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Open innovation networks: a driver for knowledge mobilisation in schools?

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Abstract

Purpose – In organisational and innovation research, the term "open innovation" refers to the inflow and outflow of knowledge to and from organisations: with open innovation theory suggesting active exchanges of knowledge with external actors leads to the development of exploitable new ideas. In the field of education, however, the exchange of knowledge with external parties represents a paradigm shift. In response, this article presents findings from research design to explore the nature and composition of school innovation networks, and the effects of such these networks on knowledge mobilisation.

Design/methodology/approach – The study draws on data from a representative random sample of 411 German school leaders. Respondents were asked to detail their engagement in open and closed innovation activity and their school's external collaborations during the last 12 months. A latent class distal outcome model was developed to examine whether different types of collaboration associate with different knowledge mobilisation processes.

Findings – The study findings suggest that schools in Germany mainly use internal knowledge for innovation, with external knowledge exchange taking place on a very limited basis. Knowledge mobilisation varies depending on the innovation network. The authors use the findings to indicate new insights for how schools can further innovate learning and teaching in future.

Originality/value – Although there is increasing discussion on Professional Learning Networks in schools, the discourse on knowledge mobilisation within educational networks is limited, making concept of open

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innovation so far completely absent from discourses on school improvement. This paper initiates the population of this new research space.

Keywords Open innovation, Innovation networks, Latent profile analysis
Paper type Research paper

Introduction

Schools are historically weak in knowledge sharing within and beyond their institutional borders (Fullan, 2002). Accordingly, they have few systems and little experience in strategic knowledge management (Cheng, 2021). Yet, at the same time, the generation, mobilisation and exchange of knowledge are essential to the introduction of innovation and change in schools and teaching (Greany, 2018). In this context, knowledge is not only a means to an end but also the product of organisational learning: that is, the "change in the organization's knowledge that occurs as a function of experience" (Argote and Miron-Spektor, 2011, p. 124). As Hargreaves (1999) argues, the effective generation, mobilisation and exchange of knowledge in schools must be based on interactive learning processes conditioned by structural and institutional arrangements in complex networks in order to become "milieux of innovation." Seen from this angle, innovation in education is a dynamic collaborative process of various actors and stakeholders across organisational boundaries. Accordingly, Castells (1996, p. 390) state: "What defines the specificity of a milieux of innovation is its capacity to generate synergy, that is the added value resulting not from the cumulative effect of the elements present in the milieux but from their interaction."

In organisational and innovation research, the term open innovation has become established in this regard over the last 20 years, with open innovation referring to "the use of purposive inflows and outflows of knowledge to accelerate internal innovation" (Chesbrough, 2006, p. 1). Open innovation theory assumes that through the active exchange of knowledge with external actors, new ideas emerge and are brought into practice in organisations that would otherwise not be exploited (Chesbrough, 2012). The open innovation approach, however, is less about crowdsourcing or the managed participation of stakeholders and more about an open, distributed mindset of actors in terms of knowledge creation, knowledge mobilisation and knowledge sharing (Chesbrough, 2017). A large number of empirical studies show that the use of external knowledge and the transfer of one's own knowledge to external parties result in significantly improved innovation performance, for example, more, more radical and more creative innovation (Cammarano *et al.*, 2019; Nguyen *et al.*, 2021; West and Bogers, 2014).

Especially for public service organisations, however, the exchange of knowledge with external parties represents a paradigm shift (De Coninck *et al.*, 2021) and, consequently, most public sector organisations are in the early stages of adoption of open innovation (Kankanhalli *et al.*, 2017). Accordingly, Mu and Wang (2022) show in a systematic review that there are currently still a large number of barriers that prevent open innovation from becoming effective in public service organisations, that is, relational-, capacity- and technology-related barriers. However, various studies show that networks that allow a wider range of knowledge types to be recombined can be helpful in overcoming such obstacles and mobilising external knowledge for internal innovation (Tidd and Bessant, 2020; West and Bogers, 2014). Although there is a broad discussion on professional learning networks (PLNs) in schools, the discourse on knowledge mobilisation for schools in networks has only just begun (Poortman and Brown, 2021) and the concept of open innovation is so far completely absent. Our article addresses this research gap.

Theoretical framework

Closed and open innovation in schools

The way an organisation creates and manages knowledge is a key requirement when it comes to successfully implementing innovations (Donate and Pablo, 2015; Grant, 1996). This so-called

knowledge-based view (KBV) of innovation assumes that the superiority and prosperity of an organisation depend on its ability to harness and develop its knowledge resources (Ode and Ayavoo, 2020), an idea that is also increasingly found in educational research (Cheng, 2021; Lenart-Gansiniec *et al.*, 2021; Supovitz, 2010; Stoll and Kools, 2017; Thambi and O'Toole, 2012). These resources can be divided into internal and external knowledge sources (Diáz-Diáz and Sáá-Pérez, 2014). In the context of innovation, Chesbrough (2003) refers to the use of these two sources of knowledge as "closed" and "open" innovation regimes, respectively, and emphasises that organisations are more likely to innovate when they collaborate with external partners and use external knowledge for their own innovations, rather than rely solely on the internal knowledge present within the organisation for this. In this regard, we consider the following definition by Chesbrough (2012, p. 20) helpful:

> "(. . .) the open innovation paradigm can be understood as the antithesis of the traditional vertical integration model in which internal innovation activities lead to internally developed products and services (. . .). The vertically integrated model is what I term a closed innovation model. Put into a single sentence, open innovation is 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation'".

