of openness and agility: these show that both a school leader's openness to change and (entrepreneurial) proactivity are relevant psychological resource for successful school leadership in dynamic and changing environments and may affect both teacher and school innovativeness (Leithwood, 2012; Pihie et al., 2014). Since the preliminary empirical findings on transformational and digital instructional leadership indicate that they are positively associated with technology integration in schools (Berkovich & Hassan, 2022; Dexter & Richardson, 2020; Schmitz et al., 2023), it is expected that the digital mindset of school leaders will have a positive effect on it, mediated through these two aspects of leadership in schools (Fig. 1).

H6 School leaders' digital mindsets positively affect AI implementation in schools indirectly—that is, mediated by both transformational and digital instructional leadership.

Methods

Sample

In our study, we use data from $N = 179$ school leaders located in Germany. The school leaders attended a conference in the federal state of Lower Saxony in August 2023, which was organized by the State Institute for Quality Development in Schools (NLQ) and to which all school leaders from public schools in the state were invited. An online survey was conducted at the beginning of the conference, the data from which we use for our study. For privacy reasons, only a small amount of personal and contextual data were collected, and for test efficiency a selection of the shortest possible scales was used. The gender distribution of participants was 51.4 percent female and 48.6 percent male. Of the participants, 13.4% are principals of schools at the ISCED 1 level (primary schools) and 86.6% are principals of schools at a different ISCED level (secondary schools) or special needs schools

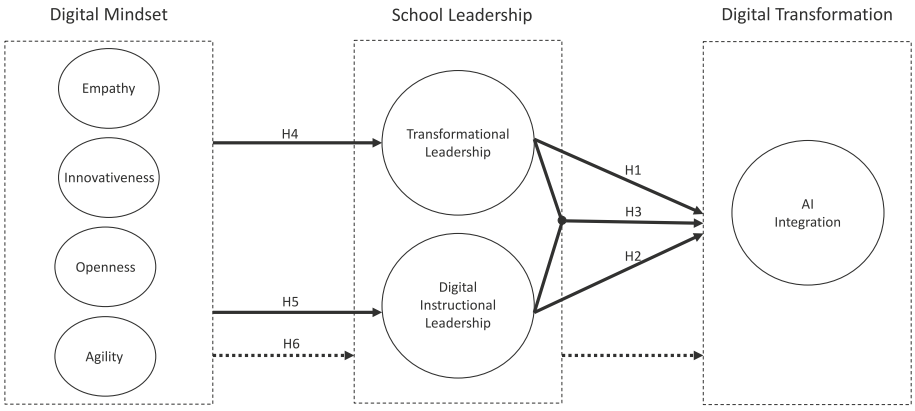

Fig. 1 Conceptual model of our study and hypotheses

(UNESCO Institute for Statistics, 2012). Of these schools, 37.1% were located in urban areas and 62.9% in rural areas. The average size of the schools the participants run was 835.6 students (*SD*: 634.4), ranging from 50 to 3400 students.

Data analyses

Since our data come from a single instrument, we preliminary examined the common variance by loading all items used in the analyses on a single unrotated factor (Harmann, 1960). If the value determined here is less than 50%, it is unlikely that method bias in model estimates due to common variance is to be expected (Lance et al., 2010). In our data, the common variance amounted to 24.5%. To test our hypotheses, we estimated structural equation models in MPLUS 8.5 (Muthén & Muthén, 2017). For each scale, reliability coefficients were estimated based on the data set employed in the study. In light of the fact that our study is conducted within the framework of structural equation modeling (SEM), we adhered to best practice recommendations (Cheung et al., 2024; Dunn et al., 2014; Hayes & Coutts, 2020) and, therefore, employed McDonald's omega (ω) as an alternative to Cronbach's alpha (α) for the purpose of evaluating the reliability of the measurement instruments utilized. To answer our research questions and evaluate the posed hypotheses, we followed a three-step procedure: In the first step, we investigated the factorial structure of all measurement models by applying confirmatory factor analysis (CFA) and investigating their model fit. In the second step, we investigated the assumed relations between our model variables. In both cases, a root mean square error of approximation (*RMSEA*) of < 0.08, a standardized root mean square residual (*SRMR*) of < 0.08, and a comparative fit index (*CFI*) of > 0.90 indicate acceptable fit (Hu & Bentler, 1999). As we estimated an indirect path model, a model containing mediator variables, in a third step, we further tested mediation effects' robustness by applying a bootstrapped mediation analysis, providing 95% bias-corrected bootstrap confidence intervals with 2000 bootstrap replications (Hayes, 2018; Preacher & Hayes, 2008). According to Hayes (2018), the estimates of indirect effects can be viewed as statistically significant if the 95% confidence intervals (*CIs*) do not contain zero. Since only 0.2% of the data was missing, we used a full information maximum likelihood estimator (*FIML*) to deal with missing data.

