Research paper

Analyzing a teacher and researcher co-design partnership through the lens of communities of practice

Golnaz Arastoopour Irgens [a, *], Shanna Hirsch [a], Danielle Herro [a], Matthew Madison [b]

[a] *Clemson University, United States*
[b] *University of Georgia, United States*

H I G H L I G H T S

- Teachers mutually engaged by having shared goals, values, and experiences.
- Teachers viewed the researchers' roles in the community as multifaceted.
- Teachers co-constructed knowledge with other teachers and researchers, while identifying conflicts and negotiating meaning.
- We present suggestions for seeding and cultivating a sustainable co-design researchpractice partnership.

A R T I C L E   I N F O

A B S T R A C T

Research-Practice Partnerships (RPP) bridge the gap between schools and universities. However, few have embraced the co-design process through a *communities of practice* lens and investigated how knowledge is co-constructed and negotiated. This mixed-method study explored how elementary school teachers co-construct knowledge with researchers to understand better how a community of practice can be cultivated during a co-design RPP. Findings from a survey, journal entries, observational field notes, and focus groups suggest teachers co-constructed knowledge while acknowledging and mitigating conflicts. Based on these findings, we offer ways to seed and cultivate communities of practice among teachers and researchers for co-designing educational innovations.

© 2022 Elsevier Ltd. All rights reserved.

In the last few decades, educational researchers have explored models in which researchers and teachers co-design curricula. Penuel et al. (2007) define co-design as a highly facilitated collaborative process with defined roles in which teachers and researchers design, develop, and implement educational innovations. Teachers play an active role by helping to frame the vision for the creation, testing the innovation in their classrooms, and providing input for improvement. Although the principal investigator of a research project initiates and organizes activity, partnerships between teachers and researchers should be mutually beneficial (Matuk et al., 2016). For example, teachers can shape the future of their practice, and researchers can learn from teachers' experiences about the role of tools in teaching and learning. Co-designing often occurs in more formal research-practice partnerships (RPPs) in which the commitments are long-term and open-ended. The

stakeholders of an RPP collectively define their approaches for investigating problems of practice and solutions for improving outcomes in educational systems (Coburn & Penuel, 2016). Studying how the processes and products of co-design build capacity in the partnership for bringing about educational change is a bold and vital undertaking (Penuel & Gallagher, 2017). However, research involving RPPs is relatively new, and several questions remain about outcomes and consequences, comparative studies with different designs, practical strategies and frameworks, and the political dimensions of partnerships (Coburn & Penuel, 2016).

Preliminary RPP research has focused on relationships among partners. Researchers and teachers negotiate their roles and responsibilities with the shared goal of innovating education (Farrell et al., 2019). The negotiation process is built upon a foundation of trust, transparency, and flexibility (Harrison et al., 2017). When there is trust and vulnerability, sharing knowledge and aligning goals can take place. As Connolly (2019) argues, the core strength of an RPP is conducting rigorous research that practitioners can use

* Corresponding author.
E-mail address: garasto@clemson.edu (G. Arastoopour Irgens).

directly to impact policy and practice. In a co-design RPP, much of this process occurs during professional development sessions. Research outcomes related to teacher development in co-design RPPs include promoting teacher ownership over curriculum (Matuk et al., 2016; Westbroek et al., 2019), providing opportunities to reflect and improve practices (Scornavacco et al., 2021), and developing knowledge and skills to address just-in-time needs in the classroom (Kyza & Nicolaidou, 2017). However, the research is still nascent regarding cultivating and maintaining engagement and how knowledge is constructed and negotiated in RPPs (Farrell et al., 2022).

To address these gaps, in this study, we relied on the *Communities of Practice* framework (Lave & Wenger, 1991; Wenger, 1999; Wenger et al., 2002) to guide the development of a professional development program in which teachers and researchers co-design multi-disciplinary data science curricula for elementary school-aged children. A community of practice lens allowed us to focus on how knowledge is co-constructed in the partnership and how teachers navigated the shared goal of improving education for all students through mutual engagement with researchers. The following questions guided our study:

[RQ1] To what extent did teachers view the co-design RPP as a newly developing community of practice?

[RQ2] How did teachers conceptualize their engagement and knowledge-building with researchers in a co-design RPP?

In the following sections, we describe the theory of communities of practice and its use in teacher education research. Then, we present results from a mixed-methods analysis of data from a communities of practice membership measure, daily journal entries, observational notes, and focus groups collected from a summer professional development program. We discuss three emerging themes related to teachers' perceptions of the co-design process in a newly developing community of practice. Based on these findings, we summarize what we have learned about cultivating a co-design RPP community of practice. Our findings offer researchers a way to guide the design of co-design RPPs and build sustainable, mutually beneficial relationships with teachers.