With regard to innovation in schools, the idea of closed innovation corresponds primarily to that of schools as knowledge-creating organisations, which are supposed to develop innovative professional practices and processes from within and in which knowledge creation within the school is central for educational innovation and change (McCharen *et al.*, 2011). However, as Greany (2018, p. 66) argues, it is not enough to rely only on internal school knowledge if schools and teaching are to be sustainably changed, but "we need to understand that change and innovation are orchestrated through complex combinations of vertical and lateral knowledge mobilisation." This means that schools are dependent on exchanging knowledge with equal organisations but also with collaborators who have different and/or exclusive knowledge from their own (Greany, 2022) not least because schools often lack the necessary capacities and resources to generate and implement appropriate knowledge on their own (Hargreaves, 1999). Rather, for far-reaching educational changes and the creation of knowledge within the school, an enabling context or environment, as well as new knowledge from outside a school, is needed (Harris, 2008).

This discussion in educational research is similar to that more generally on open innovation. Here, it is suggested that organisations need to be open to external contributions, ideas and contributors: in other words, inbound open innovation (West and Bogers, 2014). At the same time, internal knowledge needs to transcend organisational boundaries in order to realise its full potential (Chesbrough, 2012): this is referred to as outbound open innovation (West and Bogers, 2014). Here too, the assumption is that linear innovation models are no longer sufficient to keep pace with societal and social developments and that organisations need to collaborate with external stakeholders through the iterative exchange of knowledge, technology and resources across organisational boundaries (Bigliardi *et al.*, 2021).

Accordingly, a single organisation cannot innovate in isolation and so must draw on external knowledge, whereby access to external knowledge sources and the linking of internal and external knowledge must be actively managed (Bogers *et al.*, 2019). Furthermore, open innovation theory suggests that open innovation regimes are particularly successful when they are aligned with an organisation's business model and tailored to the specific conditions and structural characteristics of an organisation (Chesbrough, 2006, 2012, 2017). As in educational research, it is assumed that both diversity and depth of knowledge are important for innovation and change. Research on KBV for innovation refers this as external knowledge search breadth and depth (Laursen and Salter, 2006). Here, the "breadth attribute captures the horizontal dimension of knowledge and heterogeneous knowledge content, whereas the depth attribute reflects a vertical dimension and unique, complex, within-field

knowledge content" (Zhou and Li, 2012, p. 1091). In the context of schooling, the horizontal dimension encompasses the diversity of mobilised knowledge when introducing innovations, for example, ICT knowledge and pedagogical knowledge when it comes to enabling digital teaching and learning. The vertical dimension in turn describes how intensively a school uses the knowledge of external collaborators for innovation, for example, working closely with a university to introduce evidence-based teaching methods.

In this regard, both the breadth and depth of external search are found to be related to organisational innovation performance (Foss *et al.*, 2013; Laursen and Salter, 2014).

Networks for innovation in schools

According to Enkel *et al.* (2009), organisations can set up networks to build strategic alliances between partners for combining inbound and outbound open innovation strategies in order to create coupled open innovation mechanisms, with the ultimate goal of generating reverse knowledge flows (West and Bogers, 2014). It is therefore expected that in addition to unidirectional exchange and co-creation of knowledge, networks can help to ensure that the knowledge created in one organisation can be enriched in a partner organisation and flow back to the original school in this revised (or optimised) form. As a result, the role of networks in innovation has become an emerging theme in research on open innovation (Bagliardi *et al.*, 2021; Fichter, 2009; Chesbrough, 2006).

In conceptualising what such cooperation networks might comprise, it is useful to begin with a definition of what networks are; in essence, representing the connections between individuals which enable the exchange of specific resource: for instance, communication, complex and routine knowledge, assistance, or norms and behaviours (Christakis and Fowler, 2010). Strong networks between individuals thus lead to more potent opportunities to exchange such resource; with innovation networks, specifically focussed on the exchange of resources that represent "an idea, practice, or object that is perceived as new by potential adopters" (Rogers, 1995: xvii). Innovation networks do this, not only through providing access to innovations but by also providing a supportive mechanism through which network members can build the culture and capacity required to effectively create and spread new knowledge within their organisations (Brown, 2020).

Within the field of education, a network represents a "group or system of interconnected people and organizations whose aims and purposes include the improvement of learning and aspects of well-being known to affect learning" (Hadfield *et al.*, 2006: p. 5; also see Hargreaves and Shirley, 2009). For instance, one form of educational network are PLNs (Brown and Poortman, 2018), defined as "any group who engage in collaborative learning with others outside of their everyday community of practice in order to improve teaching and learning" (Brown and Poortman, 2018: p. 1). PLNs typically focus on a range of goals, including those relating to innovation. For instance, PLNs can be focussed on knowledge sharing, as well as collaboration and practice development. This can be useful in plugging "structural holes" through the access to expertise that is not available in individual schools, especially those in rural areas which or where teacher turnover is low (Brown and Handscomb, 2022; Huxham and Vangen, 2013; Muijs, 2015). Likewise, PLNs can be geared towards supporting network members to engage in the development of educational improvement-related innovation. For instance, PLNs might centre on addressing challenging circumstances and/or persistent issues of inequity and underperformance (in other words, ensuring all students, irrespective of background, gain the minimum skills required to function in today's society) (Arkhipenka *et al.*, 2018; Armstrong *et al.*, 2021; Muijs *et al.*, 2010).

