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ORIGINAL ARTICLE

ICT knowledge absorptive capacity: A critical factor for technology integration in schools

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Abstract

This study examines whether and how a school's information and communication technology (ICT) knowledge absorptive capacity (ACAP) affects technology integration in schools. In addition, it investigates the influence of various contextual factors on the degree of contingency of ACAP, such as activation triggers, social integration mechanisms and regimes of appropriability. The study is based on a random sample of $N = 411$ schools representative of Germany. Structural equation modelling and machine learning were employed. The findings indicate that ICT ACAP has a positive impact on technology integration in schools and serves as a mediator in the relationship between external knowledge and technology integration. The impact of ICT ACAP on technology integration is contingent upon the presence and efficacy of knowledge-sharing mechanisms within the school, as well as the extent to which schools engage in collaborative efforts with competitors (coopetition). The insights of this study have implications for policymakers and educational leaders, who could prioritize building ACAP and fostering collaborative networks to create more adaptable and innovative school environments.

KEYWORDS

absorptive capacity, innovation, knowledge transfer, school leadership, technology integration

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Practitioner notes

What is already known about this topic

- For schools, technology integration is considered an important educational innovation.
- Acquiring, creating and sharing knowledge are essential for an efficient technology integration.
- Knowledge absorptive capacity (ACAP) is a critical factor in the acquisition of knowledge.

What this paper adds

- Higher information and communication technology (ICT) ACAP is associated with increased technology integration.
- ICT ACAP mediates between the depth of external knowledge and technology integration.
- The efficacy of ACAP is contingent upon a number of contextual variables, in particular, knowledge sharing in schools and coopetition.

Implications for practice and/or policy

- Schools need to identify, integrate and exploit relevant ICT knowledge to integrate technology successfully.
- Schools must develop systematic knowledge management systems to ensure that newly acquired knowledge is used reasonably.
- Schools must collaborate, even if they compete, to succeed in technology integration.

INTRODUCTION

The integration and use of technology are crucial for 21st-century life and education. Teaching practice can be enhanced or transformed when technology is used (Ventista et al., 2024). Research likewise indicates that technology can positively impact student achievement (Juuti et al., 2022), especially when utilized as a supplement to traditional teaching methods (Higgins et al., 2012). Further imperatives for technology integration in schools include a recent suggestion, in a call by the European Commission (2023), that 'boosting the development of digital skills from an early age and in a continuous manner is essential for influencing the level of digital skills of the EU population'. Simultaneously, achieving the goal of quality education is often hindered by issues that can be effectively addressed through the use of technology. For instance, traditional educational models often fail to accommodate the diverse needs, learning styles and paces of individual students. This issue can be addressed by adaptive learning technologies and the use of algorithms to adjust content and pace based on individual student performance, allowing for more personalized instruction (Hwang & Tsai, 2011). In particular, artificial intelligence (AI) in education has enormous potential to improve learning, teaching and education administration (Pelletier et al., 2023; Pietsch & Mah, 2025). Likewise, education can be disrupted by external events (such as natural disasters; Hodges et al., 2020) or economic constraints which limit access to high-quality resources (Means et al., 2010). This latter point was powerfully demonstrated during the recent COVID-19 pandemic, where the vital use of technological applications to support inclusive and adaptive education, thereby empowering all learners, achieved prominence

(Schleicher, 2022). At the same time, supporting conditions are required if technology is to be effectively integrated into schools and within teaching and learning (Schleicher, 2022).

As observed by Pietsch et al. (2023, 2024), educators working within schools require external knowledge and intersectoral collaboration if they are to implement innovations, especially when it comes to complex innovations that require knowledge that cannot be sufficiently created among within-school groups of teachers alone. This is particularly evident concerning technological innovation. For instance, Chen and Vanhaverbeke (2019) persuasively argue that, for organizations with limited resources, relying on their own knowledge is no longer enough to exploit and improve their innovation capabilities, as these resources can no longer meet the demands and dynamics of today's technological innovation. Instead, technological innovation requires knowledge and technologies from an expanding range of disciplines, reflecting the growing complexity of technological innovation (Chen & Vanhaverbeke, 2019; Pietsch et al., 2024).

Especially for schools, a lack of technology knowledge, technology integration knowledge, technology-supported pedagogical knowledge and technology-related classroom management knowledge has been identified as significant barriers that impede their ability to effectively integrate technology (Ertmer, 1999; Hew & Brush, 2007; Wilson et al., 2020). To reverse this situation, schools must be able to identify, integrate and exploit relevant external knowledge into their structures and processes (Da'as & Qadach, 2020). Such a dynamic organizational capability (Lichtenthaler & Lichtenthaler, 2009) is referred to as absorptive capacity (ACAP; Cohen & Levinthal, 1990), which is seen as a set of organizational routines and processes (Zahra & George, 2002) or, more broadly, the ability of schools to integrate, build and reconfigure internal and external competencies to address rapidly changing environments (Teece et al., 1997).

Although the concept of ACAP was first proposed over 30 years ago by Cohen and Levinthal (1990), and a substantial body of empirical research has examined how dynamic capabilities (Vogel & Güttel, 2013), and ACAP (Lichtenthaler & Lichtenthaler, 2010) in particular, affect technological innovation and adaptation in organizations, there are no studies in the field of educational research on this topic. While numerous models and frameworks address the long-standing challenge of technology integration in schools (eg, the Digitally Innovative School model; Ilomäki & Lakkala, 2018), many focus on determining which technologies to adopt rather than on how to effectively implement and adapt these frameworks in a rapidly shifting landscape. By contrast, ACAP is highly relevant in a context where schools must grapple with selecting digital tools *and* with continuously engaging external expertise and refining teaching practices to align with evolving educational goals. To address this gap, this paper examines the intersections of technology integration (TI) in schools, collaborative innovation and ACAP. Specifically, using data from a nationally representative sample of school leaders in Germany, we investigate the role of ACAP in facilitating TI as well as the role of knowledge sharing and coopetition, alongside the influence of various contingency factors.

THEORETICAL BACKGROUND

Technology integration in schools

TI in schools can improve teaching and learning processes (Backfisch et al., 2021). It supports students and enables participation in a digitalized society (Fraillon et al., 2019). However, the success of TI is attributable less to the quantity of its use, though an important factor, but rather to the quality of its application alongside teachers' motivation, beliefs and knowledge (Backfisch et al., 2021). Quality, in turn, is expressed in the level of exploitation of TI and the degree of teaching quality in general, expressed primarily through task-specific strategies and teachers' individual learning support (Backfisch et al., 2021).

As noted by numerous scholars, the successful integration of technology in schools is fundamentally a knowledge-driven process (Ertmer, 1999; Hew & Brush, 2007; Hong et al., 2019; Koehler & Mishra, 2005; Wilson et al., 2020). The knowledge relevant to TI in schools, the definition of which is often based on Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPACK) model, is thus considered dynamic and contextually situated (Schmid et al., 2024). Such knowledge is inherently tacit, encompassing a broad range of in situ teaching skills related to subject matter, pedagogy, curriculum and technology (Mena et al., 2017); thus forming the foundation for teachers' everyday decision-making activities (Fenstermacher, 1994).

Shulman (1986), however, argued that such tacit knowledge is regularly acquired via a complex, iterative process that requires continuous exploration and learning to support professional development and growth. Consequently, Holland (2001) and Hixon and Buckenmeyer (2009) proposed that the capacity to integrate technology in schools and classrooms represents a developmental process comprising several stages, wherein progressively sophisticated forms of knowledge are employed to utilize technology in a targeted and appropriate manner. As such, effective TI in schools is contingent upon an ongoing expansion of associated knowledge among teachers (Holland, 2001; Hong et al., 2019; Wilson et al., 2020).