Measures

School Leaders' Digital Mindsets. Following Pabst von Ohain's (2023) framework for describing and measuring characteristics of prototypical digital leaders, we assessed the digital mindsets of school leaders in four dimensions, selecting one specific facet per dimension that was considered most relevant by the experts in his qualitative study:

- *Empathy:* perspective taking ($\omega = 0.644$). Empathy is a multidimensional and fuzzy concept (Cuff et al., 2016), although according to Coplan (2011), from a theoretical point of view, empathy is best understood as an active process in which a person sees things from another's perspective. Following this (narrow) understanding, three items from Davis' (1983) interpersonal reactivity index (IRI) were used to measure school leaders' tendencies to spontaneously adopt the psychological point of view of others, called perspective taking. Items were answered on a seven-point scale (1 = strongly disagree, 7 = strongly agree). Example item: "When I'm upset at someone, I usually try to 'put myself in his shoes' for a while."

- *Innovativeness:* technology orientation ($\omega = 0.790$). Three items developed by Gatignon and Xuereb (1997) were adapted to assess school leaders' tendencies to support new ideas and the adoption of new technology and, hence, to measure technology orientation. Items were answered on a seven-point scale (1 = strongly disagree, 7 = strongly agree). Example item: "I actively promote the use of technically advanced products and services at my school."
- *Openness:* openness to change ($\omega = 0.768$). Three items from Ruvio et al.'s (2014) organizational openness scale were adapted and used for measuring school leaders' openness to change. Items were answered on a seven-point scale (1 = strongly disagree, 7 = strongly agree). Example item: "I am always open and responsive to changes."
- *Agility:* proactivity ($\omega = 0.762$). Three items from a scale developed by Ruvio et al. (2014) were adapted to assess the proactive agility of school leaders, that is, proactivity. Items were answered on a seven-point scale (1 = strongly disagree, 7 = strongly agree). Example item: "I am always looking for opportunities for my school."

Transformational Leadership ($\omega = 0.651$). School leaders' practices to foster significant change in others were measured through four items from the Multifactor Leadership Questionnaire (MLQ: Bass & Avolio, 1995), indicating idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. Transformational leadership is modeled as a unidimensional construct because the validation of the German MLQ showed that it cannot be divided into sub-facets (Heinitz et al., 2005). All items were measured on a four-point scale (1 = very rarely or never, 4 = very often). Example item: "I seek differing perspectives when solving problems."

Digital Instructional Leadership ($\omega = 0.624$). A three-item scale, developed as part of the International Computer and Information Literacy Study 2018 (ICILS; Vennemann et al., 2021) and adapted by Tulowitzki et al. (2023) for school leader questionnaires, was used to capture school leaders' instructional leadership in the context of digitalization. All items were measured on a four-point scale (1 = strongly disagree, 4 = strongly agree). Example item: "I provide support to teachers who are struggling with the use of digital media in the classroom."

AI Integration ($\omega = 0.745$). Based on the assumption that changes in schools must take place at all levels of any given school, and thus comprehensively, in order to be sustainable, we developed a new three-item scale to measure AI integration in schools, which measures the extent to which AI is used in the classroom, at the school level, and at the school management level. All items were measured on a four-point scale (1 = strongly disagree, 4 = strongly agree). Example item: "In the classroom, we use AI-based tools (e.g. DeepL, ChatGPT)."