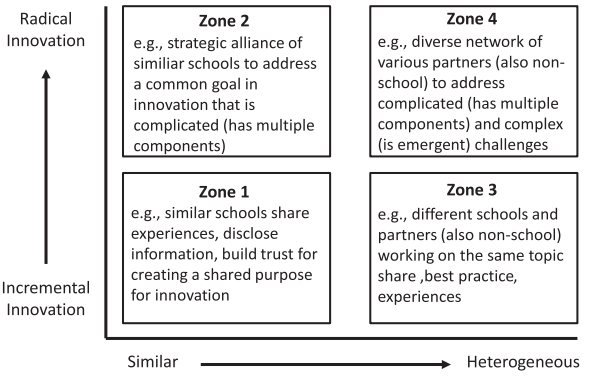
While PLNs are a common type of network, other networks also exist and can be corralled under the heading of "inter-school social capital networks," that is, networks that seek to enable the exchange of both "instrumental" and "expressive" resources through the creation of relationships between schools and other organisations. A four-year project funded by the

Dutch Ministry of Education provides a good example of such networks. Here, the aim of the network was to support teachers to develop new lesson materials teaching or undertake research in their schools. A total of 23 networks were established, with coaches providing support by providing expertise and academics studying educators' resulting satisfaction, learning and application to practice (Prenger *et al.*, 2019).

Networks, such as PLNs or inter-school social capital networks can vary in composition, nature and focus (Brown and Poortman, 2018; Brown, 2020). Yet the nature of the composition of such networks matters at a fundamental level, both in terms of the type of innovation that is required and/or that which will result from network activity. Thus, consideration should be given to network attributes, such as the actors situated within the network and the nature of the knowledge and expertise they bring to the table (Sebba *et al.*, 2016). This argument is effectively framed by Tidd (2006) and Tidd and Bessant (2020), whose argumentation we have adapted for schools, presented as Figure 1.

Here, the diagram can be interpreted in one of two ways: first the nature of the network partners affects the type of innovation possible; second, the type of innovation required will affect who should be involved and contribute towards the network. For instance, in situations in which complicated or complex challenges [1] are present (i.e. where radical innovations are required in response to paradigm shifting situations—such as that of Covid-19 pandemic, or the emergence of new technologies, such as ChatGPT AI); heterogenous partners are needed to ensure that broad knowledge types and experiences are needed. The diametrically opposite situation exists when the innovation goal is more akin to sharing effective practice around an issue, or in developing innovations that are incremental in nature, rather than propose fractures in the way education is done.

Nonetheless, despite having a strong theoretical understanding of the importance of networks, the benefits and advantages different network composition can offer, as well as the requirement for different network structures depending on the innovation problem to be addressed, little is known in terms of (1) whether different types of schools are more or less likely to participate in different types of networks; (2) how the integration (or non-integration) of school within networks affects their likelihood to embrace open or closed forms of innovation; (3) and how innovation networks and school type impact on how open and closed innovations are be mobilised. Yet developing our understanding of these areas is vital if school leaders are to maximise the benefits to their schools of engaging in innovation networks (Brown, 2020; Poortman and Brown, 2023; Poortman *et al.*, 2022).



Source(s): Figure created by author based on Tidd (2006) and Tidd and Bessant (2020)

Figure 1.
Innovation radicalness and network heterogeneity

Research questions

With the above context in mind, our study is guided by the following five questions which also structure the subsequent presentation of results:

R1. Can different innovation networks of schools be detected?

R2. Does the type of innovation network depend on school structural characteristics (i.e. type of school)?

R3. To what extent do schools that are less integrated in networks more often use internal knowledge for innovation (i.e. closed innovation)?

R4. Does the type of network have an impact on knowledge mobilisation in schools?

R5. Does the effect of innovation networks on knowledge mobilisation depend on the structural characteristics of the school (i.e. the type of school)?

Methodology

For our study, we use data from the third wave of the *Leadership in German Schools (LineS)* study. In this study, a random sample of school leaders, which is representative of Germany, is regularly surveyed in each wave about their work and other topics (Pietsch *et al.*, 2022). In the third wave, the focus was on the topic of innovation in schools (Dedering and Pietsch, 2023). The data for our study were collected by the forsa Institute for Social Research and Statistical Analysis in the context of their omnibus and omninet panels. Here, a random sample of around 1,000 people aged 14 and above is surveyed on a mixed-topic daily basis, also asking on their current occupation. Based on this, $N = 411$ school leaders were identified on a random basis, leading to a nationally representative sample for schools in Germany. This sample received personalised access to an online questionnaire, hosted also by forsa. Model-relevant information is available for $N = 407$ of the $N = 411$ cases (99%), so we use this for our analyses.