TI in schools, however, describes a ‘messy, complex, and unstructured phenomenon’ (Kimmons et al., 2020, p. 176), which is difficult to capture empirically. Moreover, prominent technology-related pedagogical knowledge models like the TPACK model exhibit a certain fuzziness and, despite their widespread popularity, would appear to be stagnating in terms of theoretical and methodological progress (Schmid et al., 2024). While some scholars thus call for a reset of research on the topic (Saubern et al., 2020), others ‘call for more data triangulation, inclusion of more neighboring constructs, and development of better TPACK measures’ (Schmid et al., 2024, p. 13).

Regarding neighbouring constructs, various models have been developed to describe and assess the degree of TI in schools. For instance, the Digitally Innovative School model (Ilomäki & Lakkala, 2018) offers a multidimensional lens to understand innovation practices at both the leadership and classroom levels. This model highlights the critical interplay between school leadership, teacher practices and the broader organizational culture, aligning closely with the concept of ICT absorptive capacity (ACAP) as a driver of knowledge integration and technological adoption. Similarly, the Digital Mirror framework (Pata et al., 2022) adds depth by focusing on the reflective and self-assessment practices that underpin digital innovation in educational settings. This framework complements the ACAP processes by emphasizing the continuous interplay between internal and external knowledge flows, enhancing our understanding of how schools adapt and evolve in dynamic digital environments.

Furthermore, with regard to practical application, the integration of insights from the SELFIE for Schools tool (https://education.ec.europa.eu/selfie) enables schools to assess their digital maturity and identify areas for growth, illustrating how reflective practices can inform and shape innovation strategies. The model utilized in this study, however, is the Substitution, Augmentation, Modification, Redefinition (SAMR; Puentedura, 2006) model: the most commonly used integration model in educational research (Blundell et al., 2022; Hamilton et al., 2016). As a framework, SAMR suggests that technology in schools can serve as a lever for change and enhance educational practices from acquisition to the point where it is integrated into a teacher's everyday practice to achieve targeted outcomes (Puentedura, 2006; Tunjera & Chigona, 2020). As such, the benefits of the SAMR—in contrast to the models described above, stem—from its progression from basic substitution to transformative redefinition: resonating well with the stages of knowledge acquisition, assimilation, transformation and exploitation outlined in the ACAP model. This ensures a coherent framework to explore how ICT knowledge ACAP drives technology integration. What's more, SAMR offers tangible, practice-oriented insights that align with our focus on practical implications for schools. This distinguishes it from more abstract models like the Digitally Innovative School model or Digital Mirror framework, which are broader in scope and less directly focused on the classroom level and instructional impacts of technology.

Knowledge for collaborative innovation

Knowledge creation, activation and sharing are essential for efficient TI in schools. Given that schools frequently lack internal expertise regarding the most recent technological advancements and their potential applications and applicability in the classroom (Hew & Brush, 2007), they often rely on external sources of knowledge. Schools are, however, historically weak in sharing knowledge within and beyond their institutional borders (Fullan, 2002).

Collaborative innovation represents an integrative process in which multiple stakeholders contribute their diverse knowledge to create novel solutions (da Silva Meireles et al., 2022). Facilitating knowledge creation, activation and sharing as part of the collaborative innovation process involves complex interactions among individuals and organizations with an end goal of effective knowledge use. Of particular relevance is Flyvbjerg's (2001) argument that individuals can only become true experts as a result of continuously engaging in 'real life performances'. By this, Flybjerg means that expertise derives from individuals' increasing recognition of different situations and how best to employ (activate) new practices or innovations in response (that is, in order to achieve their desired impact). Likewise Nonaka and Takeuchi's (1995) notion of knowledge creation suggests that internalizing new knowledge through repeated use ensures that it becomes tacit, and thus employed more effectively: with knowledge creation taking place most effectively among communities and networks (Wenger et al., 2011). For example, research–practice partnerships (RPPs) as a boundary-crossing collaboration between universities, schools and local district authorities foster professional development and co-constructive knowledge acquisition for the divers and individual stakeholders (Fischer-Schöneborn et al., 2025; Fischer-Schöneborn & Ehmke, 2023), whereby in particular the boundary infrastructure plays an important role, composed of 'boundary spanners', 'boundary objects' and 'boundary practices' (Farrell et al., 2022; Penuel et al., 2015). But such processes also need to be facilitated by formal and informal mechanisms. The first of these includes structured processes, such as strategic alliances, where knowledge transfer is often governed by formal agreements. Informal mechanisms rely on social interactions, networks and communities of practice (Castaneda & Cuellar, 2020). These informal channels are crucial for tacit knowledge transfer. Both formal and informal mechanisms depend on social capital, which encompasses trust, norms and networks, in fostering an environment conducive to knowledge sharing (Brown, 2021). Additionally, digital platforms, collaborative tools and information systems can enable seamless communication and data exchange across geographic and organizational boundaries.

Collaborative knowledge sharing leads to numerous benefits for innovation: (1) it enables access to a wider pool of expertise, resources and perspectives, which enhance the creativity and quality of innovative outcomes; and (2) organizations can address complex problems more effectively, developing solutions that are more robust and comprehensive. Moreover, collaborative innovation fosters learning and capacity building. Participants gain new insights and skills through their interactions, which can be applied to future projects. This continuous learning loop is essential for maintaining competitive advantage in rapidly changing environments (Castaneda & Cuellar, 2020; da Silva Meireles et al., 2022).

Absorptive capacity as a dynamic capability

Nevertheless, the extent to which knowledge generated in such a cross-boundary collaborative manner is translated into successful change and innovation within an organization is largely contingent upon the internal capacity of that institution to recognize the value of novel external knowledge, process it and utilize it effectively for purposes that align with the organization's goals and those of its members: its ACAP (Cohen & Levinthal, 1990).

ACAP is defined as a set of organizational routines and processes by which organizations ‘acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability’ (Zahra & George, 2002, p. 186). Although ACAP emerged from business environments characterized by competition and the creation of proprietary advantages, its components—acquisition, assimilation, transformation and exploitation of knowledge—can be fruitfully applied to schools as well. In school contexts, external knowledge need not be viewed as a competitive asset, but rather as a resource that can be integrated in service of the common good. While ‘coopetition’ and competitive dynamics are highlighted in ACAP literature, this approach can be balanced by, and integrated with, models from organizational learning and knowledge creation frameworks (eg, Nonaka & Takeuchi, 1995; Wenger et al., 2011), placing stronger emphasis on value co-creation and shared societal aims.

ACAP is domain-specific and path-dependent, meaning that each knowledge domain has its own process and depends on pre-existing knowledge within an organization (Cohen & Levinthal, 1990). The fundamental premise is that ACAP facilitates accelerated organizational learning and a self-reinforcing spiral of knowledge acquisition and utilization. This organizational capability thus enhances an institution's ability to gain and sustain a competitive advantage (Cohen & Levinthal, 1990), mainly by influencing the creation of other organizational competencies (Barney, 1991). Therefore, to ensure the appropriate TI in schools, it is important to focus on the relevant knowledge, that is, information and communication technology (ICT) knowledge. It is dynamic in that it represents the ability to integrate, build and reconfigure internal and external competencies to respond to a rapidly changing environment characterized by uncertainty and dynamism (Bogers et al., 2019).

Three contingency factors are typically considered relevant (Crain-Dorough & Elder, 2021; Todorova & Durisin, 2007; Zahra & George, 2002): *activation triggers*, *social integration mechanisms* and *regimes of appropriability*. However, there is a lack of consensus regarding the precise functioning of these factors. ACAP as organizational learning and driver of innovation has so far mainly been investigated in studies on management and performance in business settings (Cohen & Levinthal, 1990; Lane et al., 2001; Sancho-Zamora et al., 2021; Zahra & George, 2002). Meta-studies proved its positive effect, among others, on technological innovation, organizational learning, financial performance and knowledge transfer (Apriliyanti & Alon, 2017; Maldonado et al., 2018; Song et al., 2018; Zou et al., 2018). But studies on effects in educational contexts are rare. Insofar as ACAP is addressed in those, it is mainly undertaken as part of investigations on overcoming the persistent gap between research and practice (Crain-Dorough & Elder, 2021): for example, by analysing collaborative formats, such as RPPs (Farrell et al., 2019; Farrell & Coburn, 2016).

