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EDITED BY
Stephen MacGregor,
University of Calgary, Canada

REVIEWED BY
Yiu Kwong Man,
The Education University of Hong Kong, Hong Kong SAR, China
Ozden Sengul,
Boğaziçi University, Türkiye

*CORRESPONDENCE
Angel X. Bohannon
bohannon-angel@norc.org

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Overcoming or overstepping? Boundary infrastructure for learning in the context of continuous improvement research-practice partnership

Angel X. Bohannon[1]*, Caitlin C. Farrell[2] and Spencer Cook[3]

[1]The Bridge, NORC at The University of Chicago, Chicago, IL, United States, [2]School of Education, University of Colorado Boulder, Boulder, CO, United States, [3]School of Education and Social Policy, Northwestern University, Evanston, IL, United States

Introduction: Under federal policy guidelines, school districts are increasingly expected to engage with research evidence to guide their efforts around instructional improvement. This article explores how a continuous improvement research-practice partnership (CI RPP) can create opportunities for educators to learn new research-based ideas and practices.

Methods: We present a year long case study of two rural school districts engaged in a CI RPP focused on math instruction.

Results: We focus show how research-based mathematics ideas introduced by research partners were taken up by teachers, school leaders, instructional coaches, and district leaders. Then we describe how the county office of education created important opportunities for learning through a boundary infrastructure: the network of people, practices, and objects that supported the movement of ideas between research, practice, and CI communities.

Discussion: We highlight the possibilities of county offices as critical actors in CI efforts. We also highlight how the county office's efforts to broker knowledge did not involve just overcoming or transcending boundaries but also maintaining them when they perceived external partners to be "overstepping."

KEYWORDS

research-practice partnership, improvement science, county office of education, boundary infrastructure, rural school districts

Introduction

Under federal policy guidelines, school districts are increasingly expected to engage with research evidence to guide their efforts around instructional improvement (Penuel et al., 2017). Research-practice partnerships (RPPs) using continuous improvement (CI) as an approach to research represent a potential strategy for supporting connections between research and practice (Coburn and Penuel, 2016; Farrell et al., 2021). CI efforts typically involve researchers and practitioners seeking to make progress on shared problems of practice, adapting reform ideas to meet the needs of local contexts, and spreading these ideas beyond individual classrooms (Bryk et al., 2015; Hinnant-Crawford, 2020; Yurkofsky et al., 2020).

However, there is still much to learn about how CI RPPs can support the uptake of research evidence in school districts. Importantly, existing scholarship has primarily focused the use of research in large urban school districts (Bohannon et al., 2024; Coburn et al., 2020; Penuel et al., 2017), but a large proportion of the nation's students are served in rural districts (Gutierrez and Terrones, 2023). Rural districts possess unique assets and challenges, raising

questions about how CI and other partnership models could be adapted in rural contexts (Sutherland et al., 2023; Zuckerman, 2019). Although definitions of rurality differ, rural districts have been traditionally delineated by their smaller population sizes and geographic distance from urban areas (Johnson et al., 2014; Gutierrez and Terrones, 2023). Existing scholarship notes how federal educational policies are designed in urban contexts in mind, disproportionately disadvantaging rural districts (Johnson et al., 2014; Sutherland et al., 2023). Thus, questions of capacity can be very real for rural districts who have similar instructional responsibilities to their peers in larger systems but with very different conditions (O'Shea and Zuckerman, 2022; Sutherland et al., 2023).

This article explores how a CI RPP can create opportunities for educators to learn new research-based ideas and practices required to carry out ambitious instructional reforms. We present a year-long case study of two small rural districts engaged in a CI RPP focused on mathematics education. First, we show how research-based mathematics ideas introduced by research partners were taken up by teachers, school leaders, instructional coaches, and district leaders. Then, we describe how the county office of education created important opportunities for learning through a boundary infrastructure: the network of people, practices, and objects that supported the movement of ideas between research, practice, and CI communities.

Empirical review

Interest in RPPs, including RPPs leveraging CI approaches to research, has grown over the past decade, as evidenced by increased financial investment by the federal government and philanthropic foundations, the rapid emergence of multiple RPPs, and professional learning networks that bring together multiple RPPs (Arce-Trigatti et al., 2018; Farrell et al., 2021). RPPs share a few key features, including sustained relationships between researchers and practitioners, engagement with research, and intentional centering of diverse expertise (Farrell et al., 2021). RPPs, under some conditions, can support educators' engagement with research ideas (e.g., Penuel et al., 2020).

In this paper, we focus on an RPP using a CI approach (Farrell et al., 2021), and the role of county offices of education within the context of this RPP (Manansala and Cottingham, 2019). Although existing literature indicates the potential for CI approaches in small rural school districts, educators, like in other contexts, face limited time and capacity for doing CI (Andreoli et al., 2020; Sutherland et al., 2023; Wargo et al., 2021). These capacity challenges may be related to rural leaders' multiple roles and responsibilities as both educational and community leaders, as well as limited financial resources and staffing constraints (Andreoli et al., 2020; Sutherland et al., 2023). Thus, more research is needed on what structures can support learning between research and practice in context of small rural districts or how this learning unfolds.

Relatedly, state policy has looked to county offices of education as a potential source of support for school districts engaging in CI (Manansala and Cottingham, 2019). County central offices may, for instance, co-design CI plans, provide CI professional development and coaching, and connect school districts with researchers and other external partners to support implementation. Understanding the role of the county offices in a CI RPP is paramount for illuminating best practices for other county offices, who may also face expanding state-level mandates around CI (Manansala and Cottingham, 2019).

Conceptual framework

For conceptual guidance, we turn to sociocultural learning theory to understand how a county office can support small rural districts' use of research in the context of a CI RPP. Based on existing literature (e.g., Akkerman and Bakker, 2011; Penuel et al., 2015; Farrell et al., 2021), we theorize that boundary infrastructure in a CI RPP – compromised of an interconnected network of boundary practices, spanners, and objects – can create learning opportunities across researcher, practitioner, and CI communities. We also theorize four key mechanisms by which learning between researchers, practitioners, and CI communities take place: identification, coordination, reflection, and transformation. Figure 1 provides a visual representation of our conceptual framework.

Learning at the boundaries

We theorize that participants in a CI RPP can face multiple boundaries where the interconnected but distinct worlds of research and practice can meet, leading to often new and unfamiliar ways of interacting (Penuel et al., 2015). We define boundaries as encounters where individuals negotiate sociocultural differences related to, for instance, differing language, practices, norms, and expectations, leading to discontinuities in (inter-)action (Akkerman and Bakker, 2011; Farrell et al., 2022; Penuel et al., 2015).

Boundaries do not just create problematic disruptions but are also important sites for learning (Akkerman and Bakker, 2011). In this paper, we focus on one form of learning: the uptake of research-based ideas across educators involved in the CI RPP (Anderson et al., 2023; Farrell et al., 2022). Indeed, educators (and others) can interact with research-based concepts and ideas in ways that shift how they think about an issue, including how they think about problems and potential solutions – what existing scholarship calls conceptual use of research (Anderson et al., 2023; Penuel et al., 2020; Weiss and Bucuvalas, 1980). For instance, one study documents how district staff in three RPPs took up research-based ideas about math teaching and learning introduced by their research partners (Penuel et al., 2020).