Measures

From this questionnaire, we use six out of 35 item blocks surveyed in the study, in which several measures were taken to avoid common method bias (Podsakoff *et al.*, 2012), that is, varying wording and scale properties across scales and rotating and scrambling item and item block positions randomly across individual surveys. For our analyses we use the following items and scales:

Open innovation measures open inbound innovation as defined by Laursen and Salter (2006). This scale thus refers to both the diversity of external knowledge sources of a school—called open innovation *breadth*—and the intensity with which these sources are used by a school—called open innovation *depth*. In order to capture this, the surveyed school leaders were asked in a first step to indicate whether process innovations affecting teaching and learning had been implemented in the last 12 months prior to the survey (0 = no, were not introduced, 1 = yes, were introduced):

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

In addition, this explanation was displayed:

> Process innovations include new or noticeably changed processes with regard to the pedagogical work of the school (e.g. teaching and instruction).

If this item was answered with "no," both the open innovation depth and the open innovation breadth were set to zero, as no knowledge was used for corresponding innovations. In this respect, these scales have an absolute zero. If the item was answered with "yes," the school leaders were asked (a) what the most relevant innovation was during the last

12 months (free-form field), (b) how radical this innovation was for their school on a scale ranging from 1 (incremental innovations—improving and/or supplementing and/or adapting what already exists) to 10 (radical innovations—introducing something completely new) and (c) where the knowledge for corresponding innovations came from.

Eight different sources of knowledge were surveyed (item stem: "The knowledge we used for the innovations came . . ."), with the answer options for each source ranging from "not at all" to "to an exceptionally high degree" on a six-point scale, comprising: (a) from parents or guardians, (b) from other schools, (c) from authorities or state institutes, (d) from universities and other scientific institutions, (e) from independent school-improvement consultants, (f) from commercial companies, (g) from professional trainings and/or conventions and (h) from professional literature. Open innovation depth represents the mean of these items and has an internal consistency, reported as McDonald's omega (1999), of $\omega = 0.76$. These items also form the basis for the open innovation breadth scale. However, here the items were recoded so that "not at all" corresponded to a zero and all other categories to a one, indicating whether a source was generally used or not. The open innovation breadth scale represents the mean of the eight recoded items and has an internal consistency of $\omega = 0.79$.

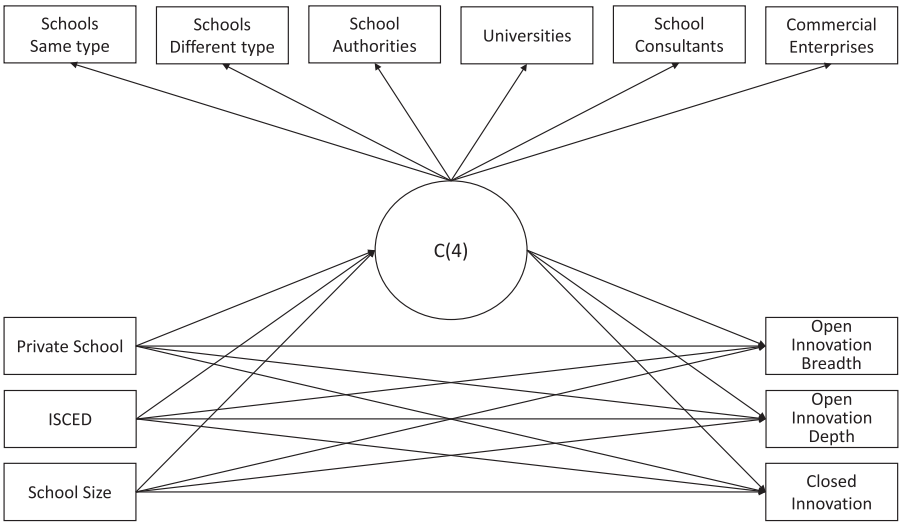
Closed innovation refers to the use of internal knowledge used by schools for innovations in teaching and learning during the last 12 months. This was surveyed with one item integrated in the item block mentioned above, where the response option was: "The knowledge we used for the innovations came from the school itself/the teachers of our school." Like open innovation depth, closed innovation was measured on a six-point scale, ranging from "not at all" to "to an exceptionally high degree."

Innovation networks were determined by asking school leaders about collaborations with external institutions during the last 12 months. Here, using a four-point scale, ranging from "not at all" to "very closely", participants were required to indicate, for the following six possible cooperation partners, how close the cooperation was during this period: (a) other schools of the same school type, (b) other schools of a different school type, (c) school authorities, other authorities or official institutions, for example, state institutes, (d) academic institutions, for example, universities, (e) freelance or independent school improvement consultants and (f) commercial enterprises. The internal consistency of the innovation network scale was $\omega = 0.72$.

In addition, our analysis takes into account school structural characteristics. In other words, (a) school size, indicated by the number of students enrolled in a school; (b) school type (primary, secondary, other), following UNESCO' International Standard Classification of Education (ISCED; UNESCO Institute for Statistics, 2012); and (c) whether a school is private or public.