Studies on applying these frameworks to school settings and thus investigating schools' organizational learning and innovation capacity are again lacking. Those that exist include the investigations by Harvey et al. (2009, 2011), which examined ACAP as a framework to assess organizational learning capability and identify key areas for improvement for underperforming organizations in the public sector. Furthermore, Da'as and Qadach (2020) created an ACAP measurement instrument for the school context, while Da'as et al. (2020) investigated the mediating role of school ACAP and teacher's commitment. Finally, Lenart-Gansiniec et al. (2022) identified context-specific antecedents to schools' ACAP. Figure 1 presents a condensed model of ACAP, including its antecedents, moderators and effects.

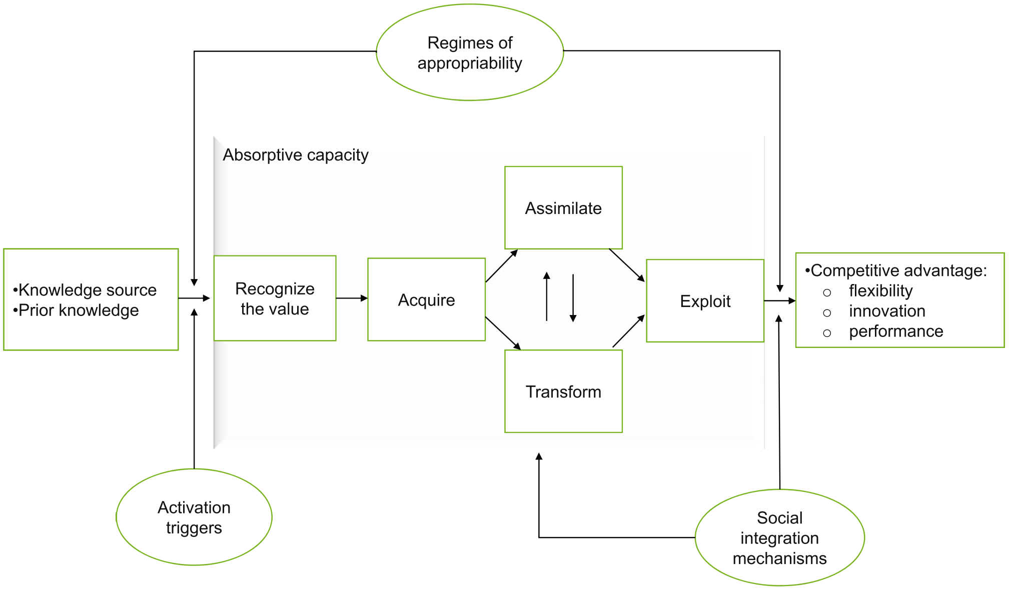

FIGURE 1 An absorptive capacity (ACAP) model for schools.

Research hypotheses

Against this backdrop, the first objective of our study was to investigate whether ICT ACAP exerts any influence on TI, understood as SAMR, which encompasses substitution, augmentation, modification and redefinition of technology use for teaching and learning at the school level. Our second objective was to examine the extent to which ACAP enables the transfer of externally sought knowledge and to elucidate the role of contextual factors, specifically activation triggers, regimes of appropriability and social integration mechanisms, in this process.

In line with Backfisch et al. (2021), we understand TI as an important educational innovation to enhance teaching and learning processes in the 21st century. Hence, our research is guided by the recommendations set forth in the Oslo Guidelines for Collecting, Reporting and Using Data on Innovation (OECD/Eurostat, 2018), the Frascati Manual for Measuring Scientific, Technological and Innovation Activities (OECD, 2015), as well as the Copenhagen Manual for measuring public sector innovation (CO-PI, 2021).

Consequently, our study is guided by the following three questions:

R1. Does ICT ACAP positively relate to TI in schools?
R2. Does ICT ACAP mediate the relationship between external knowledge and TI in schools?
R3. Does the magnitude and effect of ICT ACAP on TI depend on contingency factors?

METHODS

Sample

Our analyses are based on a random sample of school leaders that is representative of Germany. The data were collected in Autumn 2021 by *forsa* Institute for Social Research and Statistical Analysis in accordance with ESOMAR guidelines. Participants were recruited through forsa's Omnibus and Omninet panels, which include approximately 100,000 participants and are representative of the German-speaking population in Germany, and in which a random sample of approximately 1000 individuals aged 14 and over are interviewed daily on a mixed topic basis, including questions about their current occupation. The target population comprised principals of all general education schools in Germany, with stratification by school type, gender and region (East and West Germany) to ensure representativeness. In this way, school leaders ($N=411$) were randomly identified, resulting in a nationally representative sample for general education schools in Germany. Participants received personalized access to an online questionnaire, also hosted by *forsa*.

53.2% of the schools are primary, 38.8% secondary and 8.0% represent other kinds of education, including special-needs education (2.0%). The average total enrolment is $N=381$ students, with a standard deviation of 316 and a range from the 5th to the 95th percentile of 60 to 1027 students. Competition with other schools in the local school market is relatively high: on average a school competes with 2.28 schools (SD: 1.11) for students, with only 18% of schools not facing any competition.

Measures

Technology integration (TI)

Following the assumption that TI in schools is considered an important educational innovation (Backfisch et al., 2021), we assessed the construct using the European Community Innovation Survey (CIS; Behrens et al., 2017) framework, which is based on the Oslo Guidelines for collecting, reporting and using data on innovation (OECD/Eurostat, 2018). The survey was conducted in accordance with the guidelines outlined in the *Copenhagen Manual for Collecting Innovations in the Public Sector*, which provides a framework for implementing Innovation Barometer-type surveys (CO-PI, 2021). To meet the objectives of this study, questions Q5, Q6, Q7 and Q9 from the questionnaire included in Appendix 2 of the manual were adopted and adapted. Minor modifications were made to these questions to align them with the specific requirements of the study. Consequently, we followed an open, qualitative approach: First, school leaders were asked whether any process innovations in pedagogical work, that is, teaching and instruction, had been introduced in their school in the past 12 months, using a binary-coded item (0 = no, not introduced, 1 = yes, introduced). If school leaders answered ‘yes’, they were then asked to identify up to three of the most important innovations in the past 12 months, using open-ended fields that were ranked by them in order of importance. In relation to these statements, in a third step, they were asked to justify why they considered these innovations to be important, again in free-form fields.

Next, we binary coded the open-ended responses, where digital innovation refers to the appropriate use of digital media in teaching and learning (0 = no innovation at all or no digital innovation, 1 = digital innovation). Subsequently, we used the specific answers given for digital innovations and the associated justifications to categorize these innovations according to the SAMR scheme (Puentedura, 2006; Tunjera & Chigona, 2020), following the coding scheme of Crompton and Burke (2020). For example, the following innovations were coded as *substitution*: The digitalization of the class register; synchronous digital teaching; and the introduction of video-conferencing systems, with the aim (justification) of contributing to a ‘switch to digital documentation and communication’. For *augmentation* we coded answers, such as: The introduction of a digital learning platform; the use of the school's own messenger for communication between teachers and parents; and the use of digital tools in the classroom for collaboration and communication. It was not possible for us to separate the two SAMR dimensions *modification* and *redefinition*. Hence, we combined them in a single dimension. Exemplary answers were: The use of learning apps in the classroom; the use of digital devices and methods, justified by the argument that they offer 'additional technical possibilities for learning and teaching processes'; and expansion of digital teaching in collaboration with the university justified with the argument that 'we wanted to give the students this opportunity to experience and try out new things for themselves'.