Results

Descriptives and measurement models

The results of the descriptive statistics (mean, standard deviation, and latent correlations) and fit measures (*CFI*, *RMSEA*, *SRMR*) of the measurement models are shown in Table 1. The results demonstrate a good fit of all measurement models ($CFI > 0.90$, $RMSEA < 0.08$, $SRMR < 0.08$). It should be noted, however, that digital instructional leadership and AI

Table 1 Means, standard deviations, correlations of latent variables, and fit indices of measurement models

	M	SD	PA	OP	TO	PT	TL	DL	CFI	RMSEA	SRMR
PA	5.29	0.90							.983	.031	.051
OP	6.03	0.69	**.538**								
TO	5.41	0.87	**.621**	**.407**							
PT	4.83	0.56	− .115	**.316**	− .089						
TL	3.12	0.41	**.380**	**.553**	**.284**	**.664**			1.000	.000	.003
DL*	2.89	0.59	**.619**	**.352**	**.555**	-.130	**.213**		1.000	.000	.000
AI*	2.01	0.73	**.331**	**.297**	**.278**	**-.171**	**.395**	**.405**	1.000	.000	.000

PA proactivity, *OP* openness, *TO* technology orientation, *PT* perspective taking, *TL* transformational leadership, *DL* digital instructional leadership, *AI* AI integration

Bold correlations $p < .05$; *Just identified model, therefore perfect fit

implementation in schools were only measured using three items each; these were, therefore, just identified and thus have a perfect model fit.

With regard to the digital mindsets of the school leaders surveyed, we observed consistently high scores across all dimensions, with the exception of empathy, or more specifically, perspective taking ($M = 4.83$). It is striking that the surveyed school leaders considered themselves to be particularly open-minded ($M = 6.03$), namely, flexible and adaptable to new ideas and changes. On average, their leadership was more transformational ($M = 3.12$) than digital ($M = 2.89$). In the schools they run, AI has only been introduced to a limited extent ($M = 2.01$).

Structural equation model

We tested hypotheses H1, H2, H4, and H5 by estimating a structural equation model. The proposed model again demonstrated an acceptable fit to the data ($CFI = 0.93$, $RMSEA = 0.04$, $SRMR = 0.07$). Table 2 provides the standardized path coefficients and standard errors for each path, as well as variance explained (R^2) for the dependent latent variables. The model accounted for 26% of the between-school variance in AI integration, 43% of the variance in school leaders ' digital instructional leadership practices, and 67% of the variance in their transformational leadership behaviors. The results show that school leaders' digital mindsets influence their leadership activities, with each facet of the mindset having differential effects on transformational and digital instructional leadership. Especially, proactivity seems to be particularly important for both aspects of leadership. School leaders who see themselves as proactive are more likely to lead their schools both transformatively ($\beta = 0.338$, $SE = 0.159$, $p < 0.05$) and digital instructionally ($\beta = 0.424$, $SE = 0.147$, $p < 0.05$). In contrast, there are no significant associations between openness and both transformational ($\beta = 0.126$, $SE = 0.114$, $p > 0.10$) and digital instructional ($\beta = 0.035$, $SE = 0.138$, $p > 0.10$) leadership. A school leaders' technology orientation, however, is only associated with their digital instructional leadership practices ($\beta = 0.272$, $SE = 0.114$, $p < 0.05$); a statistically significant correlation with transformational leadership is not observable ($\beta = 0.083$, $SE = 0.116$, $p > 0.10$). The opposite is true for perspective taking: here we find statistically significant associations with transformational ($\beta = 0.671$, $SE = 0.116$, $p < 0.001$) but not with digital instructional ($\beta = -0.068$, $SE = 0.114$, $p > 0.10$) leadership in schools. It is striking that both leadership styles do not correlate