Analytical strategy

To investigate the relationship between innovation networks and external and internal knowledge mobilisation processes, that is, open and closed innovation, we tested a latent class distal outcome model (see Figure 2). Accordingly, we investigate whether different types of collaboration are associated with different knowledge mobilisation processes. Specifically, we investigate latent or unobserved heterogeneity in the sample regarding innovation networks, by identifying latent subpopulations within the sample based on patterns of responses to the observed variables (Hagenaars and McCutcheon, 2002) and investigate how these are related to knowledge mobilisation in schools. To do this, we estimate latent classes or more precisely latent profiles (Oberski, 2016) of cooperation networks and relate them to the open and closed innovation variables. Following Nylund-Gibson *et al.* (2019), we consider the effect of latent class membership on the distal outcomes (i.e. open innovation breadth, open innovation depth, closed innovation) adjusting for observed potential confounders (i.e. school size, ISCED school type, public–private school).



Source(s): Figure created by author

Figure 2. Schematic model of analysis

All analyses were conducted using Mplus 8.6 (Muthén and Muthén, 1998–2023). As recently demonstrated by Nylund-Gibson *et al.* (2019), an unconditional model was first utilised to decide the number of latent classes based on the six-item innovation network scale. We treated indicators as continuous variables and completed the estimation with a robust maximum likelihood procedure. To determine the final number of latent classes loglikelihood (LL), sample size-adjusted Bayesian information criteria (ABIC), entropy, average posterior probabilities (AvePP) for most likely membership and class sizes were assessed, and Vuong-Lo-Mendell-Rubin (VLMR) and Lo-Mendell-Rubin (LMR) adjusted likelihood ratio tests (LRT) were employed (Lo *et al.*, 2001). We considered lower values of ABIC and -2LL as an indication of better fit and larger values of AvePP and entropy as an indication of better class separation without cut-off criteria. The type-I error rate was set to 0.05 for the VLMR and LMR tests. Overall, the final number of classes was decided based on multiple criteria, visual inspections of model estimated means and expert judgement.

Subsequent to the unconditional model, the manual BCH three-step method (Bolck *et al.*, 2014; Vermunt, 2010; Bakk *et al.*, 2013) was implemented as one of the suggested procedures to include distal outcomes in mixture models (Nylund-Gibson *et al.*, 2019). In our analyses, step 1 BCH included covariates (i.e. public–private school, ISCED school type, school size) and distal outcomes (i.e. open innovation breadth, open innovation depth, and closed innovation) as auxiliary variables. Step 2 requires the computation of weights, and this step is completed by the software. Hence, the output of the first step included individual weights computed as the inverse logits of the individual classification errors. Step 3 utilised these weights to estimate the model given in Figure 1 in which three distal outcomes are regressed on three covariates and the latent class indicator, whereas the latent class indicator is also regressed on the same three covariates.

Results

Descriptives

Of our sample, $N = 35$ (8.5%) of the school leaders work in private schools, $N = 374$ (91.0%) work in public schools, while $N = 2$ (0.5%) did not answer that question. Classified according to UNESCOs' ISCED scheme, within our sample, 53.2% of the schools are primary schools,

38.8% are secondary schools and 8.0% are other schools, including 2.0% special needs schools. Participating schools had an average enrolment of 381 students, with a standard deviation of 316 and school sizes ranging from 60 to 1,027 students in the 5-95th percentile.

At 78.8% of the schools, innovations affecting teaching and learning were introduced during the last 12 months; 19.2% of the schools did not introduce any teaching and learning related innovations during the last 12 months; and 2% of the school leaders did not provide any information on this. The innovations were manifold and the school leaders named things like "digital learning" (example open response: "Use of digital media in the classroom"), "parental involvement in learning" (example open response: "Introduction of a reliable messenger for communication with parents") and "introduction/expansion of concepts for inclusion" (example open response: "Expansion of the implementation of pedagogical measures on the topic of inclusion") as the most important innovation for their school. These innovations were seen as rather radical ($M = 6.31$, $SD = 2.73$) by school leaders.

The knowledge for these innovations came mainly from the school itself, so they were mostly based on closed innovation mechanisms ($M = 4.45$). Knowledge from outside the school, that is, open innovation mechanisms, on the other hand, was used much less to introduce innovations in learning and teaching ($M = 2.39$). The difference in internal and external knowledge mobilisation was statistically significant ($W(1) = 992.587$, $p < 0.001$). Most of the external knowledge used for innovations in the school flowed into the schools from professional teacher training and professional conferences ($M = 3.50$), while the least knowledge came from external school consultants ($M = 1.66$). Innovation breadth was $M = 0.51$ ($SD = 0.33$); on average, schools obtained knowledge from about four external sources.

Looking at the innovation networks of schools, it becomes apparent that schools mainly cooperate with schools of the same school type ($M = 2.67$) and educational authorities ($M = 2.48$) when it comes to implementing innovations and changes. In very rare instance, however, schools cooperate with external school improvement consultants ($M = 1.41$) and commercial enterprises ($M = 1.46$). Schools in Germany also only rarely work together with universities ($M = 1.69$) and schools of other types ($M = 1.97$) when it comes to innovating teaching and learning. Further, 1.2% of school leaders report that their school has not cooperated with any of these external partners when introducing innovations in teaching and learning. In this respect, almost all schools cooperate in innovation networks with other partners, although the cooperation is usually not very close.