Boundary infrastructure

We theorize that learning may be related to a CI RPP's "boundary infrastructure" (Bowker and Star, 1999); that is, the interconnected network of practices, objects, and people that "keep moving things along" (p. 313). In a CI RPP, enacted roles (i.e., boundary spanners), routines (i.e., boundary practices), and tools (i.e., boundary objects) can support participants within a RPP in navigating sociocultural differences across research, practice and CI communities (Farrell et al., 2022). Indeed, one study showed how individuals across multiple university-district CI RPPs intentionally designed and enacted a boundary infrastructure to support joint work and learning (Biag et al., 2023). Boundary infrastructures have multiple key characteristics: they are taken-for-granted and invisible, except for when they break down, are fundamentally relational, and support the

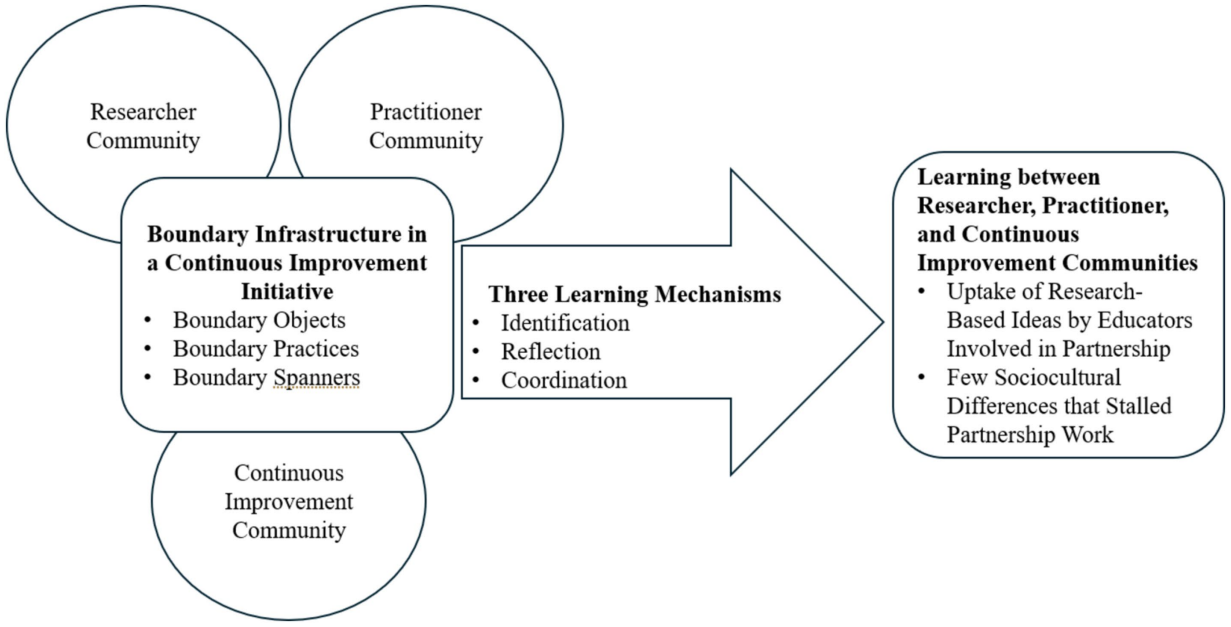

FIGURE 1
Boundary infrastructure in a CI RPP.

enactment of multiple tasks beyond just a single task (Star, 2010; Star and Ruhleder, 1996).

Importantly, existing research suggests that boundary infrastructures, and the objects, people, and practices, which comprise them, are not neutral or apolitical (Collien, 2021; Wegemer and Renick, 2021). Rather, the design and enactment of boundary infrastructures can reflect and reproduce power asymmetries to privilege those in power. Within the context of RPPs, these power imbalances may be related to formal roles, such as power asymmetries traditionally afforded to researchers versus practitioners, but also due to race/ethnicity, socioeconomic status, sexuality, gender, [dis]ability, and immigration status, as rooted in broader inequitable and oppressive systems (Denner et al., 2019; Farrell et al., 2021; Wegemer and Renick, 2021). Power imbalances may also be related to an individual's position in a broader social network, for instance, network brokers who connect two unconnected groups may be advantageously positioned to control the flow of information between these groups (Burt et al., 2013).

Now that we have provided a brief overview of boundary infrastructures, we now turn to describing its three core features that make up this infrastructure: boundary spanners, boundary practices, and boundary objects.

Boundary spanners

Boundary spanners are those who move across boundaries and facilitate connections between different communities (Akkerman and Bakker, 2011; Penuel et al., 2015). Boundary spanning can be a formal part of an individual's role, as well as an emergent part of their everyday work. Boundary spanners both serve as a bridge between different communities and do not fully belong to either community (Akkerman and Bakker, 2011; Penuel et al., 2015; Suchman, 1994). Boundary spanners may enact purposeful moves that navigate sociocultural differences, facilitate connections across boundaries, and move RPP work forward (Penuel et al., 2015).

Boundary practices

Boundary practices are routines that regularly bring together different communities in interaction with each other (Akkerman and Bakker, 2011; Penuel et al., 2015; Farrell et al., 2022). Boundary practices serve as hybrid spaces that take up work that is familiar to some but also differ from each community's existing ways of doing work (Penuel et al., 2015). Boundary practices can clarify participants' roles and responsibilities as it relates to joint work, as well as elicit their perspectives and expertise (Farrell et al., 2022). In the context of RPPs, boundary practices can provide ongoing opportunities for researchers and practitioners to interact in novel and unfamiliar ways (Penuel et al., 2015).

Boundary objects

By boundary objects, we refer to the material and conceptual tools that support ongoing, joint work in RPPs (Akkerman and Bakker, 2011; Farrell et al., 2022). Boundary objects do not fully belong to any community, but rather, exist at the intersection of multiple communities (Star and Griesemer, 1989; Star, 2010). They have interpretative flexibility; that is, they are open-ended enough in that they can reflect multiple perspectives and be understood by multiple communities (Star and Griesemer, 1989; Star, 2010). They can support the coordination of work even in the absence of consensus within a community and between different communities (Star, 2010).

Four mechanisms for learning at boundaries

Akkerman and Bakker (2011) outline four mechanisms by which boundary infrastructure can create opportunities for learning: identification, coordination, reflection and transformation. In this

study, we theorize that the CI RPP boundary infrastructure can contribute to learning between researcher, practitioner, and CI communities via these four learning mechanisms. Although we describe these learning mechanisms individually, we recognize that they may operate in interdependent ways (Bohannon and Coburn, 2023).

Identification involves considering how intersecting practices relate or do not relate with each other, including how they diverge from or complement each other (Akkerman and Bakker, 2011). Educators (and others) engage in identification when they demarcate how one set of practices differ from other practices or what Akkerman and Bakker call "othering," and when they consider how different practices complement each other by providing their unique value and contribution to the ongoing work, or what they call "legitimating co-existence" (Akkerman and Bakker, 2011, p. 142). Identification involves recognizing and delineating boundaries between intersecting sets of practices, rather than overcoming boundaries (Akkerman and Bakker, 2011).

Coordination is about maintaining the ongoing flow of work across boundaries, even in the absence of consensus (Akkerman and Bakker, 2011). Coordination can involve using objects or routines to foster efficient cooperation across diverse practices (Akkerman and Bakker, 2011; Star, 2010). Educators (and others) may engage in coordination, for instance, by communication that translates perspectives and understandings across boundaries, enhancing the permeability of boundaries, and creating coordinating routines (Akkerman and Bakker, 2011).