Table 2 Results for the standardized direct effects

	β	*SE*	*p*	R^2
Direct Effects on Transformational Leadership				
Proactivity → Transformational Leadership	0.338	0.159	0.033	.667
Openness → Transformational Leadership	0.126	0.145	0.386	
Technology Orientation → Transformational Leadership	0.083	0.116	0.475	
Perspective Taking → Transformational Leadership	0.671	0.116	0.000	
Direct Effects on Digital Instructional Leadership				
Proactivity → Digital Instructional Leadership	0.424	0.147	0.004	.434
Openness → Digital Instructional Leadership	0.035	0.138	0.801	
Technology Orientation → Digital Instructional Leadership	0.272	0.114	0.017	
Perspective Taking → Digital Instructional Leadership	−0.068	0.114	0.552	
Direct Effects on AI Implementation in Schools				
Transformational Leadership → AI Implementation	0.323	0.092	0.000	.264
Digital Instructional Leadership → AI Implementation	0.336	0.094	0.000	

significantly with each other ($r = 0.003$, $p > 0.10$) but show comparably high associations with AI integration in schools ($\beta_{transformational\ leadership} = 0.323$, $SE = 0.092$, $p < 0.001$; $\beta_{digital\ instructional\ leadership} = 0.336$, $SE = 0.094$, $p < 0.001$). In conclusion, the findings reported here provide general support for our hypotheses H1, H2, H4, and H5. Transformational and digital instructional leadership have a positive effect on comprehensive AI integration in schools, while the digital mindset of school leaders exerts a positive influence on both leadership behaviors.

Latent interaction analysis

Next, we included a latent interaction between transformational and digital instructional leadership in our structural equation model to investigate possible joint effects of both leadership practices on AI implementation in schools and, thus, to answer hypothesis H3. Here, we applied a random effects model to estimate a latent moderated structural equation model. To receive standardized path coefficients, we first standardized all manifest indicator variables, following Maslowsky et al. (2015). Since no fit indices are available for random effects models, we compared the log-likelihoods of the model without and of the model with latent interaction in order to investigate if the addition of the transformational-digital instructional leadership interaction added significant value to the analysis, using a log-likelihood ratio test and report coefficient *D* (Klein & Moosbrugger, 2000). Further, we investigated whether more variance in the AI integration between schools (ΔR^2) could be explained as a result of the addition of the newly added parameter (Maslowsky et al., 2015). In accordance with best practice recommendations for interaction reporting, we also use a *pick-a-point*, simple slope procedure (Finsaas & Goldstein, 2021). Accordingly, we show graphically how ambidextrous leadership affects AI integration in schools when digital instructional leadership is equal to the sample mean (*average*) or 1 SD below (*low*) or 1 SD above (*high*) this value.

The results show that the latent moderated structural equation model fits our data better than the model without latent interaction ($D = 1245.552$, $df = 1$, $p < 0.001$). Therefore, in addition to the unique effects of transformational and digital instructional leadership on AI

integration in schools, the interplay between the two leadership approaches is also important to achieve change in this regard ($\beta = 0.225$, $SE = 0.100$, $p < 0.05$). The interaction plot in Fig. 2 is also an illustration of this: As assumed in the theory, the likelihood of comprehensive AI integration depends on ambidextrous leadership practices, i.e. the interaction of transformational and digital instructional leadership. This is also reflected in the explained variance of the dependent variable, AI integration. Here, R^2 for AI integration is increased to 0.305 by adding the latent interaction. The corresponding value for ΔR^2 is 0.04. In other words, adding the latent interaction to the model increases the explanatory power of the model for AI integration in schools by about 15%. It is also clear that this is an additional, unique effect; even when the interaction term is added, the effects of transformational ($\beta = 0.325$, $SE = 0.091$, $p < 0.001$) and digital instructional leadership ($\beta = 0.320$, $SE = 0.095$, $p < 0.001$) remain stable. The results support our hypothesis H5, indicating that ambidextrous leadership exerts an independent influence on the comprehensive integration of AI in schools, extending beyond the effects of transformational and digital-instructional leadership.