Identification of latent innovation network groups

Table 1 reports the statistical criteria for the subgroup search for 407 respondents. The five-class solution resulted in a subgroup comprising only 5% of the schools; the LRT tests indicated no significant improvement compared to the four-class model along with a small ABIC difference of 14 and thus discarded from model comparisons. There were relatively large differences in terms of ABIC and LL between the single-class and four-class solutions. Despite larger entropy values for the two and three-class, LRT tests suggested a four-class solution. Overall, the four-class solution was found to be best fitting model with appropriate entropy value of 0.845 and visual inspections of estimated mean plots confirmed this decision.

Step 1 BCH included distal outcomes and covariates as auxiliary variables and the subgroup search is repeated. In order to address the standard error warnings, we fixed the loadings for an item to its estimated value for each class. Consistent with Nylund-Gibson *et al.* (2019), step 1 BCH results were in agreement with the unconditional model and supported the decision of a four-class solution. The subgroups contained 46%, 24%, 20% and 10% of the cases. The latent classes were labelled as *low cooperation* (46%), *system-oriented cooperation* (24%), *science-oriented cooperation* (20%) and *market-oriented cooperation* (10%). The first group of schools cooperates little or not at all with all kinds of potential partners. The second group cooperates mainly with actors in the school system, that is, other schools and

# classes	#param	ABIC	LL	AvePP	pVLMR-LRT	pLMR-LRT	Entropy	Class size	Class %
Unconditional model									
1	12	5579	−2772	–	–	–	–	407	100
2	19	5371	−2659	0.94–0.99	0.22	0.22	0.921	286/121	70/30
3	26	4737	−2332	0.99–1.0	0.32	0.32	0.999	286/82/39	70/20/10
4	33	4666	−2286	0.87–1.0	0.01	0.01	0.845	188/98/82/39	46/24/20/10
5	40	4652	−2269	0.81–1.0	0.44	0.45	0.835	148/117/82/39/21	36/29/20/10/5

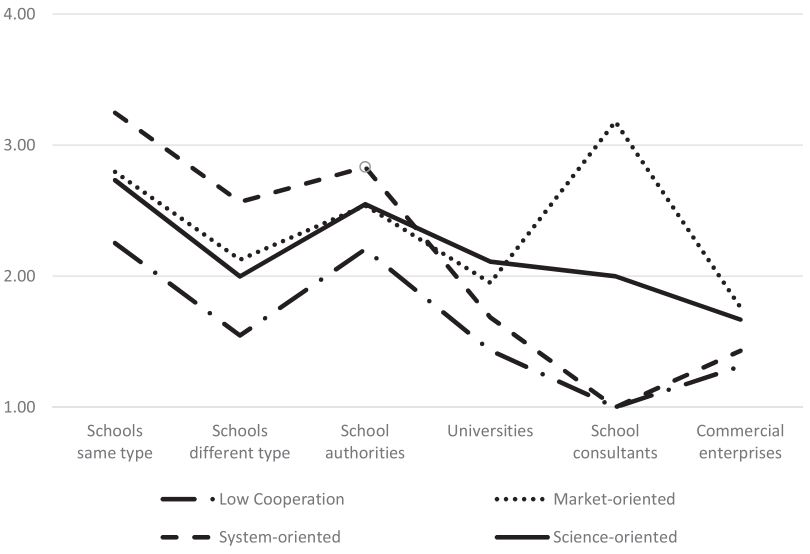
Note(s): ABIC = Adjusted BIC, LL = Log Likelihood, AvePP = average posterior probabilities
Source(s): Table created by author

Table 1.
Goodness of fit criteria and group sizes for the subgroup search with mixture models

authorities. The third group differs in that it cooperates more than average with universities and other research institutions. And the fourth group of schools cooperates remarkably strongly with external consultants and companies. Estimated item means for each class are depicted in Figure 3.

Mixture model with covariates and distal outcomes

Due to missing values in covariates and distal outcomes, 10 cases corresponding to only 2.5% of the sample size were removed due to the default settings of the software, and no additional missing data technique, such as full information maximum likelihood, was employed given the small amount of missingness. The results of the step 3 BCH for the model in Figure 2 are mainly threefold: (a) covariate effects on each outcome separately for each class, (b) covariate effects on predicting latent class membership and (c) pairwise comparison of adjusted outcome means across latent classes.