According to surveyed school leaders, $N=328$ (78.8%) schools have implemented innovations in teaching and instruction in the past 12 months; $N=81$ (19.2%) schools have not implemented any innovations; no data on innovations were provided by 2.0% of school leaders. $N=208$ of the innovations that were mentioned were coded as digital innovations. Accordingly, digital innovations were introduced at around half of all schools (50.6%) in the 12 months prior to the survey. Correspondingly, other (28.2%) or no (19.2%) innovations were implemented in $N=201$ schools. The majority of digital innovations involve TI at the substitution level ($N=125$); $N=53$ of the innovations fall into the augmentation category; and very few digital innovations fall into the combined modification and redefinition category ($N=30$). For our analyses, we treated TI as a metric variable, coded 0 to 3. Accordingly, the variable we use is a ratio scale that includes an absolute or true zero (Stevens, 1946), indicating the total absence of digital innovations in a given school, and assumes a hierarchical structure of SAMR.

External knowledge

To assess the knowledge inflow in schools, that is the amount and diversity of external knowledge utilized by schools for digital innovation, we followed the Oslo Guidelines for collecting, reporting and using data on innovation (OECD/Eurostat, 2018). Specifically, we adopted the approach of Laursen and Salter (2006) to measure inbound open innovation, focusing on both open innovation depth (the amount or intensity of external knowledge) and open innovation breadth (the diversity of external knowledge) employed in innovation. To capture this, school leaders were asked where the external knowledge for the reported innovations came from (base question: 'Now we would like to know where the knowledge came from for pedagogical innovations, ie, teaching and instruction, introduced at your school in the last 12 months.'). In line with the guidelines of both the Oslo Manual (OECD/Eurostat, 2018) and the Frascati Manual for measuring Scientific, Technological and Innovation Activities (OECD, 2015), we broadly categorized the sources of knowledge into four main groups: schools and business enterprises, government, higher education and private non-profit organizations and individuals. Additionally, we incorporated knowledge flows from conferences and literature as potential sources, in alignment with the OECD Manual (OECD/Eurostat, 2018, tab. 6.7).

Precisely, we provided eight potential knowledge sources (item stem: 'The knowledge we used for the innovations came from…'): (a) parents, guardians, (b) other schools, (c) authorities, state institutes, (d) universities and other scientific institutions, (e) independent school-improvement consultants, (f) commercial companies, (g) professional trainings and/or conventions, and (h) professional literature. All items were measured on a 6-point scale ranging from 'not at all' to 'to an exceptionally high degree'. Following Laursen and Salter (2006), two new manifest variables were created from these data as sum scores: Open Innovation Depth represents the sum of the eight knowledge source items. The ordinal Cronbach's alpha for this scale was $\alpha=0.72$. The same items were used to determine open innovation breadth by first coding the 'not at all' category as zero and the other five categories as one, and then summing the number of all external knowledge sources and dividing by eight. This index of open innovation breadth thus has a minimum of zero (no external innovation sources used) and a maximum of one (all possible external innovation sources used). The ordinal Cronbach's alpha of the open innovation breadth scale was $\alpha = 0.84$.

ICT absorptive capacity

Because we asked school leaders about their school's ICT ACAP, we adapted a scale from Schweisfurth and Raasch (2018), based on the preliminary work of Lowik et al. (2012), to measure our central construct. To help respondents understand what is meant by ICT knowledge, the following explanation, based on Katz (2007), was provided: 'Information and communication technology (ICT) knowledge involves knowledge of digital technologies and their appropriate use. It includes the ability to use technology as a tool to locate, organize, evaluate, and communicate information, as well as a basic understanding of the ethical/legal issues involved in accessing and using this information and technology'. Accordingly, the definition of ICT knowledge utilized within our study follows the idea of ICT literacy and is based on the notion that such literacy predominantly involves knowledge about the autonomous use of technologies for processing information, specifically the ability to access, evaluate and manage information (Hübner et al., 2023). A total of six items measure a school's ability to recognize, assimilate and apply new ICT knowledge. Items were answered on a 4-point scale (1 = strongly disagree, 4 = strongly agree). Example items were: 'We can easily identify the information and communication technology (ICT) knowledge that is most valuable to us.'; 'We translate new information and communication technology (ICT) knowledge into a language that everyone in the school understands.'; and 'We exploit newly acquired information and communication technology (ICT) knowledge to change teaching'. The ordinal Cronbach's alpha of the ICT ACAP scale was $\alpha = 0.91$.

Contingency factors

According to Zahra and George (2002) and Todorova and Durisin (2007), the effectiveness of ACAP and the way it harnesses external knowledge in organizations is influenced by contingency factors, namely *activation triggers*, *social integration mechanisms* and *regimes of appropriability*:

- *Activation triggers*. One item was developed to investigate an event that was expected to encourage a school to respond (Zahra & George, 2002) to the lack of ICT literacy of teachers within a school: 'What challenges does your school face and how big do you think they are? Heterogeneity among teachers in technical/digital literacy'. This item was answered on a 4-point scale (1 = no challenge, 4 = extreme challenge).
- *Social integration mechanisms*. To assess the mechanisms that facilitate sharing relevant knowledge in schools (Zahra & George, 2002), we adapted five items from Donate and Sánchez de Pablo's (2015) knowledge transfer practices scale. The base question was: '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 sharing take place within the school in the last 12 months?'. An example item is: 'There were projects involving interdisciplinary teams or working groups to share knowledge'. Items were answered on a 4-point scale (1 = strongly disagree, 4 = strongly agree). The ordinal Cronbach's alpha of the knowledge-sharing scale was $\alpha = 0.79$.
- *Regimes of appropriability*. To measure the extent to which knowledge and innovation in schools are institutionally protected from imitators (strong regime) and shared (weak regime) in collaborations and alliances (Teece, 1986), we adapted Bouncken and Fredrich's (2012)

coopetition scale. The scale captures the paradox of simultaneously collaborating and competing with other schools, as coopetition is regarded an essential prerequisite for technological innovations, especially in dynamic environments (Corbo et al., 2023; Jorde & Teece, 1990). It should be noted that appropriability goes beyond coopetition and that in this regard, only one aspect of appropriability is examined here. An example item was: 'We collaborate with schools with which we compete for students to achieve common goals'. The four Items were answered on a 4-point scale (1 = strongly disagree, 4 = strongly agree). The ordinal Cronbach's alpha of the coopetition scale was $\alpha = 0.85$.

Data analyses

For evaluating the effects of ACAP, we applied structural equation modelling (SEM) in M*plus* 8.6 (Muthén & Muthén, 2021) and used Full Information Maximum Likelihood (FIML) to address missing data (Lei & Shiverdecker, 2020). Preliminary, we checked for multicollinearity by predicting SAMR with the observed independent variables in a linear regression model, and variance inflation factor values were lower than 3.60, which is considered acceptable (Grewal et al., 2004; Kline, 2016). In order to assess the goodness of fit of the models, we used the standardized root mean square residual (SRMR) and the comparative fit index (CFI), with cut-offs of SRMR <0.08 and CFI >0.95 (Schermelleh-Engel et al., 2003; Shi & Maydeu-Olivares, 2020). As explained in the measures section and depicted in Figure 2, only ACAP was treated as a latent variable, and the dependent variable was treated as a continuous variable. To assess indirect or mediated effects, we further tested the robustness of the mediation effects through bootstrapped mediation analysis that provides 95% bias-corrected bootstrap confidence intervals with 5000 bootstrap replications (Hayes, 2018; Preacher & Hayes, 2008). Indirect effects are significant if the 95% confidence intervals (CIs) do not include zero (Hayes, 2018). From a sensitivity analyses approach, we tested the same equations with the dependent variable declared as categorical.