1. Background and theory

A community of practice is a group of people who share values and concerns about a domain and regularly interact to improve their practice together (Wenger, 1999). This framework characterizes learning as fundamentally situated, social, and participatory. In other words, through a community of practice lens, people mutually and actively construct and negotiate meanings related to a particular domain. By engaging with each other over time, members refine their practices, which Wenger (1999) defines as implicit and explicit ways of doing that are meaningful to the group. Members willingly negotiate the practice and set new norms as the community participation, roles, and membership change. Through this engagement, members not only negotiate the practice itself but also how they view themselves. For example, Lave and Wenger (1991) studied non-drinking alcoholics attending Alcoholics Anonymous meetings. They noted that one common practice was learning to tell a personal story to provide examples for other members. This practice was not explicitly learned or taught. Instead, newcomers learned the practice by observing and engaging with existing members in various ways. By engaging in such practices, members changed their behaviors and how they made meaning in the world. This example of an existing community of practice exemplifies how membership entails *mutual engagement* and changes in how one acts and views the world (Wenger et al., 2002).

Researchers have explored how teachers and researchers come together to create communities of practice with the shared goal of critiquing and improving education. This is a significant shift from Lave and Wenger's initial conceptualization of describing *existing* communities of practices to *creating* communities to develop innovative learning environments and improve practices. However, as Palincsar et al. (1998) argue, in the flexible world of education, there is no consensus about the goals of learning, and there is no single best practice for all students in all situations and communities. Unlike communities that emerge in anthropological research, teachers typically have limited opportunities to interact with other teachers or with researchers. In other words, traditional educational settings are not ideal for naturally occurring communities of practices for the profession of teaching. Thus, creating and cultivating communities of practice unites researchers and teachers with the shared goal of developing innovative educational materials. In later years, Wenger et al. (2002) agreed that communities of practice could and should be cultivated. They argue that "cultivation is an apt analogy … some communities of practice grow spontaneously while others may require careful seeding" (p. 13). "Seeding" a community of practice in educational settings requires fostering participation and negotiating goals rather than imparting plans and structures.

More recently, the cultivation of communities of practice has been applied to research on teacher professional development (Chalmers & Keown, 2006; Ervin-Kassab & Drouin, 2021; McLoughlin et al., 2018; Patton & Parker, 2017). A core principle of creating a community of practice for integrating educational research and practice is that members must have a *shared purpose* (Buysse et al., 2003). Typically, an RPP has a shared purpose to improve teaching and learning. Palincsar et al. (1998) found that when teachers and researchers relied on diverse expertise, it was distributed among members to achieve their shared goals. In their research bringing together teachers and researchers to design science curricula, they discovered that creating a learning community requires sharing responsibilities and authority.

Hence, members rely on each other to fulfill their tasks and goals. When people rely on each other's expertise, they guide one another through their different understandings of the same problem. This process of *thinking together* (Pyrko et al., 2017) includes technical, practical, historical, and relational knowledge relevant to the communities' goals. Members share explicit and tacit knowledge and (re)develop how they make meaning in the world. In other words, they guide one another through their respective ways of thinking and use each other's insights to help them reach their goals more effectively. Through a communities of practice lens, thinking together requires not only knowing together but also doing together to enact and (re)create knowledge. By engaging in repeated interactions of thinking together, members can reach a deep understanding of essential knowledge of the practice. To facilitate repeated episodes of thinking together, members relate to each other through *social and professional* forces (Palincsar et al., 1998). Members engage in social behaviors such as coffee breaks and sharing personal stories that are not directly in service to the shared goals or improvement of practices. Rather, these activities indirectly build trust connections among members to help reach shared goals more effectively.

In short, what keeps a community of practice together and functioning is that the members can learn together about something that interests them. Wenger (1998) claims that a sustainable community of practice "is defined by knowledge rather than by task, and it exists because participation has value to its members" (p. 2). In other words, not only are the community's goals of interest to the members but they are deeply valued. Because members

value the goals and the practices in the community, they are motivated to create, organize, and share knowledge and feel ownership over the co-constructed knowledge (Wenger, 1998).

This body of empirical work denotes examples of applying the communities of practice framework to teacher professional development contexts in which teachers and researchers might collaborate to develop curricula. The participatory nature of being a member of a community of practice allows teachers to engage in empowering professional learning by being co-creators of curricula that directly address problems of practice that are meaningful for them (Goldman et al., 2019; Voogt et al., 2015). Thus, cultivating a community of practice within a co-design RPP highlights teachers' and researchers' shared and conflicting goals, thinking together, negotiating meaning, and combining the social with the professional to develop sustainable, respectful relationships.