Source(s): Figure created by author

Figure 3.
Estimated item mean plots for the four-class solution

The covariate effects on predicting latent class membership were all insignificant with the smallest p-value of 0.154. Accordingly, it does not depend on the type of school, the size of the school or whether a school is privately or publicly run, whether and the extent to which it cooperates with external partners. The pairwise comparison of adjusted distal outcome means in order to investigate the differences between latent classes resulted in four significant effects. Three out of these four significant differences were flagged for the covariate closed innovation outcome; the computed-adjusted mean for the low cooperation class was 3.99 ($p < 0.01$) points larger than the adjusted mean computed for the system-oriented class of schools, and it was 1.71 ($p < 0.05$) points larger than science-oriented class of schools resulting in the third significant difference since the adjusted mean for science-oriented class was 2.29 ($p < 0.05$) larger than the system-oriented class of schools. This means that when controlling for covariates, the low cooperation subgroup tends to use more internal knowledge compared to two other subgroups of schools, the science and system-oriented cooperation. Further science-oriented cooperation subgroup tends to use more internal knowledge compared to the system-oriented cooperation subgroup. The last significant effect was flagged for the open innovation breadth outcome; the adjusted mean for the market-oriented class was 0.57 ($p < 0.01$) points larger than the adjusted mean for the system-oriented class, indicating that schools cooperating more closely with school improvement consultants and commercial enterprises use an overall more diverse knowledge for innovation in teaching and learning than schools that rely on traditional cooperative partners in the system, that is, other schools and educational authorities.

Table 2 reports the covariate effects on distal outcomes separately for each class. For the low cooperation class, there were four coefficients flagged as significant; the difference between other schools and primary schools ($B = -0.87$, $p < 0.05$), in addition to the difference between public schools and private schools ($B = -0.80, p < 0.01$), was found to be noteworthy for the open innovation depth outcome, whereas the latter effect was also present for closed innovation ($B = -1.61$, $p < 0.01$) and open innovation breadth ($B = -0.20$, $p < 0.05$). This means that controlling for other variables, where little cooperation is involved: (a) other schools, such as schools catering for special needs students, use less knowledge from cooperation even from that with external partners; (b) public schools use less external knowledge than private schools; (c) public schools draw on less external sources of knowledge than private schools; and (d) public schools use less internal school knowledge for innovations in teaching and learning than public schools if they cooperate little overall.

For the market-oriented class of schools, there were no coefficients flagged as significant, indicating that the effects on knowledge mobilisation through increased networking with companies and external consultants for school improvement, do not depend on school structural characteristics. For the system-oriented class of schools, the differences between secondary and primary schools were flagged significant for all three outcomes ($B = 0.86$, $p < 0.05; B = 2.22, p < 0.01; B = 0.28, p < 0.05$) in addition to the difference between public and private schools in terms of closed innovation ($B = 1.34, p < 0.05$). Accordingly, it can be seen that (a) primary schools, which mainly cooperate with other schools and authorities, can mobilise more internal and external knowledge than secondary schools, and (b) public schools, which cooperate on a system-related basis, can mobilise internal school knowledge for the innovation of teaching and learning to a larger extent compared to private schools. For the science-oriented class of schools, the differences between other schools and primary schools were flagged significant for all three outcomes ($B = 0.77, p < 0.01; B = 1.77, p < 0.01; B = 0.21, p < 0.05$). This means that primary schools, especially, can mobilise knowledge for the innovation of teaching and learning in their institutions through cooperation with universities and other research institutions (compared to other schools).

	Low cooperation			Market-oriented			System-oriented			Science-oriented		
	Est	SE	*p*	Est	SE	*p*	Est	SE	*p*	Est	SE	*p*
OI Breadth												
Secondary vs. Primary	0.02	0.08	0.78	0.01	0.11	0.95	0.28	0.13	0.03*	0.19	0.14	0.19
Other vs. Primary	−0.11	0.15	0.47	−0.22	0.21	0.29	0.06	0.11	0.60	0.21	0.10	0.03*
Public	−0.20	0.10	0.05*	−0.20	0.13	0.13	0.13	0.14	0.34	−0.09	0.07	0.22
School size	0.00	0.00	0.50	0.00	0.00	0.46	0.00	0.00	0.69	0.00	0.00	0.42
OI Depth												
Secondary vs. Primary	0.26	0.29	0.36	0.21	0.37	0.56	0.86	0.44	0.05*	0.49	0.48	0.31
Other vs. Primary	−0.87	0.43	0.04*	0.12	1.0	0.91	0.60	0.42	0.15	0.77	0.29	0.01*
Public	−0.80	0.27	0.01*	−0.12	0.51	0.81	0.04	0.48	0.93	−0.28	0.25	0.26
School size	0.00	0.00	0.85	0.00	0.00	0.95	0.00	0.01	0.94	0.01	0.01	0.39
CI												
Secondary vs. Primary	0.61	0.52	0.24	−0.12	0.76	0.87	2.22	0.78	0.01*	1.06	0.87	0.22
Other vs. Primary	−1.11	0.96	0.25	0.53	0.80	0.50	1.41	0.78	0.07	1.77	0.42	0.01*
Public	−1.61	0.57	0.01*	0.96	0.88	0.28	1.34	0.61	0.03*	−0.15	0.33	0.65
School size	0.01	0.01	0.17	0.00	0.01	0.75	0.00	0.01	0.71	0.00	0.01	0.81

Note(s): Est is estimate, SE is standard error, * indicates $p < 0.05$
Source(s): Table created by author

Table 2.
The covariate effects on each outcome separately for each class

Discussion

Knowledge-heterogeneous innovation networks are considered an important prerequisite for knowledge mobilisation in organisations, yet little is known about the underlying mechanisms and structures of knowledge mobilisation through networks. Our study fills this research gap by introducing the concept of open innovation into educational research and by linking the KBV of innovation from general organisational and innovation research with the PLNs concept in educational research.