As a second step, we investigated the role of contingency factors in the relation between external knowledge, ACAP and TI in schools applying a classification and regression trees (CART) procedure (Breiman et al., 1984) as a machine-learning approach using *R*. This approach was adopted due to the lack of clarity surrounding the precise nature of the relationships

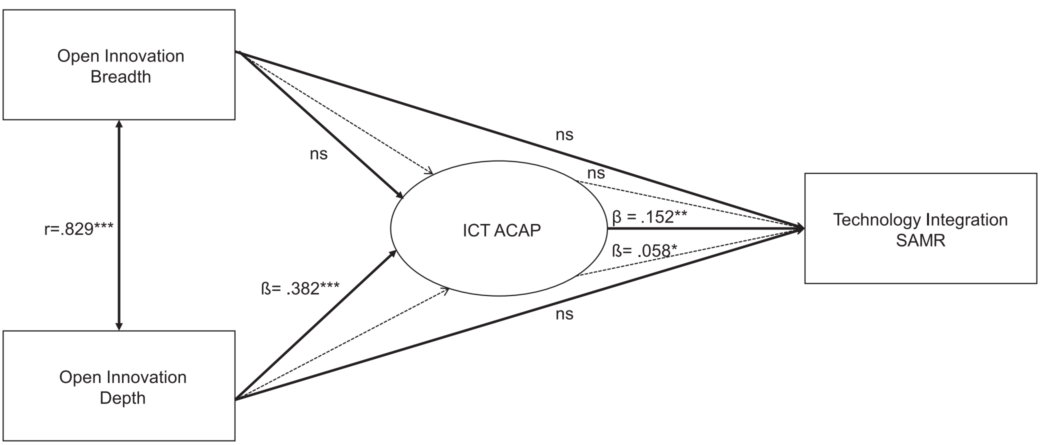

FIGURE 2 Structural equation model on open innovation breadth and depth, information and communication technology (ICT) knowledge absorptive capacity (ACAP) and Substitution, Augmentation, Modification, Redefinition (SAMR). *$p < 0.05$, *$p < 0.01$, ***$p < 0.001$, ns = not significant.

between variables in the ACAP model. Additionally, even valid controls may be endogenous, representing a combination of multiple causal mechanisms (Hünermund & Louw, 2020; Pietsch et al., 2025). Consequently, the CART procedure, a machine-learning approach, was employed to predict TI without making assumptions about linearity or predefined non-linearity (ie, SEM). The *rpart* function (Therneau & Atkinson, 2014) was chosen to implement the algorithm that divides data into subsets based on the predictive power of independent variables with a minimum subset size of 20 to prevent overfitting. A successful implementation of CART can be used for sensitivity analysis and can uncover additional predictive insights (Hilbert et al., 2021; Leavitt et al., 2021). We used *rattle* (Williams, 2011) to visualize CART results.

RESULTS

Descriptives and correlations

The results of the descriptive statistics are presented in Tables 1 and 2. They show that TI in schools ranged between non-existent and substitution (M_{SAMR} = 0.781). Schools, on average, used five knowledge sources for educational innovation (M_{INNO_B} = 5.12) but generally incorporated little external knowledge into internal school innovations (M_{INNO_D} = 19.10). The heterogeneity of teachers' ICT skills was seen as a major to extreme challenge (M_{CHAL} = 3.24). ICT ACAP in schools was at a medium level (M_{ACAP} = 16.50) as is knowledge sharing (M_{KS} = 13.30). In contrast, there was little collaboration between schools with which they are in competition for students; hence, coopetition (M_{COOP} = 6.05).

TABLE 1 Descriptive statistics of variables.

	SAMR	INNO_B	INNO_D	CHAL	ACAP	KS	COOP
N	411	398	398	411	388	403	373
Missing	0	13	13	0	23	8	38
Mean	0.78	5.12	19.10	3.24	16.50	13.30	6.05
Median	1.00	5.00	19.00	3.00	17.00	13.00	6.00
SD	0.93	1.99	5.40	0.77	3.53	3.45	2.41
Minimum	0	0.00	8.00	1.00	6.00	5.00	3.00
Maximum	3	8.00	37.30	4.00	24.00	20.00	12.00

Abbreviations: ACAP, ICT absorptive capacity; CHAL, challenge: heterogeneity among teachers in ICT literacy; COOP, coopetition; INNO_B, open innovation breadth; INNO_D, open innovation depth; KS, knowledge sharing; SAMR, SAMR TI.

TABLE 2 Correlation coefficients for variables.

	SAMR	INNO_B	INNO_D	CHAL	ACAP	KS	COOP
SAMR	–						
INNO_B	0.017	–					
INNO_D	0.036	0.829***	–				
CHAL	−0.119*	0.006	0.071	–			
ACAP	0.139**	0.142**	0.227***	−0.119*	–		
KS	0.140**	0.252***	0.323***	−0.054	0.413***	–	
COOP	0.064	0.148**	0.148**	−0.026	0.237***	0.254***	–

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Correlation coefficients indicate that TI in schools was significantly lower when teacher heterogeneity in ICT literacy was perceived as a challenge ($r=-0.119$, $p<0.05$). ICT ACAP ($r=0.139$, $p<0.01$) and knowledge sharing ($r=0.140$, $p<0.01$), however, are linked to increased TI in schools. Consistent with the theory, a positive correlation between external knowledge and ICT ACAP ($r_{INNO\_D}=0.227$, $p<0.001$; $r_{INNO\_B}=0.142$, $p<0.01$) and knowledge sharing ($r_{INNO\_D}=0.323$, $p<0.001$; $r_{INNO\_B}=0.252$, $p<0.001$) was observable. Also, in line with theory, we found positive correlations between ACAP and both knowledge sharing ($r=0.413$, $p<0.01$) and coopetition ($r=0.237$, $p<0.01$) and a negative correlation between ICT ACAP and teacher heterogeneity in ICT literacy perceived as a challenge ($r=-0.119$, $p<0.05$).

Structural equation model

Next, we investigated the fit of our ACAP measurement model and constructed the basal SEM shown in Figure 2. Confirmatory factor analyses (CFA) for the ICT ACAP model resulted in a good fit, with CFI = 0.98 and SRMR = 0.03. In the theory-driven SEM, we allowed for the correlation between open innovation breadth and depth ($r=0.829$, $p<0.001$) and regressed both measures of external knowledge on ICT ACAP and ICT ACAP on TI in schools. The results revealed a statistically significant relation between open innovation depth and ICT ACAP ($\beta=0.382$, $SE=0.093$, $p<0.001$) and between ICT ACAP and TI in schools ($\beta=0.152$, $SE=0.055$, $p<0.01$). The path between open innovation breadth ($\beta=-0.162$, $SE=0.095$, $p>0.05$) and ICT ACAP as well as the direct paths of both open innovation depth ($\beta=0.014$, $SE=0.091$, $p>0.05$) and open innovation breadth ($\beta=-0.017$, $SE=0.089$, $p>0.05$) on TI in schools showed no relevant associations. In our sensitivity analyses in which the dependent variable was treated as categorical, decisions on statistical significance remained the same; specifically, the relation between open innovation depth and ICT ACAP ($\beta=0.371$, $SE=0.082$, $p<0.001$), ICT ACAP and TI ($\beta=0.182$, $SE=0.064$, $p<0.01$), open innovation breadth and ICT ACAP ($\beta=-0.153$, $SE=0.083$, $p>0.05$), open innovation depth ($\beta=0.026$, $SE=0.112$, $p>0.05$) and open innovation breadth ($\beta=-0.018$, $SE=0.103$, $p>0.05$) on TI.

Furthermore, the standardized indirect effect of open innovation depth on TI via ICT ACAP was positive and significant ($\beta=0.058$, $p<0.05$; 95% CI [0.017, 0.122]) and the standardized indirect effect of open innovation breadth on TI via ICT ACAP was negative and insignificant ($\beta=-0.025$, $p>0.05$; 95% CI [−0.074, 0.001]). The model fit was good, with CFI = 0.95 and SRMR = 0.033. In total, the model accounted for 7% of the between-school variance in ICT ACAP, and 2% of the variance in TI in schools. The observed effect of ICT ACAP on TI, however, is meaningful, with an incremental f^2-value (Fey et al., 2023) of 0.069. This value is well above the cut-off suggested by Cohen (1992), that is, 0.02, and the effect size can therefore be considered between small and medium.