Reflection involves looking differently at one's own practice by taking the perspective and viewpoints of individuals in other practices (Akkerman and Bakker, 2011). Educators can engage in reflection by perspective making; that is, making sense of one's practice in relation to the perspectives of others and perspective taking; that is, learning about one's practice by looking at it from the perspectives of others. Whereas identification involves reconstructing current identities, reflection involves learning about and expanding one's perspectives in light of other perspectives and practices.

Transformation involves substantial shifts in practices and sometimes the emergence of a new hybrid practice (Akkerman and Bakker, 2011). Transformation is often prompted when educators (and others) confront some problem at the boundary and collectively recognize a shared problem space. To address this problem, educators may develop new hybrid practices and integrate these practices into ongoing routines and practices.

We draw on constructs of boundary infrastructure, learning mechanisms, and uptake of research-based ideas to ask the following questions:

1 What proportion of educators involved in a CI RPP took up different research-based ideas introduced by their research partners?
2 What potential and actual boundaries occurred between researcher, CI, and practitioner communities?
3 How, if at all, did the county office create opportunities for learning across boundaries between researcher, CI, and practitioner communities?

Research methods

This paper draws on data from a descriptive, comparative case study of three different RPPs (Yin, 2009), all focused on improving mathematics outcomes for K-8 students (Penuel et al., 2020). We drew on a purposeful sampling strategy (Patton, 2002) to select three RPPs that were paradigmatic of the three major types of RPPs in the field during the time of data collection: research-alliances, design-based research partnerships, and CI RPPs (Coburn and Penuel, 2016). These partnerships had different designs but were all centered around the goal of improving mathematics outcomes for middle school students.

We began by creating a list of RPPs through funding agencies and organizations that support partnerships. RPPs needed to be well established; that is, working together for three or more years, and focused on supporting mathematics teaching and learning. This yielded an initial pool of 28 partnerships, five of whom were CI RPPs. The study team then had discussions with RPP leaders to gauge interest in their participation.

Our focal CI RPP – which we pseudonymized as the Eastern Ridge Networked Community (ERNIC) – represents an "illuminative" or deviant case (Patton, 2002, p. 232). This case also stood out because of educators' high degree of take up of ideas related to math teaching and learning that were introduced by their research partners, amidst ongoing concerns about the limited or uneven impact of research on practice (e.g., Gamoran, 2018; Slavin, 2002). Due to our single case design and sampling strategy, it is important to emphasize that our findings are not representative of other county offices. Rather, our study could serve as a model for other county offices looking to support CI, especially given increasing policy mandates for doing so (Manansala and Cottingham, 2019). Given limited research on county offices in the context of CI RPP efforts, an in-depth case study is an appropriate strategy (Ragin and Becker, 1992).

Description of the case

The county office of education served as the educational services hub for 40+ districts and served as the main organizer of the ERNIC. The focus of the ERNIC was on improving achievement in elementary mathematics using CI methods. Individuals participating in the partnership sought to use iterative, small tests of change—trying out new strategies and measuring their effects—to make improvements to mathematics instruction. The study team focused on two small districts; we selected these districts because they were highly active within the ERNIC, which provided opportunities to see the dynamics and influence of RPP work. Both districts had similar numbers of teaching staff and racially diverse student populations ranging from 3,000–5,000 students, many of them from Latine communities.

The ERNIC included teachers, coaches, principals, and district leaders from eight districts. It also included county leaders, who served as the "hub" for the network and were charged with planning and facilitating different network activities. The initiative also included two different external partners; the School Improvement Partner brought CI expertise and coached county leaders around CI implementation. A second research partner – pseudonymized as Kinsley – from Eucalyptus University brought substantive expertise in mathematics education.

TABLE 1 Key constructs and sample interview questions.

Key constructs	Sample interview questions
Boundary spanners	• What's happening behind the scenes to make the [partnership] work happen? Who is involved? • Of the people involved in the work, who have been the key people responsible for connecting the work of the partnership to district initiatives?
Boundary practices and objects	• I know there are different ways the district collaborates in the partnership. "Let us start with [practice 1]: How would you describe [practice 1] to someone who is unfamiliar with it?" "What goes on in it?" "What do you discuss or work on?" • What has been most beneficial most relevant about [practice 1] for your work?" • "What has been most challenging (least relevant) about the [practice 1] for your work?"
Key research-based ideas research partners sought to convey	• "What ways of thinking about (instructional) improvement are you trying to bring to the district? How, if at all, did research inform your understanding of [idea] at all? • Are there specific strategies, materials, practices, tools, or routines that you want to see district use in improvement work? How, if at all, did research play a role as you developed this [strategy/materials/practice/tool/routines]?"
Uptake of research ideas by educators	• "Can you think of an example of research that was useful to you in your work?" How did you find out about this piece of research? Why was it useful to you? • "How, if at all, has partnership with [partner name] contributed to mathematics initiatives in the district this year (fine if not)?" • "If [the partnership] ended tomorrow, what would be left behind from the partnership? What would be the footprints?"

Data collection

We and a broader research team collected all study data from the 2016–17 and 2018–19 school years. We conducted a total of 26 observations of different RPP meetings, including network meetings, planning meetings where the county office and others would design network meetings, leadership meetings where school and district administrators focused on implementation and scale, meeting with funders, professional development around mathematics, and CI coaching meetings. We took detailed jottings that were subsequently turned into field notes that recorded details of interaction.

We conducted interviews with educators ($n = 25$) and external partners ($n = 19$). We asked educators about their general perceptions of mathematics problems facing the districts, key improvement initiatives in districts related to mathematics, key activities of the partnership and their involvement in them, and perceived benefits and challenges of the partnership. We asked external partners to identify the key research ideas they sought to convey during the 2017–2018 study year. We also included targeted questions related to constructs in our conceptual framework (see Table 1).

Interviews lasted approximately an hour and were audio-recorded. All interviews were transcribed, anonymized, and loaded into qualitative data analysis software package NVivo. We also gathered and analyzed relevant artifacts from the partnership, such as meeting agendas, CI tools (e.g., driver diagram), and slide decks.

Data analysis

Research question 1: uptake of research-based mathematics ideas across the CI RPP

Overall, we engaged in thematic analysis that incorporated deductive analysis and inductive approaches to understand patterns in the data (Miles et al., 2018). To analyze the uptake of research-based mathematics ideas, the study team took a more deductive approach via what we call a "big ideas" analysis (Penuel et al., 2020). Using interviews, existing publications, and member checks with external research partners, we identified research-based mathematics ideas central to the CI RPP and drafted key words and phrases associated with these ideas. We then used these key words and phrases to code for research-based ideas within educator interviews in our focal districts. Doing so allowed us to examine how educators involved in the CI RPP took up and conceptualized research-based ideas introduced by research partner Kinsley. Table 2 lists the research-based ideas, key words and phrases, and example quotes.

Then, we analyzed all coded instances of each big idea and analyzed them for attribution; that is, the extent to which educators directly mentioned Kinsley, Eucalyptus University or the ERNIC, and congruence; that is, when educators talked about big ideas in ways that were consistent with researchers' definitions. Our analysis was limited in its ability to assess congruence. Many educators' mentions of research-based mathematics ideas were ambiguous. In other words, the excerpt was too short or educators described the idea too tangentially for us to assess if the excerpt was congruent with how Kinsley talked about these ideas.