Mediation analysis

To examine H6 and, thus, a school leader's digital mindset's indirect effect on AI integration in school, we finally re-estimated the structural equation model using a bootstrapping procedure with 2,000 replications and calculated total effects—that is, the sum of direct and indirect effects (Preacher & Hayes, 2008). The analyses demonstrate a significant total indirect effect of school leaders' proactivity ($\beta = 0.252$, CI [0.036, 0.400], $p < 0.05$) and perspective taking ($\beta = 0.194$, CI [0.041, 0.508], $p < 0.05$) on AI integration in schools. However, we do not find such total effects for the mindset facets of openness ($\beta = 0.052$, CI [−0.087, 0.235], $p > 0.10$) and technology orientation ($\beta = 0.118$, CI [−0.032, 0.267], $p > 0.10$). For the facet of openness, no specific indirect effects on a school's AI

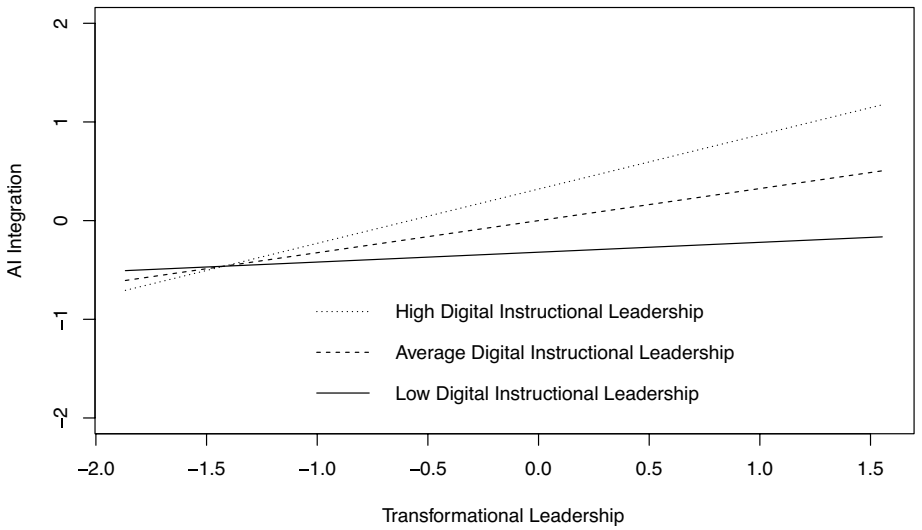

Fig. 2 Interaction plot: Ambidextrous leadership and its effect on AI integration in schools

implementation could be demonstrated either ($\beta_{transformational\ leadership} = 0.041$, CI [−0.067, 0.130], $p > 0.10$; $\beta_{digital\ instructional\ leadership} = 0.012$, CI [−0.027, 0.242], $p > 0.10$). For technology orientation, on the other hand, we demonstrate a significant specific effect that is mediated by digital instructional leadership ($\beta = 0.091$, CI [0.010, 0.216], $p > 0.10$). We also find a specific indirect effect for the perspective taking facet. In this case, it is mediated only by transformational leadership ($\beta = 0.194$, CI [0.081, 0.413], $p < 0.05$). The analysis also revealed that 31.7% of the impact that school leaders have on AI integration in schools can be attributed to their digital mindset; 11.6 percentage points are attributable to the perspective taking facet ($p < 0.05$), 10.3 percentage points to the proactivity facet ($p < 0.05$), 5.9 percentage points to the technology orientation facet ($p > 0.10$), and 3.9 percentage points to the openness facet ($p > 0.10$). The findings provide empirical evidence to support our hypothesis H6 that a school leader's digital mindset exerts a distal influence on the comprehensive integration of AI in schools, which is mediated by his or her leadership behavior.

Discussion

Summary of results

The objective of our investigation was to address the following research questions: (RQ1) Does a digital mindset positively affect school leadership and AI integration in schools?; (RQ2) Do transformational and digital instructional leadership positively affect AI integration in schools?; and (RQ3) Does ambidextrous leadership positively affect AI integration in schools?