Classification and regression trees—Base model

According to Leavitt et al. (2021), machine learning can act as a tool to test and prune mid-range theory and as a catalyst to expand the explanatory range that theory can inhabit. As such, it can play a critical role in validating empirical models in educational research (Hilbert et al., 2021). Consequently, we applied CART as a data-driven machine-learning approach to investigate the relations and interactions of our model variables open innovation depth, open innovation breadth, ICT ACAP and their joint impact on TI in schools. As suggested by McClure et al. (2024), we first tested the predictive power of items instead of scale scores. To compare the predictive accuracy of CART with scale scores and CART with items, we employed 5000 resamples using the *caret* package (Kuhn, 2008), in which the median

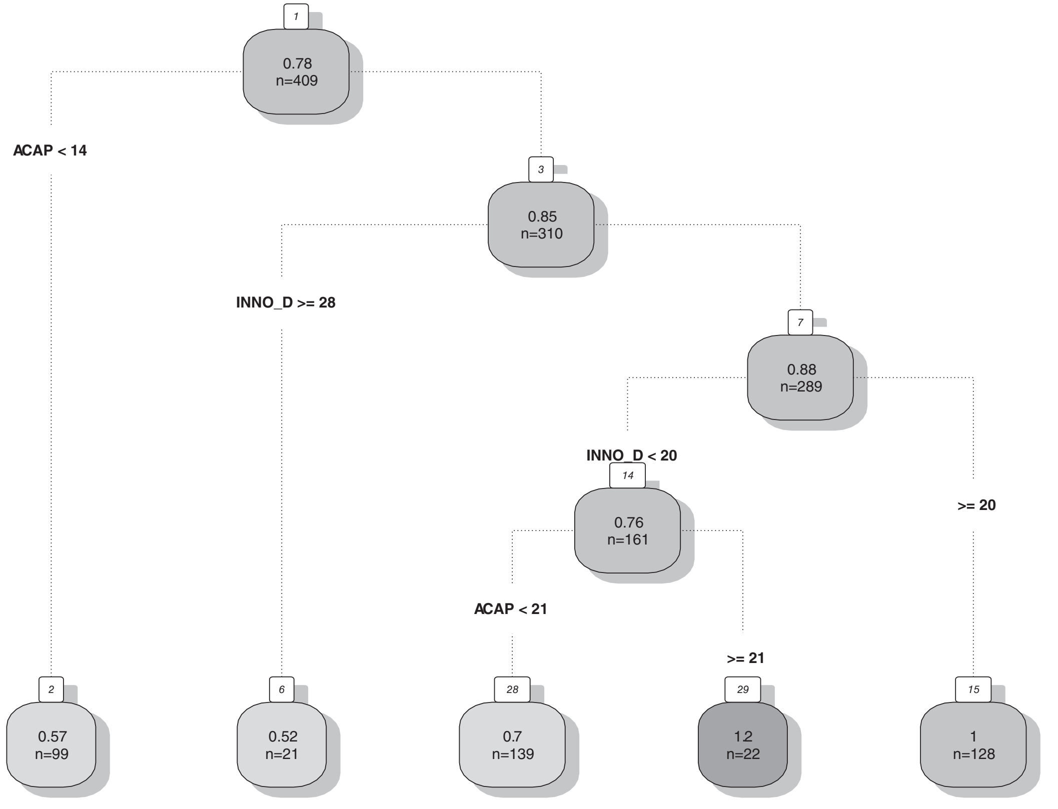

FIGURE 3 CART plot for the base model, without contingency effects.

value of the root mean square error was 0.946 with scale scores and 0.936 with items as predictors. This indicates slightly better performance for the former, so we report results for the model in which we used scales (Figure 3).

The CART results indicated that all predictors have at least 10% importance to predict TI in schools with the following weights: (1) ICT ACAP 56%; (2) open innovation depth 33%; and (3) open innovation breadth 10%. Of these three variables, ICT ACAP is therefore the most relevant variable for successful TI. It also becomes clear how relevant the interaction of the different factors for a successful TI in schools is and that non-linear effects are observable: a generally very low probability of TI can be seen when the ICT ACAP of a school is rather low (ACAP < 14), but also when ICT ACAP is comparatively high (ACAP > 14), while simultaneously the open innovation depth is extremely high (OI_D > 28). On the contrary, schools with a very high ICT ACAP (ACAP ≥ 21) and an open innovation depth at a medium range (OI_D < 20) have a particularly high probability of successful TI that goes beyond substitution.

Classification and regression trees analysis—Contingency model

To address research question 3, we added contingency factors to our CART model—while keeping ICT ACAP, open innovation depth and open innovation breadth—to explore the role of contingency factors, that is, the reported within-school heterogeneity of ICT literacy of teachers (=challenge), knowledge-sharing mechanisms and coopetition. Results are depicted in Figure 4 indicating interactions among variables.

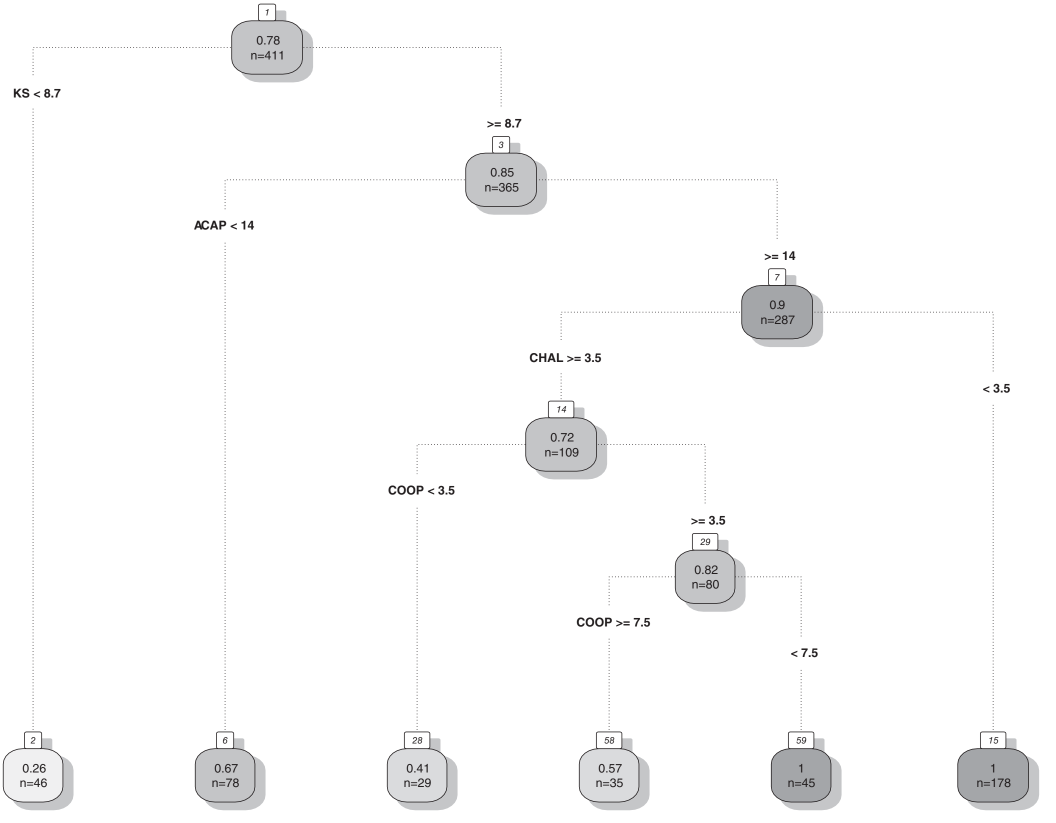

FIGURE 4 Classification and regression trees (CART) plot for contingency effects, hierarchical Substitution, Augmentation, Modification, Redefinition (SAMR).