Research question 2: potential and actual boundaries between educators and partners

To begin analyzing boundaries, we first coded interview data for any challenges related to participating in the ERNIC. Using this data, we then constructed a qualitative matrix (Miles et al., 2018) where we distinguished between potential and actual boundaries, given existing work that emphasizes not all sociocultural differences are boundaries, just those "leading to discontinuities in action or interaction" (Akkerman and Bakker, 2011, p. 133; Wegemer and Renick, 2021). By potential boundaries, we refer to any talk of sociocultural differences between researcher, practitioner, and CI communities. By actual boundaries, we refer to any talk when these sociocultural differences led to a particular strand of work

TABLE 2 Research-based ideas, key words and phrases, and example quotes.

Research-based idea	Definition	Key words and phrases	Example quotes
Growth mindset	Students should have a "growth mindset" around math, which means they can grow their intelligence. Students with a growth mindset are likely to be persistent and keep working even when the work is hard, whereas students with a fixed mindset are likely to give up easily. Ideas about growth mindset can also apply to teachers.	Growth mindset, fixed mindset, minds can grow, effort creates ability, brains can grow, brain can grow, fixed, growth, growing intelligence, brains are malleable, malleability, malleable,	"Do not tell me all the answers. Do not tell me how to solve. Let me figure it out. Let me struggle. Mistakes grow my brain. I like to struggle. I know it's good for me. Let me work with my friends."
Rich tasks	Rich mathematical tasks are those that are challenging but accessible. They are inquiry based and call on students to apply mathematical reasoning and provide justification for their answers. These tasks are multidimensional, requiring fluid representations of mathematics in different ways.	Rich tasks, rich task routines, rich mathematical tasks, cognitively demanding math tasks, cognitive demand, inquiry task, inquiry based, high ceiling, low floor, task is challenging but accessible, task is difficult and accessible, justifying methods, open tasks, multidimensional	"With this rich teaching routine, there was more emphasis on what students are doing and learning and asking in the classroom rather than the teacher showing and modeling and demonstrating everything. I think it really just opened up the mathematics to put more responsibility on the student."
Depth not speed	Doing mathematics well does not mean being fast at mathematics. Focusing on fast computation may discourage deep slow thinkers. Instead of getting students to think fast, students should think deeply.	Depth not speed, thinking deeply, depth, deep thinking, slow thinking, deep slow thinking, slow computation	"Just to really build students mindsets about how they can all achieve in math and how math is about depth and not speed. Just really teaching all the positive norms."
Multiple ways of engaging in math	Teach math in multiple ways as a "multidimensional subject." Target the multiple ways that students are seeing and understanding math, such as developing a mathematical model, applying methods, drawing diagrams, connecting ideas, and connecting and communicating in different forms.	Multidimensional math, multiplicity, multiple, more than one way, different ways, more than one approach, more than one solution, multiple solution strategies, multidimensional, fluid representation	"A lotta kids see it as a burden because it's work, to a lotta kids, especially at this age. Trying to get them to kinda think about maybe different ways to tackle math problems."

involving two or more partner organizations coming to an abrupt halt or stop.

Using the 'challenges' code above, we then categorized data into potential and actual boundaries between the five organizations involved in the partnership: Frederick School District, Carlton School District, the county office, Eucalyptus University, and School Improvement Partner. When doing so, we paid attention to any talk of metaphors that might indicate boundaries, such as not speaking the same language, crossing a divide, coming from different worlds, and any talk of fences and walls. At times, we were unable to code for boundaries when there was not enough information to tell whether a challenge involved talk of a boundary. Our final qualitative matrix included information about all potential and actual boundaries, which organizations were involved, and the nature of the boundaries (i.e., whether boundaries related to differences in roles, perspectives, goals, language, and/or other).

Research question 3: boundary infrastructure and mechanisms for learning

To examine boundary infrastructure, we were interested in identifying and examining the boundary spanners, objects, and practices that compromised the ERNIC CI RPP. Overall, our analytic strategy was start by identifying key people, tools, and routines that were central to the ERNIC CI RPP theory of change, and then examine if and how these people, tools, and routines fulfilled the criteria to operate as boundary spanners, boundary objects, and boundary practices. Table 3 provides definitions and examples of boundary spanners, objects, and practices.

We identified *boundary spanners* by coding for boundary spanning moves (Penuel et al., 2015), because we were interested in identifying individuals who spanned boundaries in their everyday work, regardless of their formally designated roles. To do so, we coded for moves that attempted to work across or get past boundaries between the five organizations involved in the ERNIC. We found that almost all boundary crossing moves were done by the county office and district improvement coaches. We then developed two analytic tables where we described the county and district coaches' specific boundary crossing moves, what organizational boundaries were being crossed, any challenges they experienced when boundary crossing, and the interviews that referenced this boundary move.

We then identified *boundary objects* by focusing on tools and artifacts that were central to CI RPP's theory of action and were also located at the organizational boundaries among the research, practice, and CI communities. These included, for instance, fishbone or

TABLE 3 Boundary spanners, objects, and practices codes.

Codes	Definition	Example
Boundary spanners	Individuals that enact moves that attempt get pass or work across organizational boundaries in the ERNIC (Penuel et al., 2015). These moves must include talk of the organizational boundaries being crossed. We are interested in boundary spanners as enacted; that as individuals who cross boundaries regardless of their formally designated role.	County central office District improvement specialists
Boundary objects	Tools and artifacts that were central to CI RPP's theory of action and were also located at the organizational boundaries among the research, practice, and CI communities (Akkerman and Bakker, 2011; Farrell et al., 2021) Boundary objects are also likely to include these other characteristics (Akkerman and Bakker, 2011; Star and Griesemer, 1989; Star, 2010): • Interpretative flexibility; that is, open-ended enough to be interpreted and used, albeit differently, by multiple organizational groups • Reflect and communicate the perspectives and experience of each organizational group to some extent • Coordinate work with or between different organizational groups	Driver diagram Mindset surveys
Boundary practices	Ongoing routines that regularly brought together individuals from two or more organizations involved in the CI RPP (Akkerman and Bakker, 2011; Farrell et al., 2021; Penuel et al., 2015). Boundary practices also (a) regularly bring together participants from different organizational domains (e.g., Carnegie, County), (b) represent hybrid routines that take up work that is familiar to some but also differ from each community's existing ways of doing work (Penuel et al., 2015). Boundary practices are not one-off meetings or ad-hoc events. Boundary practices do not involve individuals from just one organization.	Network planning meetings Network meetings Cross district visits

root-cause diagrams, mindset task cards, mindset surveys, driver diagrams, and plan-do-study act forms. We then coded all interviews and observations for any mention of these objects. Two specific objects were mentioned more than three times as frequently as the others: the driver diagram and the mindset survey. Drawing on existing literature (Akkerman and Bakker, 2011; Star, 2010; Star and Griesemer, 1989), we then memo-ed on whether and how these objects operated as boundary objects, including if and how these objects were recognizable by multiple communities, reflected and communicated the perspectives of different communities, were used and interpreted by different communities, and coordinated work within and across different communities.

We also analyzed *boundary practices*. To do so, we first identified mentions of key organizational routines in our data (Feldman and Pentland, 2003) that involved repetitive, recognizable, and interdependent interactions rather than one-off meetings, as well as two or more individuals. To be boundary practices, these routines had to regularly bring together individuals from two or more organizations involved in the CI RPP. Following this, we identified three main boundary practices: Network planning meetings, network meetings, and cross-district visits. Using interviews and observations, we coded for these boundary practices and then wrote analytic memos describing these practices, including who the typical participants were, what organizations they were from, how often they took place, and what activities were involved.