With regard to RQ1, we were able to show that school leaders' digital mindsets influence their leadership activities. Being proactive or agile is the most important aspect of the leadership mindset for AI integration in schools, as it affects both transformational and digital instructional leadership. Hence, schools in which leaders consider themselves to be proactive are more likely to implement AI at scale. Almost as important is the empathy or perspective taking facet. The ability to empathize with others and understand their emotions is a major contributor to a comprehensive implementation of AI at all levels of a school, namely classroom, school, and school leadership and management levels. The emergence of AI tools, especially ChatGPT, and its possibilities, challenges, and changes for education has caused mixed feelings among educators (Grassini, 2023; Lo, 2023; Mah, 2023). A major concern is assessment. Currently, there are few guidelines and regulations for the appropriate use of AI in exams. Thus, educators are concerned about the misuse of AI tools for cheating and the consequences for the learning process, grades, and integrity (Cotton et al., 2023). Overall, AI tools raise ethical considerations, such as privacy concerns, data bias, and regulations (Bianchi et al., 2023; Fengchun & Homes, 2023). Therefore, being aware of these concerns, being an empathetic school leader, and understanding teachers' concerns about the implementation of AI in schools might be relevant to start a constructive conversation and discussion about how to implement AI in schools in a meaningful way.

Regarding RQ2, our results indicate that leadership is strongly associated with AI integration in schools and that its antecedents, namely, a digital mindset, have a significant impact on school leadership and whether AI is integrated at all levels of any given school. Both, digital instructional and transformational leadership exert independent effects, and

can therefore influence AI integration in schools to a certain degree. In this regard, our findings are consistent with those in the area of technology leadership in schools, which indicate that either digital instructional or transformational leadership contributes to enhanced technology integration in schools (Berkovich, 2023; Berkovich & Hassan, 2023; Hassan & Berkovich, 2023; Ruloff & Petko, 2022; Schmitz et al., 2023). What stands out is the fact that transformational leadership and digital instructional leadership are independent dimensions. In contrast to traditional (non-digital) instructional and transformational leadership (Bellibas et al., 2021; Marks & Printy, 2003), no demonstrable correlation between these two leadership facets was observable when covariates were controlled for. As a result, just because one leads in a transformational or digital instructional way does not mean that AI will be successfully implemented in schools. Thus, according to our findings, one of the two leadership facets alone is not sufficient to drive digital transformation in schools.

In terms of RQ3, our findings demonstrate a significant interaction effect between transformational and digital instructional leadership. Consistent with the few empirical studies empirically investigating integrative leadership approaches in schools (Bellibas et al., 2021; Marks & Printy, 2003; Pietsch & Tulowitzki, 2017), our study showed that the interplay between the two leadership dimensions has a unique effect. Consequently, the interplay between the two leadership dimensions is important: when school leaders simultaneously lead their schools with a high level of transformational and digital instructional leadership, the likelihood of AI integration in schools is significantly higher. Thus, integrated (transformational-digital-instructional) leadership uniquely affects AI implementation in schools. Since, in our understanding, transformational leadership opens up opportunities for teachers to experiment in the context of digitalization, while digital instructional leadership closes these opportunities and forces implementation, this means that appropriate ambidextrous leadership is particularly important to actively shape digital transformation in schools. This finding is consistent with findings on ambidextrous leadership from general innovation and organizational research (Duwe, 2021; Gouda et al., 2023; Rosing et al., 2011; Rosing & Zacher, 2023).

Limitations

The results of this study must be interpreted with some limitations. We used data from only 179 school leaders in Germany. This sample size is rather small, so the results can be considered more of an exploratory study. In addition, school leaders were located in only one federal state in northern Germany (Lower Saxony). Due to the federal structure of Germany, results may vary across the country. For reasons of test economy, we also only used a selection of the constructs of the mindset dimensions mentioned by Pabst von Ohain (2023) in our study. For example, our study employed a narrow conceptualization of empathy, focusing exclusively on cognitive aspects and disregarding the emotional dimension. As this was a cross-sectional study, we were unable to investigate the extent to which ambidextrous leadership, namely, transformational and digital instructional leadership in rapid alternation, is used sequentially (Rosing et al., 2011). Although we carefully selected leadership items that best reflect opening and closing behaviors, it would be desirable to develop a new scale that explicitly measures ambidextrous leadership in the school context (Rosing & Zacher, 2023). Further, our analyses are based on self-reporting by school leaders, so misreporting cannot be completely ruled out. In this context, school leaders' responses to a survey conducted in the summer of 2023 may reflect general uncertainty in

society and schools due to the rapid and dynamic development of AI applications, especially generative AI. In addition, digital instructional leadership and AI implementation in schools were measured with only three items each, so they were just identified and have a perfect model fit. Therefore, future research should seek to collect data with a more comprehensive instrument and to longitudinally collect data from across the country, at different school levels, and in different contexts.