Consistent with findings on open innovation in public service organisations (De Coninck *et al.*, 2021; Mu and Wang, 2022), our findings show that schools mainly use internal knowledge for innovation and that knowledge exchange beyond organisational boundaries takes place only to a very limited extent. This finding is hardly surprising, given that schools in Germany tend to be structurally conservative institutions that often wait skeptically for societal developments before gradually adopting newer trends (Groβ Ophoff and Cramer, 2022). However, our results also make clear that innovation networks have the potential to overcome corresponding barriers. Our results show that close(r) cooperation with other actors in networks is generally associated with increased knowledge mobilisation for learning and teaching, regardless of the structure or heterogeneity of the network. What is striking here is that only cooperation with market actors (companies and external consultants) makes a significant difference when it comes to the diversity of knowledge mobilised for learning and teaching in schools. This suggests that cooperation with these actors generally can increase the diversity of knowledge in schools that can be used for innovation. All other forms of cooperation primarily increase innovation depth, that is, the amount of unique, complex knowledge from the field of education that is important for innovation in teaching and learning in schools.

The type of network formation is independent of the school's structural characteristics. However, depending on the structural covariate, different effects emerge. First and in general, public schools in particularly seem to benefit from cooperation. If they cooperate little overall, they usually manage to mobilise knowledge (both internally and externally) much less successfully than private schools. In some ways, this puts public schools at a double disadvantage: they already have weaker networks and also have a harder time mobilising knowledge in these sparse networks.

Furthermore, primary schools in particular benefit from system-related cooperation (with other schools and authorities) regarding knowledge mobilisation. This could indicate that especially schools with a heterogeneous student body—the primary school is the only type of school in Germany that does not group students according to their abilities (Becker *et al.*, 2017)—need to use networks to cope with the diversity of the student body. Surprisingly, it is the same with regarded to a science-oriented cooperation. Primary schools benefit particularly strongly (compared to other schools) from cooperation with universities. When primary schools are involved in networks with universities, knowledge becomes more mobilised and diverse than average in all areas: open innovation breadth, open innovation depth and closed innovation. This is even though upper secondary education in Germany in particular is considered to be close to science and to have the task of providing scientific propaedeutics (Rosenmund, 2016).

The findings from our study thus add distinctly significant and original findings, since they now provide empirical results, where, previously, there was only theoretical frameworks to drive action. Our findings are thus timely. In particular, while the pandemic was a catalyst for many teachers and schools to engage in networks (Brown and Handscomb, 2022), we now provide tangible proof that this way of working likely had benefits, since it enabled increased knowledge mobilisation for learning and teaching. Likewise, with the emergence of virtual and augmented realities (e.g. the "metaverse"), networks (such as PLNs) now offer the possibilities of engaging with open innovation-related activities across the globe (Brown and Handscomb, 2022), with our study providing the justification for doing so and the benefits such global co-operation can offer. Further, given the interconnected and complex issues facing education systems in the 21st century), we now show that attempts to engage in open innovation can provide access to new forms of knowledge and ideas that can help address such issues.

Further, our study provides new insights into how schools can innovate learning and teaching through the mobilisation of external knowledge. We find that networks are promising for knowledge-based innovation and change, but that there is also a long way to go for schools to take both close cooperation in heterogeneous networks and the use of external knowledge for internal innovation for granted. For practice, we therefore recommend that schools should, in principle, network with various external actors and develop mechanisms for knowledge exchange with them following an open innovation approach, whereby the open innovation strategies must be aligned with the needs, structures and goals of the respective schools (Chesbrough, 2003).

With a view to further research, our findings make it clear that it can be profitable to combine models of general organisational and innovation research with those of educational research. Thus, on the one hand, future studies could focus in particular on the reciprocity of knowledge flows and the dynamic development of open innovation networks for learning and teaching in schools. On the other hand, however, general open innovation research also shows that the mobilisation of knowledge alone is not yet sufficient to achieve innovation—this should also apply to schools. In particular, a curvilinear relationship between open innovation breadth and innovation performance has been observed in other studies (Laursen and Salter, 2006, 2014), suggesting that the use of too many external knowledge sources may have a negative impact on the innovation performance of organisations. This can be explained by the fact that it is often not known *ex ante* what relevant knowledge is available externally and therefore there are "risks of over searching, i.e. complicating the identification and resource

allocation to valuable knowledge sources" (Shi *et al.*, 2019, p. 2139). This especially includes the question of the quality of the mobilised knowledge (Corral de Zubielqui *et al.*, 2019), that is, knowledge accuracy, adaptability, extensibility, relevance, timeliness and so on (Waheed and Kaur, 2016). Against this background, it is particularly important to clarify in further studies whether open innovation regimes lead to innovation outcomes in schools and ultimately improve the quality of education.

Note

1. With complicated challenges, referring to interventions with multiple components and causal strands, and complex challenges referring to those with elements of recursive causality and emergent outcomes (Rogers, 2008).

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