We then analyzed if and how this boundary infrastructure created the conditions for learning via different learning mechanisms. To do so, we drew on Akkerman and Bakker's (2011), focusing on three out of four learning mechanisms: identification, coordination, and reflection. Table 4 provides a list of codes and definitions. Given the cross-sectional nature of our data, we were unable to see if and how the boundary infrastructure in this CI RPP supported transformation. We might imagine that transformation as a learning mechanism might involve a process by which individuals in a CI RPP confront a problem at a boundary, collectively recognize a shared problem space, develop hybrid practices, and integrate hybrid practices into ongoing routines and practices (Akkerman and Bakker, 2011). Yet, we did not observe the CI RPP over enough time to see if new practices or objects stuck and were integrated into the RPP.

Finally, we created an analytic table that brought together our boundary infrastructure analysis and learning mechanisms analysis to analyze how different features of boundary infrastructure provided opportunities for learning in the ERNIC. We also engaged in a few techniques to ensure patterns described here represented what was happening at the research site, including systematically coding data, triangulating data across multiple sources, and interrogating surprising data (Miles et al., 2018).

Findings

Overall, we found evidence of the uptake of research-based mathematics ideas by educators involved in the CI RPP, including teachers, school leaders, and district leaders. Although educators involved in the CI RPP named many boundaries between educators and external partners, few of these boundaries halted their ongoing partnership work. These findings can be explained, in part, by how the county office designed and cultivated a boundary infrastructure that created important learning opportunities around research ideas introduced by external research partners. Importantly, we found that the county office's efforts to span boundaries did not just involve overcoming or transcending boundaries but also maintaining boundaries in cases where they perceived external partners to be "overstepping."

TABLE 4 Three learning mechanisms and definitions.

Learning mechanisms in ERNIC
Learning mechanisms refer to the dialogical processes by which boundary infrastructure supports learning across different organizational boundaries (Akkerman and Bakker, 2011), which in this paper, we have defined as the uptake of research-based ideas (Anderson et al., 2023). All learning mechanisms included below also need to talk of: • Boundary spanners, objects, and/or practices or interactions between spanners, objects and practices • Movement or interaction across different organizational boundaries Learning mechanisms do not include talk of beliefs or thinking without reference to boundary infrastructure.

Learning mechanism	Definition	ERNIC example
Identification	Involves delineating or (re-) defining how intersecting practices do or not relate with each other. Could include talk of how different intersecting practices complemented each other (i.e., othering). Could also include talk of how different intersecting practices differed or diverged from each other (i.e., legitimating co-existence).	The county office explicitly delineated between their own expertise in the everyday realities of school districts and the mathematics research and CI experience of other organizations in the ERNIC.
Coordination	Involves developing shared procedures or activities for fostering efficient cooperation across diverse practices to support the ongoing flow of work, even in the absence of individual consensus. May include talk about facilitating movement between research, practitioner, and CI communities, while also maintaining clear boundaries between these communities.	The county office, in partnership with the broader RPP, designed and led ongoing ERNIC boundary practices such as network meetings, network planning meetings and cross-district sharing sessions that regularly brought together individuals from different organizations and clearly established roles and responsibilities of different groups and how they contributed to joint work.
Reflection	Involves valuing and taking the perspectives and viewpoints from other organizational communities to look differently at one's own practice. Could include making one's perspective explicit in relation to another's perspective (i.e., perspective making). Could also include taking up others' perspective of their practice (i.e., perspective taking)	Educators in the ERNIC described looking at their own teaching practices via the perspectives and lens of mathematics ideas espoused by Eucalyptus University when they "did math" together during network meetings.

Research question 1: uptake of research-based ideas around mathematics

We found that educators in the CI RPP (i.e., teachers, school leaders, district leaders) took up four research-based mathematics ideas: the importance of rich tasks, multiple ways of engaging in math, growth mindset, and depth not speed in problem-solving. Most notably, among educators in the CI RPP ($n = 28$), 93% referenced the research-based idea of growth mindset in their interviews. Table 5 shows the percentage of educators that mentioned a research-based mathematics idea and the percentage that attributed this idea to external partners.

There were four big ideas about mathematics learning that the external partners sought to circulate and move into practice in the CI RPP. One was the idea of a *growth mindset,* which refers to students' beliefs that they can grow their intelligence (Boaler, 2015; Dweck and Yeager, 2019). Students with a growth mindset are likely to be more persistent amidst challenges and adversity compared to those with a more fixed mindset. A second was the idea that there are *multiple ways of engaging in mathematics,* that is, there is no single right way to solve a mathematics problem; rather, students can engage with mathematical problems in multiple different ways. Teachers can target and support the multiple ways that students are understanding and approaching mathematics. A third idea was the importance of *depth, not speed* in problem-solving, that is, teachers should support students to think deeply and go in-depth during mathematics problem-solving, instead of emphasizing speed. Doing mathematics well does not mean being fast at mathematics. A fourth was the idea of using the *rich mathematical tasks.* Rich mathematical tasks are challenging but accessible, inquiry-based, and multidimensional; that is, they involve the fluid representation of mathematics in different ways.

As Table 5 highlights, we found evidence that Kinsley's mathematics research ideas spread to educators across the CI RPP and some direct attribution of these ideas to Kinsley. The most cited research idea was that of a growth mindset in mathematics, with 93% of educators mentioning this research idea and 38% directly attributing this research idea to Kinsley. For example, one educator shared their students exhibiting growth mindset when they heard them say, "do not tell me all the answers. Do not tell me how to solve. Let me figure it out. Let me struggle. Mistakes grow my brain. I like to struggle. I know it's good for me. Let me work with my friends." Educators also talked about Kinsley's other research-based mathematics ideas – depth not speed, rich tasks, and multiple ways of engaging in mathematics – to varying degrees and in ways that sometimes attributed these research ideas to Kinsley.

Research question 2: boundaries between research and practice

The take up of research-based mathematics ideas we described related to research question one was particularly striking as educators in the ERNIC described multiple potential boundaries related to language, expertise, perspectives, priorities, and roles between

TABLE 5 Educator take up of research-based mathematics ideas.

Research-based idea	% of educators invoking research idea	% of mentions attributed to external partner
Growth mindset	93%	38%
Depth, not speed	39%	7%
Rich tasks	36%	30%
Multiple ways of engaging in mathematics	14%	6%

educator, CI and research communities. Yet, we found few actual boundaries; that is, talk of sociocultural differences that actually disrupted or halted ongoing RPP work.

Educators named several potential boundaries between different organizations involved in the CI RPP, most notably between school districts and the School Improvement Partner and school districts and Eucalyptus University. Educators ($n = 6$) most frequently described sociocultural differences between school districts and the School Improvement Partner in terms of language, perspectives, priorities, and roles. For example, district and county staff shared how they struggled with the academic and sometimes inaccessible nature of CI approaches and learning how to "translate" this language in ways that reflected the everyday realities and work of school districts. Dana, for instance, shared how the CI language as "really heavy" and how "it was very difficult to talk that high-level learning and translate into actions at the school, and so, there were some disconnects there." District and county staff also felt that School Improvement Partner had a limited perspective on the on-the-ground realities of school districts.