Conclusion, implications, and future research

Our findings provide initial and preliminary evidence that the digital mindsets of school leaders influence the implementation of AI in schools. Specifically, proactivity and empathy emerge as critical facets that affect leadership in the context of AI implementation. This suggests that school leaders who are both proactive and empathetic will be more adept at integrating AI technologies in ways that are sensitive to the concerns and needs of teachers and students. Furthermore, the findings underscore that both transformational leadership and digital instructional leadership independently contribute to AI implementation in schools. Notably, the interplay between the two leadership approaches is uniquely important: together, they highlight the effectiveness of ambidextrous leadership in driving AI integration in schools. The study's findings have profound implications for education policy and leadership development. They argue for a nuanced understanding of the digital mindset and its components in leadership development programs. This aligns with the broader educational goal of preparing students for a future where AI in education is increasingly prevalent (Pelletier et al., 2023; Robert & Muscanell, 2023).

The findings of our study also have implications for educational and administrative practice. From an organizational perspective, institutional decision-makers, such as school leaders, should develop comprehensive institutional strategies and policies to guide the process of integrating AI in educational institutions (Pratschke, 2024). This includes the initiation and support of teachers' professional development in AI for teaching practices (Ifenthaler et al., 2027). In order to adequately assist their students in improving their AI literacy and become responsible and active citizens and users of AI in various contexts, including education, daily life, and work, educators themselves must also possess the necessary competencies related to AI (UNESCO, 2024a, 2024b; Vuorikari et al., 2022). Instruments designed to assess teachers' self-perceptions of their AI literacy (Delcker et al., 2024) and performance-based AI literacy scales may serve as an orientation for adequate professional development on AI in education, pending further development and testing (Lintner, 2024). Moreover, the critical issue of accessibility to AI-based tools in educational settings must be addressed (Mishra et al., 2023).

With regard to research on the topic, it should be noted that, according to our results, school leaders' mindsets accounts for nearly one-third of the explained variance of AI implementation in schools. This is substantial. How school leaders think about themselves in the context of digitalization has a major impact on their leadership behavior and determines whether schools will be at the forefront of AI. Here, too, the results of this study are in line with the assumption that the digital mindset is considered to be a key driver of digitalization (Hildebrandt & Beimborn, 2021; Kane, 2019; Witthöft et al., 2024) and thus provides additional empirical evidence. Our study is, to our knowledge, the first to demonstrate a corresponding association empirically in- and outside the field of education. It highlights the importance of considering the complexity involved in implementing AI in

schools: nearly 50% of the variance in AI implementation across schools could be attributed to previously unexplored factors introduced here for the first time—that is, a digital mindset and ambidextrous leadership in schools.

This also illustrates the importance of introducing innovative theoretical models and assumptions into the educational discourse—particularly during periods of digital disruption—and subjecting them to empirical investigation. Future research, further, should include a greater variety of states across the country, international perspectives, and different educational settings. For example, the perspective of higher education institutions and their change management could support digital change management in schools, at least some aspects of which may be adequate to adaptation. In addition, longitudinal studies could provide deeper insights into the long-term impact of leadership dimension and digital mindsets on AI integration in education. Examining the specific challenges and opportunities presented by different AI technologies, such as generative AI tools (Fengchun & Homes, 2023; Yusuf et al., 2024), could also provide valuable perspectives on tailored leadership strategies for effective technology integration. Further, the perspective of teachers should be investigated, for example, regarding the development of AI skills for teaching and learning (Celik, 2023; Long & Magerko, 2020; Mah, 2023).

In conclusion, this study makes a significant contribution to understanding the dynamic interplay between school leadership and AI implementation. It paves the way for future explorations of the evolving landscape of AI in education and highlights the need for adaptive, empathetic, and proactive leadership in the digital age.

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