CART results indicated that knowledge sharing, coopetition, heterogeneity of teachers' ICT literacy in school and ICT ACAP were important variables with weights 47%, 19%, 18% and 12% respectively. It can be seen that TI is almost impossible in schools with low level of internal knowledge sharing (KS < 8.7). Where knowledge-sharing mechanisms are more pronounced in a school (KS ≥ 8.7), ICT ACAP comes into play: Where ICT ACAP tends to be highly developed (ACAP ≥ 14) and the heterogeneity of teachers' ICT skills is not seen as an extreme challenge (CHAL < 3.5) the combination of high knowledge sharing and high ICT ACAP jointly lead to stronger TI in schools. But even if the heterogeneity of ICT literacy is seen as an extreme challenge (CHAL ≥ 3.5), TI in schools can succeed. This mainly depends on a school's coopetition: If coopetition is low (COOP < 3.5), TI in schools is unlikely to succeed; if it is high(er) (COOP ≥ 3.5) but not extreme (COOP < 7.5), it can almost offset the negative effects of heterogeneous ICT literacy of teachers within a school in combination with pronounced knowledge-sharing mechanisms (KS ≥ 8.7) and a decent level of ICT ACAP (ACAP ≥ 14) in a school. Overall, the model explains 15.3% of the variance in TI across schools.

Classification and regression trees analysis—Contingency model 2

Our analysis to now modelled SAMR-compliant TI in schools as a metric variable. However, it is also assumed that the 'SAMR model is not hierarchical but, rather, a fluid model of technology integration' (Hamilton et al., 2016, p. 439). Accordingly, in the final step, we

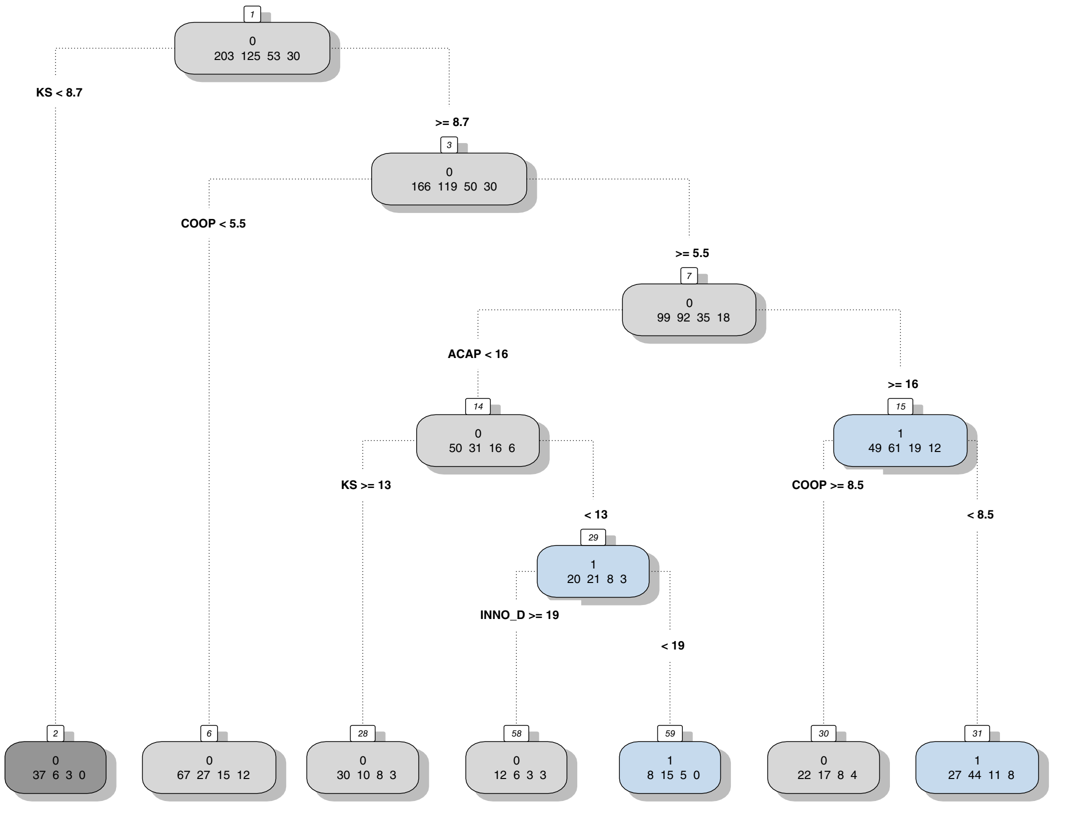

FIGURE 5 Classification and regression trees (CART) plot for contingency effects, categorical Substitution, Augmentation, Modification, Redefinition (SAMR).

tested whether the CART results were different when we treated the dependent variable as categorical (no digital innovation vs. substitution vs. augmentation vs. modification and redefinition) and applied a logistic CART model. The results are depicted in Figure 5.

The results were very similar to the previous model. Again, knowledge sharing in school plays an important role: when it is low ($KS < 8.7$), augmentation is hardly observed, and substitution, modification and redefinition are nearly not observed at all. In general, there is little TI in schools with low levels of knowledge sharing among staff. But even when knowledge sharing is high(er) ($KS \geq 8.7$) but coopetition is extremely low ($COOP < 5.5$), there is little significant TI in schools. However, technology is increasingly integrated into school when ICT ACAP is high ($ACAP \geq 16$) and coopetition is moderate ($5.5 < COOP < 8.5$). At relatively lower levels of ICT ACAP ($ACAP < 16$), however, knowledge sharing and open innovation depth make a crucial difference: if knowledge sharing is moderate ($8.7 \leq KS < 13$) and open innovation depth is not extreme ($OI\_D < 19$), TI in schools is more likely also to be observed than none.

DISCUSSION, LIMITATIONS AND OUTLOOK

Summary of results

The findings from the SEM highlight the significant role of ICT ACAP in influencing TI in schools. Our results demonstrate that higher levels of ACAP are associated with more effective TI, aligning with the observations of Backfisch et al. (2021) on the importance of high-quality application of TI. This study extends these findings by explicitly linking the quality of application, as represented by ACAP, to successful TI outcomes.

Moreover, our SEM analysis reveals that ICT ACAP mediates the relationship between external knowledge and TI in schools, underscoring the role of ACAP in facilitating the absorption and application of external knowledge, further enhancing TI. The mediation effect observed supports the theoretical framework proposed by Zahra and George (2002), which posits that ACAP serves as a crucial intermediary in the innovation process by enabling organizations to effectively leverage external knowledge.

Our CART results, further, indicate a curvilinear relationship, where moderate levels of innovation depth combined with high ICT ACAP lead to higher TI. This finding resonates with the study from Brown and Graydon (2017), which highlights the potential for increased teacher anxiety and dilution of effective practice when confronted with extensive external knowledge sources. CART analysis also identifies the critical role of knowledge sharing within schools in fostering TI. Effective knowledge-sharing practices enable continuous, collegial learning among teachers and school leaders, which is essential for adapting and evolving their knowledge and practices in response to changing educational demands (Brennan et al., 2021; Brown et al., 2024; Darling-Hammond et al., 2017; Mo et al., 2021).

At the same time, our CART analysis reveals that the effectiveness of ICT ACAP depends on contingency factors, including *activation triggers*, *social integration mechanisms* and *regimes of appropriability*, supporting the theoretical models of Zahra and George (2002), Todorova and Durisin (2007), and Crain-Dorough and Elder (2021). The interplay of these contingency factors determines the success of ACAP in facilitating TI, underscoring the need for a supportive organizational environment.

Another significant finding from the CART analysis is the role of coopetition in mitigating the challenges of heterogeneity in teachers' ICT literacy. Coopetition can facilitate continuous learning and knowledge exchange among schools, leveraging social capital resources to enhance TI (Brown et al., 2024). Inter-school networks and RPPs are particularly effective in promoting knowledge transfer and creating learning loops among educators and researchers (Fischer-Schöneborn & Ehmke, 2023). Likewise, Harvey et al. (2009) show that ACAP can be improved by establishing internal and external networks.