Educators ($n = 4$) also described potential boundaries between school districts and Eucalyptus University, highlighting sociocultural differences related to perspectives, expertise, and roles. Whereas Kinsley was interested in seeing how and to what extent their ideas about math instruction worked in school districts, county leaders were interested in how these ideas could be implemented given the realities of their specific contexts. For example, Tiana shared, "The challenge with that is, like, sometimes people like that drop in this wisdom, and then it's sort of, like, how do we—but what do we do with this now?"

Although CI participants named multiple potential boundaries, they named few boundaries that disrupted or stalled ongoing partnership work. One notable exception were a few instances when county leaders and School Improvement Partner experienced differences that stalled partnership work. When designing the driver diagram, Doreen shared how county leaders asked School Improvement Partner to stop iterating on this driver diagram: "I think it was iterations of the driver diagram, yeah. And we were all for it. Last I left off, I think they [School Improvement Partner] were on iteration 17 and that was early on but at some point, we felt like we had to stop, and we needed to do something." In this case and others, partnership work did stall but only momentarily.

Yet, overall, ERNIC participants described few actual boundaries that stalled or disrupted partnership work. Rather, they emphasized the importance of the county hub in smoothing over potential disruptions by bridging between the expertise of external partners and the expertise of educators in school districts. District leader Lacy described, for example, "I think the county hub did a really good job with understanding and then transferring that knowledge into something that related to our improvement project and making sense of it for us." Thus, we now turn to examining the role of the county office in creating opportunities for learning across boundaries between researchers, CI, and practitioner communities in our next section.

Research question 3: boundary infrastructure and mechanisms for learning

Taken together, we see educators' uptake of research-based ideas and few disruptions to partnership work, despite multiple potential boundaries between researcher, practitioner communities, and CI communities. We argue that these findings can be explained, in part, by how the county office designed and cultivated a boundary infrastructure – compromised of an interconnected network of people, objects, and practices – that supported learning across boundaries via three mechanisms: identification, coordination, and reflection. Yet, importantly, we also find that the county's engagement with this boundary infrastructure did not just involve overcoming and transcending boundaries but also maintaining boundaries in cases where they perceived external partners to be "overstepping."

The county office and the eastern ridge boundary infrastructure

The ERNIC was composed of an interconnected network of people (i.e., boundary spanners), objects (i.e., boundary objects), and practices (i.e., boundary practices). Central to this boundary infrastructure was the county office, operating as the hub of the ERNIC, who served as the main boundary spanners. The county office enacted multiple boundary crossing moves where they attempted to move across and get past different sociocultural differences between research, practice, and CI. As School Improvement Partner Brianna described,

> "Then the hub is doing things like devising a leaning strategy, they're chartering the network and updating the charter on a regular basis, they're initiating building a strong sense of community, they're integrating constant expertise, they plan action periods and consolidate action periods, and they engineer knowledge sharing across different types. Then, they provide a lot of the training and capability building across both the coaches and the networks. They regularly maintain and learn from the network data."

The county office also designed and led different boundary practices, including network meetings, cross-district visits, and network planning meetings that consistently brought together individuals from across multiple organizations involved in ERNIC, including the county office, eight districts, School Improvement Partner, and Eucalyptus University. Network meetings took place once every 2 months and brought together everyone from the initiative around the shared problem of improving mathematics. During network meetings, participants did math activities together, sometimes participated in professional development, collectively looked at district and network data, learned about CI methods, iteratively tested ideas for improving mathematics in their classroom, and discussed and shared learnings with other districts. During network planning meetings, the county, often with School Improvement Partner, would meet bi-weekly to co-plan the different

features of the ERNIC, including the agendas of network meetings, what data they should collect, and how to organize action periods when testing change ideas. Cross-district visits happened approximately three times a year and involved school district teams going to other districts and observing change ideas in math classrooms.

Further, the county office co-designed and supported the use of two key boundary objects – mindset surveys and driver diagrams – that coordinated work across research, practice, and improvement lines and supported the movement of Kinsley's research ideas into practice. The driver diagram articulated the theory of change for the ERNIC and the key levers (i.e., drivers) that would make progress on this theory of change. The mindset survey involved measures for assessing students' growth mindset in mathematics and whether the initiative was making progress on shifting classroom culture in mathematics.

Three key learning mechanisms

We find that the ERNIC boundary infrastructure provided opportunities for learning via three mechanisms: coordination, identification, and reflection. Via these three learning mechanisms, the county office designed and cultivated the use of a boundary infrastructure that supported maintaining, overcoming, and transcending of boundaries across research, practice, and CI communities. Importantly, the county's efforts to design and enact this boundary infrastructure was not always smooth. At times, it was a contentious process between (re)constructing and maintaining existing boundaries via identification, overcoming boundaries via coordination, and transcending boundaries via reflection.

Identification as a learning mechanism

When the county office engaged in identification, they made explicit the nature of boundaries between research, practice, and CI communities, both delineating how practices differed from each other (i.e., othering), as well as how they complemented each other (i.e., legitimating co-existence) (Akkerman and Bakker, 2011). The county explicitly delineated between School Improvement Partner's CI expertise and Eucalyptus University's mathematics expertise, but also described how each of their expertise complemented the others'. County leader Tiana shared, "Having a balance between someone who brought the innovations themselves, which is Kinsley, and then Brianna who said we can try to get those innovations off the ground, that was a nice division." The county office also highlighted the value of their own expertise and how it differed from yet complemented School Improvement Partner's CI expertise and Eucalyptus University's mathematics expertise. Tiana described her and the county's own expertise as bringing together Kinsley and Brianna's expertise together and figuring out how that worked in schools, sharing, "It was really left to us back in the school sites where they were not, to figure out, how do we actually do this."

Notably, identification as a learning mechanism involved not just recognizing different boundaries but also maintaining them, especially when the county office perceived that School Improvement partner overstepped their area of expertise. The county office's efforts to maintain boundaries via identification was sometimes a contentious process as partners negotiated new and unfamiliar ways of working together. For instance, Tiana shared:

> "Brianna taught for a few years…There are some moments where I felt like she might have overstepped a boundary, where she forgot the expertise and where it lied in the room. She'll try to say, you know, "In my experience with teaching"—I was, like, "You're—thank you—totally valid. I disagree, and that's not your expertise." Like, there has to be those hard boundaries. I hate to make it sound like I'm ungratefully not accepting someone's feedback. Sometimes they forget that they're here to support the improvement stuff, not content teaching."

Here, the county office did not minimize but emphasized differences between their expertise of the everyday realities of educators and school districts and the CI expertise of School Improvement Partner. We see this when Tiana described maintaining "hard boundaries" between partners involved in the CI RPP and when she delineated between School Improvement Partners' CI expertise and the county's teaching expertise in the context of CI work: "I disagree, and that's not your expertise." Thus, identification was not just about emphasizing points of connection and complementarity but also points of distinction and difference across different communities involved in the ERNIC.

Coordination

Coordination in the ERNIC involved fostering efficient cooperation between educators, School Improvement Partner, and Eucalyptus University, even without complete consensus between these partners. Specifically, the county office enacted boundary crossing moves, as well as supported the design and use of boundary practices (i.e., the network meeting), and boundary objects (i.e., driver diagrams) to support coordination across research, practice, and CI lines.

The county office, with the support of district improvement coaches, fostered coordination by translating perspectives and understandings between research, practice, and CI lines. The county office and district improvement coaches integrated CI and mathematics ideas and packaged this expertise for educators. The county office also shared the perspectives of teachers and their on-the-ground realities to external partners. Mathematics researcher Kinsley, for instance, described how the county operated as "… the bridge between us and classrooms. They knew what we were talking about. They knew what the teachers were doing and what the teachers were up against."