2. Method

This study focused on how teachers co-construct knowledge with researchers to understand better how a community of practice can be cultivated during a co-design RPP.

2.1. Setting, participants, and researcher positionalities

Our RPP began in the fall 2020 with a public elementary school. Kent Elementary School (the school's name is a pseudonym) is situated in a rural Southeastern community in the United States, located approximately 20 miles from the university. The building contains shared learning spaces, such as a collaborative learning lab, with ocean-themed wings housing each grade level. Kent's multiple initiatives are built around science, technology, engineering, and math (STEM), such as a project-based curriculum, a 1:1 technology program, and numerous community partnerships.

Before forming the RPP, research team members met with the school's administrator to discuss the school's needs and determine whether a partnership was mutually beneficial. Given Kent's STEM focus, the administrator felt the project was well-aligned with their community's goals. After two other conversations, the administrator gauged teacher interest and sent a list of potential teachers to the research team. Teachers on the list could opt to participate; the administrator did not require it. The lead Principal Investigator on the project introduced the study to teachers during a virtual meeting without district administrators on the call. Teachers were compensated with a monetary stipend for their participation.

Kent's faculty includes 23 teachers, two administrators, two instructional coaches, nine special teachers (e.g., virtual education, music, physical education), one guidance counselor, and one special educator. Kent serves 458 students in grades PK-5. The school's students include 68 Black students, 86 Hispanic students, 258 White students, and 46 students who identify as multi-racial. Of those students, 455 are free lunch eligible. The student teacher ratio is 14.77 to one.

We purposely focused on recruiting educators in grades 3–5 to ensure alignment with the data science curriculum and state standards. The school partners included nine educators: 6 general education teachers (3 general education teachers in grades 3–5 chose not to participate), two instructional coaches, and one specialist (music/gifted education). The gender and race demographics of the educators were 7 White women (instructional coaches, general educators, and specialists), 1 White man (general educator), and 1 Black woman (general educator). Years of teaching experience ranged from 2 to 23 years.

Our research team consisted of two professors specializing in learning sciences (White women), one professor of quantitative methods (African American man), one professor of special education (White woman), and three learning sciences graduate students (one White woman, two Black African men). Every member of the research team shared the goal of cultivating a long-term community of practice with teachers to co-design interdisciplinary data science pop-up curricula that improve student outcomes. We also shared a desire to improve our practices as we engaged in the co-design process.

In education, the term *pop-up* has been used to describe new material or activities not covered in the traditional curriculum through interactivity, hands-on, and discovery learning. As such pop-ups are increasingly used in STEM-focused, design, and engineering environments (Tranquillo & Matthew, 2015). The curricula were also meant to be portable or shared, between schools and classes and customizable for each grade level.

2.2. Context

The school was committed to partnering with the university team but was in the midst of a challenging situation as they navigated keeping students safe from COVID-19 while reopening schools. The PI paid careful attention to the role of research during a global pandemic, and during the fall of 2020, all communications were virtual. The principal investigator and building administrator opted to wait until the spring of 2021 to begin meetings with the teachers. In the meantime, the research team dropped off care packages for the teachers containing items such as robot mini notepads, pencils, and candy. This was an early effort to build trust and acknowledge the importance of the partners.

Initially, all meetings were virtual and then moved on-site as members of the research team received COVID-19 vaccinations. In the spring of 2021, teachers and researchers met online three times over three months (see Table 1 for a timeline of events). During the initial 1-h virtual meeting, the research team and teachers focused on getting to know each other. After the first session, teachers were invited to two additional sessions in which they shared more about their classroom spaces and student interests. The meetings also included information about computational thinking practices and data science. To encourage participation from teachers, we set up Jamboards, a digital collaborative notetaking tool, and used breakout rooms in the virtual space. This allowed for small group discussions and interactions among participants. In between meetings, the teachers and researchers emailed back and forth to discuss logistics and other topics related to the project. While all the teachers expressed interest and excitement over the partnership, several teachers asked questions specific to their learning goals and content areas to ensure that data science was a good potential fit for their students.

Next, we met at the school site for four days during the summer. The four days were dedicated to developing a data science curriculum. The first day focused on (a) goal setting, (b) discussing data science, and (c) identifying student interests. In small groups, teachers and researchers brainstormed ideas about potential topics, data sets, and lesson ideas. Teachers began to explore the free version of the digital data visualization software TUVA (http://www.tuvalabs.com). TUVA allows users to drag and drop data components to create and analyze a variety of visualizations (Wolff et al., 2019). During the last half of the day, researchers provided the teachers with a lesson template to complete as they designed their data science unit. The second day included an overview of universal design for learning (UDL; Center for Applied Science Technology, 2020). The research team provided several hands-on activities and scenarios for the teachers to explore UDL concepts. The second part of the day was devoted to stations or workshops for teachers to experience a variety of activities that they may wish to include in their units. During the third day, teachers collaboratively developed

Table 1
Timeline of events.