Finally, two configurations appear promising for stimulating TI in schools. The first involves a balanced interaction of moderate knowledge sharing, moderate ICT ACAP and high coopetition. This configuration promotes collaborative knowledge sharing while maintaining focused knowledge inflows. The second configuration includes high levels of knowledge sharing, high ICT ACAP and moderate coopetition, which supports the development and application of internal capabilities, such as the ability to identify, assimilate and utilize new ICT knowledge effectively, alongside fostering external collaborations. Both configurations emphasize the importance of a synergistic approach to knowledge mobilization and technological innovation.

Limitations

One limitation of our study is the exploratory nature of the CART results. While CART can handle non-linear relationships and interactions between variables, it is sensitive to the sample size and prone to overfitting, especially when small data subsets are used. To mitigate this risk, we used a minimum bucket size parameter to control for overfitting.

Another limitation concerns the representativeness of the sample. While our data are nationally representative of German school leaders, the generalizability of the findings may be limited to similar educational contexts and may not fully capture the nuances present in other countries or regions with different educational systems, cultural factors and technological infrastructures.

Additionally, the cross-sectional nature of the data limits our ability to make causal inferences. The relationships observed between ICT ACAP, external knowledge, knowledge sharing and TI provide valuable insights, but longitudinal data would be necessary to confirm these findings and better understand temporal dynamics. Also, potential biases due to the use of an online questionnaire have to be considered.

Lastly, our reliance on self-reported measures, such as school leaders' perceptions of knowledge sharing and technology integration, may introduce bias. With regard to knowledge flows across organizational boundaries, specifically open innovation, we followed the measurement approach suggested by Laursen and Salter (2006) and therefore measured open innovation breadth (the number of sources used) and depth (the intensity of collaboration with each source) by coding the same items differently. Although the correlation between both measures is acceptable and consistent with findings from other authors, it may be reasonable to use different measures, especially objective measures (Carrasco-Carvajal et al., 2023). In business innovation research, joint patents (Zhu et al., 2021) or the use of E-collaboration tools (Aloini et al., 2015) are used for this purpose, for example. This also applies to the reported innovations, as the information provided by the school leaders does not allow for any statements to be made about the variation within the school, for example, between teachers or classes. Therefore, future studies could benefit from incorporating more objective measures, surveying teachers too and triangulating data sources to validate the self-reported information.

Conclusion and future research

The findings of this study have implications for policymakers and educational leaders, who could prioritize the establishment of ACAP and foster collaborative networks with the objective of creating more adaptable and innovative school environments. Already in their seminal work, Cohen and Levinthal (1990) established a link between prior knowledge, ACAP and innovation. The fundamental premise is that ACAP facilitates accelerated learning and a self-reinforcing spiral of knowledge acquisition and utilization (Zahra & George, 2002). Our study demonstrates, for the first time in the context of education, that the aforementioned assumptions can be applied to schools too. In particular, it becomes evident that the extent of TI in schools is contingent upon a school's capacity to acquire, assimilate, transform and exploit new knowledge that can be linked to prior knowledge already existent within the school.

This is a new and important finding, given the fact that a lack of technological knowledge, knowledge about integrating technology, technology-enhanced pedagogical knowledge and knowledge about technology-related classroom management have been identified as significant barriers for schools, affecting their ability to effectively integrate technology (Ertmer, 1999; Hew & Brush, 2007; Wilson et al., 2020). The presented findings, thus, illuminate the mechanisms underlying TI in schools, highlighting why school development, innovation and change in this area presents significant challenges. That is, because successful implementation of comprehensive, school-wide TI requires a pre-existing foundation of knowledge, active efforts to acquire new linkable knowledge and goal-oriented collaboration, even with competing schools. Consequently, TI in schools cannot be reduced to a straightforward, unidirectional transfer of knowledge. Instead, it represents a future-oriented, continuous, multifaceted process involving self-appropriation and the co-construction of knowledge and practice.

With this in mind, it is noteworthy that the definition of ICT knowledge employed in our study is grounded in the definition of digital literacy (eg, see Hübner et al., 2023; Siddiq & Scherer, 2019). Following this understanding, ICT knowledge is defined as a domain-general construct: that is, a construct that can be applied across a variety of technology-related knowledge domains (Hübner et al., 2023). Consequently, as Gilster (1997, p. 2) notes, such knowledge is thus 'about mastering ideas, not keystrokes'. In addition, ICT knowledge ACAP is viewed as an organizational level construct that focused on collective knowledge exploration and exploitation, an approach that is relatively new to research on TI in schools (eg, see Yeh et al., 2021). In this context, the results confirm the assumption made by others (Avidov-Ungar & Eshet-Alkalai, 2014; Hakkarainen, 2009) that collective technology-related knowledge is positively associated with TI. However, our findings go well beyond previous assumptions, which usually assume that such knowledge is co-created (but between teachers) within schools (Yeh et al., 2021). Rather, we find it important that such knowledge is also co-created with other actors beyond the boundaries of the school if TI is to be successful in schools.

This leads to three main conclusions: First, as Consoli et al. (2023) recently defined as a result in a systematic review on the subject, TI is less an outcome than a process. This implies that a school needs to iterate, that is analyse the landscape for potential development and innovation opportunities, adapt promising discoveries to its specific context, and ultimately deliver and implement them (Reich, 2023). Consequently, TI as an 'innovation is a cycle that learns from previous deliver phases to enhance discover, develop, and deliver phases of future initiatives' (Kahn, 2018, p. 459). As a consequence, second, knowledge-sharing and management mechanisms within schools are imperative. It seems essential to establish social practices and mechanisms that support the professional development of teachers and the meaningful adoption of technology in teaching by fostering knowledge exchange and creation that extends beyond the individual and the school level (Ley et al., 2022; Witthöft et al., 2024). This, third, makes a strong case for collaborative and knowledge-based TI in schools. Given that a majority of schools is willing and able to engage in innovation processes, yet are unable to create their own unique pathway to change (Slavin, 2005) and lack capacities (Bryk, 2010), the findings present an exceptionally compelling argument for TI through distributed innovation processes based on purposively managed knowledge flows across organizational boundaries, that is open innovation (Pietsch et al., 2023). The results demonstrated: Even if relevant skills and competences within the school are limited, TI can still succeed, but only in collaboration with other actors.

With regard to future research, this suggests that less emphasis should be placed on individual implementations of technology in the classroom and more on understanding how a dynamic cycle of TI in schools can be established and sustained. In this context, it seems particularly important to determine how an accelerated learning process and a self-reinforcing cycle of knowledge acquisition and utilization, with regard to TI in schools and beyond, can be achieved. This particularly requires longitudinal studies and the analysis of knowledge flows within networks (Moolenaar & Sleegers, 2010; Wullschleger et al., 2023) and innovation communities (Lynn et al., 1996). Furthermore, it is essential to consider that ACAP is domain-specific and path-dependent, meaning that the mechanisms and effects could differ for each knowledge domain (Cohen & Levinthal, 1990). In this study, however, we have applied a domain-general construct with regard to technology-related knowledge in schools. In future studies, it would be beneficial to examine ACAP in a more nuanced way, that is, by investigating the individual dimensions of the TPACK model; that is, technological knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK), as well as their overlaps; hence, technological pedagogical knowledge (TPK), technological content knowledge (TCK) and pedagogical content knowledge (PCK) ACAP.

Finally, it is important to note, however, that a technology-driven transformation of schools is not an end in itself. Rather, the objective of such innovations and changes should be to empower and encourage teachers and all those involved in schooling to utilize new technologies for the greater good of their students (Navaridas-Nalda et al., 2020). Thus, in essence, the objective should be to establish an appealing vision of technology integration in schools that serves as a guiding principle for future actions (Dexter & Richardson, 2020). It would therefore be prudent to investigate whether such visions exist, what they entail, how they guide daily practice and whether they ultimately lead to enhanced learning outcomes among students.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study is available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The data were collected in accordance with ESOMAR (European Society for Opinion and Marketing Research) code of conduct and ethical guidelines. The study was conducted with informed consent and in accordance with applicable rights under the General Data Protection Regulation.

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