The county office also, in partnership with School Improvement Partner, designed and led the ongoing boundary practices in the form of network meetings, network planning meetings and cross-district sharing sessions that supported the ongoing flow of partnership work. These boundary practices regularly brought individuals from different organizations that typically did not interact in conversation with each other, both from across research, practice, and CI communities, as well as across eight different school districts. These boundary practices were routinized, potentially providing a means to make coordination a part of standard partnership practice (Akkerman and Bakker, 2011; Farrell et al., 2022). Network meetings, for instance, brought together eight district teams, often School Improvement Partner, and sometimes Eucalyptus University around the shared problem of elementary math, once every other month. Indeed, many network

meetings followed a similar format where they asked participants to engage in a similar set of activities, including icebreakers, doing math activities, looking at data, and designing and testing change idea via action periods. These network meetings also had clearly delineated roles and responsibilities for different groups that clarified expectations for how they might participate. Within network meetings, the county office was responsible for running and facilitating network activities, the district improvement specialists were responsible for CI coaching and support, teachers were responsible for learning around Kinsley's mathematics ideas and testing these ideas within the context of classroom, and school leaders were responsible for garnering school-level buy-in and supporting scale-up.

Further, the county office supported the design and use of boundary objects – especially the driver diagram – that also supported the ongoing flow of work by providing a common, albeit sometimes contested, vision for joint work. This driver diagram articulated a key aim of the CI RPP – to improve 5th grade math proficiency. It also articulated four main levers (i.e., drivers) for making progress on this aim statement: classroom culture and mindset, instructional practice, aligning supports for instructional improvement, and collective learning/shared knowledge, and multiple change ideas associated with each of these drivers. This driver diagram coordinated work across different partnership actors by serving as a theory of change to guide the work of the overall CI RPP. School districts also used the driver diagram to guide their efforts to improve mathematics, including guiding their small-scale tests of change and helping to figure out where they wanted to focus their district improvement efforts.

Boundary infrastructure in the context of coordination had two characteristics worth noting. First, coordination did not require consensus between educators, School Improvement Partner, and Eucalyptus University, but was about overcoming boundaries just enough to maintain the ongoing flow of partnership work (Akkerman and Bakker, 2011). Indeed, external partners, especially School Improvement Partner and the county central office, did not always agree on how partnership work should be done, especially given the disconnect between what the county leaders described between the "high-level" academic nature of CI and the everyday realities and ongoing work of school districts.

Second, coordination with the ERNIC did not materialize out of thin air but was built on long-standing relationships between the county office and school district, where county leaders had regularly connected districts to research evidence over the years. County leader Dana described these existing relationships as unique, and unlike what might exist in other county offices in the state:

> "Our districts already have a high level of trust with the county office, with the services we provide. They count on us to broker the knowledge between research and practice. I had a teacher once say, "Oh, I love coming here because you guys basically do all the research I need, and then you make it into bite-sized piece, so I can understand how to use it in my classroom."

Reflection as a learning mechanism

In alignment with prior work (Bohannon and Coburn, 2023), the county office, through the ERNIC boundary infrastructure, created opportunities for reflection around mathematics research ideas that supported transcending boundaries between researcher, practitioner, and CI communities. During these reflection opportunities, educators involved in the ERNIC could look differently at their own practices through the lens of CI and mathematics research, thereby potentially expanding their perspectives around their own instructional practices.

The county office designed and facilitated network meetings that provided multiple opportunities for educators to engage in perspective-taking, where school districts could look at their own practices via the perspectives and lens of reform mathematics and CI espoused by Eucalyptus University and the School Improvement Partner. For example, educators "did math" together, analyzed survey data related to students' mathematics mindsets, and participated in plan-do-study-act action periods where they iteratively tested change-ideas rooted in growth-mindset and Kinsley's other research-based mathematics ideas. During these activities, educators in school districts could look differently at their practices by taking the research-oriented perspective of Kinsley and Eucalyptus University. Nico, for instance, explained how educators looked at their practices through the lens of Kinsley's research-based idea of growth mindset. He shared, "The biggest opportunity for teachers: take something and then go apply it the next day…We constantly were able to model things that related—for example, the phase 1 was really establishing a growth mindset" … "We did a lot of things when it came to, "How does that look like in the classroom?"

These network meetings also provided opportunities for perspective-making, where educators from school districts made their own practices explicit in relation to Kinsley's mathematics research ideas and Eucalyptus University's CI ideas. These meetings, for instance, included district showcases where school district teams shared what they were testing and learning, leadership breakout sessions where administrators shared their experiences implementing and scaling the initiative within their school and district, and shared team spaces for school districts to collectively discuss and plan together around developing change ideas. Across these different activities, educators from across eight school districts shared their own perspectives, challenges, and experiences related to implementing and adapting mathematics and CI ideas within their own district and classroom contexts.

In summary, the county office designed and enacted a boundary infrastructure that provided opportunities for three learning mechanisms: identification, coordination, and reflection. Yet, as we have highlighted throughout, learning at the boundaries of research, practice, and CI did not involve full consensus but rather was often a delicate and dynamic process between maintaining boundaries via identification, overcoming boundaries via coordination, and transforming boundaries via reflection. In an especially prominent example, Doreen described how the county office acted to maintain boundaries between CI and practitioner communities (i.e., identification) when School Improvement Partner pushed too hard on wanting educators to look at their instruction practice from a CI lens (i.e., reflection). She shared,

> It was, I believe, hard for academia [School Improvement Partner] to understand the best mode in which to present the information to the K-12… There was a point too where we would, with the intensive coaching and the weekly calls, agree to disagree. When it came to a decision point and it wasn't often, but Tiana and

> I would conference and we would just say this is where we have to say we're the hub, we live in this community, we support these districts every day and we understand your expertise in research but our expertise in the context also needs to be acknowledged.

In this excerpt, the county office maintained boundaries between practitioner and CI communities by refusing School Improvement Partners' guidance. They did so by "agree[ing] to disagree" and emphasizing their own expertise in the specific contexts of their communities. Thus, the county office's efforts to design and enact boundary infrastructure was not always smooth. It was, at times, a contentious, delicate, and dynamic process that involved maintaining, overcoming, and transcending boundaries between CI, research, and practitioner communities.

It is worth highlighting how the county office's positional power likely played an important role in maintaining boundaries in the context of ERNIC. On one hand, the county received and managed the grant that funded CI work to support Common Core implementation, so they had access to power by virtue of their control over material resources that funded the CI RPP. The county office's power base was also likely related to their brokerage position in the social network as they were the main connectors between School Improvement Partners, Eucalyptus University, and school districts (Burt et al., 2013; Collien, 2021). Given this brokerage position, the county office had valuable access and insight into information about school districts' everyday realities and contexts that School Improvement Partners did not, which may have afforded the county with disproportionate influence over how information flowed between research, practice, and CI communities.

Conclusion and discussion

Given ongoing concerns about the disconnect between research and practice communities (Penuel et al., 2015; Farley-Ripple et al., 2017), our study offers an important case where participation in a CI RPP was associated with educators' uptake of research-based mathematics ideas in two rural school districts. We find ERNIC educators, to varying degrees, took up four research-based mathematics ideas – growth mindset, multiple ways of engaging in mathematics, the importance of rich tasks, and depth not speed – and experienced few actual boundaries that stalled work in the CI RPP. We argue that these findings can be explained, in part, by how the county office designed and cultivated a boundary infrastructure that created important opportunities for learning across research, practice, and CI communities via three key mechanisms: identification, coordination, and reflection.

Study limitations and future research

Our study does have several limitations that offer important opportunities for future research. While all partners brought expertise to the table, our research design focused on educators' uptake of research ideas but did less to interrogate how research partners took up practice-based ideas. As others have argued (e.g., Finnigan, 2023), future research could examine how researchers can learn from RPPs instead of focusing on practitioners' learning alone. When doing so, this scholarship could interrogate what counts as useful evidence, considering more than just academic research but also experiential and professional wisdom, and who gets to decide, examining what communities under inquiry value in research (Ming and Goldenberg, 2021).

Second, although our study examined whether and to what extent educators took up research-based ideas, including the research idea of "growth mindset," future research could interrogate the content of research evidence, as research is not neutral or apolitical (e.g., Doucet, 2019; Finnigan, 2023). Indeed, existing scholarship has noted concerns with blaming students from marginalized communities for their "growth mindset" without adequate attention to broader structural and systemic inequities (King and Trinidad, 2021). Other scholarship has critiqued color-evasive pedagogies that downplay or ignore issues of students' racialized identities and the broader sociocultural environments in which learning takes place (McKinney de Royston et al., 2021). Thus, future research could pay particular attention to the broader racialized and political contexts that shape what is valued as research evidence (Finnigan, 2023).

Contributions to theory, policy, and practice

Despite these limitations, this paper offers several contributions. First, given ongoing concerns raised by existing scholars about the limited or uneven impact of research on practice (e.g., Gamoran, 2018; Slavin, 2002), our study provides an important case where participation in a CI RPP was associated with educators' take up of research evidence. Existing literature highlights the importance of engagement with research ideas (i.e., conceptual use) as a mechanism for shifting thinking and generating new understandings (Anderson et al., 2023; Finnigan, 2023), but offers less insight how to foster these shifts in thinking. We argue that educators' take up of research evidence was associated with the CI RPPs' boundary infrastructure – or the interconnected constellation of people, tools, and practices—that can support learning across research, practice, and improvement lines. In so doing, we build on existing theorizing on knowledge brokering (Farley-Ripple et al., 2017) to offer a conceptualization of boundary infrastructure that stands in contrast to other frameworks which typically foreground the *individuals or organizations* who broker between research and practice (Ward et al., 2009). By contrast, we center the complex *systems* comprised of tools (e.g., driver diagram, mindset survey), practices (e.g., network meetings, cross-district visits, network planning meetings), and people (e.g., county office, district improvement coaches) that collectively support the movement of ideas between research, practice, and CI communities. We also show *how* this network of objects, practices, and people operated in interconnected ways to maintain the ongoing flow of work even in the absence of consensus (i.e., coordination), delineate complementary ways that different practices and expertise related to each other (i.e., identification), and support educators in expanding their perspectives on their practice from the lens of mathematics research and CI (i.e., reflection).

Second, county offices are increasingly asked to support CI and instruction (Manansala and Cottingham, 2019), but there is limited literature on how they can do so. Our study highlights the possibilities for county offices of education as critical actors in CI efforts. The

county office in our study enacted boundary spanning moves, developed and supported the use of boundary objects, and designed and led boundary practices in ways that brought together research, CI, and practice communities. In doing so, the county office centered the local assets and realities of the rural school communities that they worked with. Indeed, existing research highlights the importance of rural leaders in adapting partnership work in ways that center the local wisdom and realities of their communities, especially given the diversity and complexity of rural districts (Zuckerman, 2019; Wargo et al., 2021). Via the boundary infrastructure, the county office also supported the integration of a CI approach into existing district governance systems so that these efforts were not tangential to or separate from school districts' everyday work. This was especially important given that educators named multiple potential boundaries between what they perceived as the overly academic nature of CI approaches and rural school districts' everyday realities.

Third, existing studies of boundary infrastructure, including our own, often focus on the ways that individuals or organizations make or strengthen connections between research and practice communities (e.g., Penuel et al., 2015; Farrell et al., 2021). Our study suggests that *maintaining boundaries* can also be an important activity with RPPs that is often overlooked. As researchers and CI partners entered into "territory in which we are unfamiliar and, to some significant extent therefore unqualified" (Suchman, 1994, p. 25), they sometimes "overstepped," such as, for instance, when the county office noted how their CI partners failed to adequately acknowledge their expertise for supporting school districts around instruction. In these cases, the county office, instead of spanning or reconstructing boundaries, maintained them by emphasizing rather than minimizing differences between their expertise of the everyday realities of educators and school districts and the CI expertise of School Improvement Partner. Thus, our study provides additional evidence (Akkerman and Bakker, 2011; Wegemer and Renick, 2021) that boundary infrastructure can support overcoming discontinuities in action that may arise from sociocultural differences rather than overcoming or avoiding sociocultural differences themselves. Boundary work in the context of RPPs may not always involve full or easy resolutions, but rather, participants may "agree to disagree" and thereby maintain distinctions between researcher and practitioner communities and the value and expertise each community can bring to the table (i.e., identification).

Although our study did not explicitly ask about power dynamics in the context of boundary infrastructure, the county office's moves to maintain boundaries are an important example of how power can be produced through actions that enable and constrain the practices of others, what we have called power moves in previous work (Sandoval et al., 2024). We see this when the county office maintained boundaries with School Improvement Partner in ways that shaped the nature of future partnership work. At the same time, the county office's positional power, related to their access to grant funding and their brokerage position in the social network, likely enabled them to refuse School Improvement Partners' guidance. The county's positional power was unique amidst often described power asymmetries in the literature between researchers and practitioners, and the historical and contemporary ways that academic research is often valued over practitioner or lived expertise (Farrell et al., 2021; Ming and Goldenberg, 2021). The role of power in CI RPP boundary infrastructure is an important direction for future research.

Our study also has implications for policy and practice. With the county playing a different role that was focused on supporting CI (Manansala and Cottingham, 2019), this case could serve as a model to explore or adapt in other contexts. Our study suggests that county offices could consider how they can design and support a broader boundary infrastructure, with explicit attention to the broader network of objects, people, practices that can support ongoing interactions between research and practice communities. When doing so, county offices could also consider how CI approaches could be integrated into existing district governance systems, so these efforts are not tangential to or additional responsibilities beyond school districts' everyday work. Further, county offices could pay explicit attention to power dynamics between research, practice, and CI communities and the importance of overcoming discontinuities in action that may arise from sociocultural differences rather than overcoming or avoiding sociocultural differences themselves.

Taken together, this study shows the importance of county offices and their potential role for bridging between research, practice, and CI communities, but also maintaining boundaries between these communities when external partners overstep. Further, we hope our study represents an important starting point for moving beyond individual knowledge brokers to interrogating the interconnected, dynamic, and sometimes contested systems that link research, CI and practice and the mechanisms by which learning occurs.

Data availability statement

The datasets presented in this article are not publicly available due to confidentiality agreements and the sensitivity of research data. Requests to access the data should be made to bohannon-angel@norc.org.

Ethics statement

The studies involving humans were approved by the Northwestern University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AB: Writing – original draft, Writing – review & editing. CF: Writing – original draft, Writing – review & editing. SC: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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