Date (Duration)	Focus *Format*	Activities
1/20/2021 (1 h)	**Kick-Off Meeting** *Virtual* • Shared goals of the research study. • Learn about each other and share expertise	Met in breakout rooms and discussed the following (used Jamboards): • What are your teaching strengths? (regarding teaching practices, technology and working with your student population) • What are you looking forward to with this project (technology, data science, student differentiation)? • What are you nervous about? What challenges would you like us to be aware of?
2/17/2021 (1 h)	**Introduce Data Visualizations and Pop-Up Framework** *Virtual* • Discussed an article from Today's Kids • Shared spaces and something personal • Walk through an example data set.	Met as a whole group and discussed the following: • The Team Shared the Article: Who Will Shape the Future of Data Visualizations? Today's Kids! • Everyone pasted two pictures into a Google Slide Deck and shared their favorite workspace and a personal picture. *If someone preferred not to share a personal picture, then they left it blank or picked another image.* • A research team member presented a quick walk through of an example data set. The school (Kent) team provided feedback

3/24/2021 (1 h)	**Making Connections**
	Virtual
	• Shared interests of educators and students
	• Discussed data science through the lens of the job/career connections
	• Reviewed Pop-up Framework
		Met as a whole group and discussed the following:
		• Interests and Introductions: Paste three images:
		  1. Share an image of one of your interests/hobbies (professional, personal)
		  2. Share an image of one of your students' interests/hobbies
		  3. Share an image of a mutual interest
		• A research team member presented a data science scenario. The school (Kent) team provided feedback.

December 7, 2021 (5 h)	**Intro to Data Science and Learning to use TUVA** *In Person at School Site*	Met as a whole group: • Goal setting • Data science workshop • Identifying student interests and scenarios • Educator work time (1 h)
7/13/2021 (5 h)	**Embodied Data Science Activity, Universal Design for Learning (UDL)** *In Person at School Site*	Met as a whole group: • UDL workshop with a focus on differentiation for students with disabilities • Embodied data science activity Small Groups • Rotating workshops for inspiration for activities (robotics, graphic novels/comics/TinkerCad, and video creation) • Educator work time (1 h)
7/14/2021 (5 h)	**Standards Alignment/Formative Assessment** *In Person at School Site*	Small Groups • Standards alignment, authentic assessments, and identifying formative assessments. • Educator work time (2 h)
7/15/2021 (5 h)	**Authentic Assessments; Pop-Up Checklist, Showcase** *In Person at School Site*	Met as a whole group: • Creating a checklist/rubric for non-traditional assessment • Focus group interviews • Teacher work time (1 h) • Lunch as a group with karaoke. Participants included teachers and researchers. • Educator showcase

Note. In this table, we summarized the key topics and activities. For a complete list or copies of the agenda, please contact the first author.

their data science lesson plans and assessments with colleagues and researchers. On the fourth and final day, the teachers created rubrics, student checklists, and other formative and non-traditional assessments. We conducted three focus groups to understand the educators' perspectives better. During lunch, researchers and educators also hosted a karaoke session. After lunch, each group of educators presented their unit plan during a showcase.

It is important to note that although we refer to a community of practice in this paper, the term of art was not explicitly discussed with the teachers. Instead, the researchers wanted to partner with the teachers during the co-design process. For example, at the beginning of the study, we discussed our vision for the research study as co-creators. During an initial meeting, a research team member described the team's roles as researchers and co-creators of the curriculum (e.g., address research questions, co-create of curriculum as part of the process to learn and evaluate, work to create pop-ups together, support implementation collect data to analyze, and write reports to NSF). The researchers also shared the expectations for teachers as co-creators of the curriculum (e.g., use your expertise to inform our research,Use our expertise to inform your teaching (and your existing expertise), complete surveys, interviews, reflections, participate in classroom observations, share curriculum artifacts). During subsequent meetings, the researchers frequently asked teachers for formative feedback on the summer

co-design sessions (e.g., pacing) and the curriculum and technology tools (e.g., TUVA).

2.3. Data collection and analysis

We used a mixed methods exploratory design (Creswell & Clark, 2017) where qualitative data were emphasized and analyzed to explain the quantitative results. We collected data using a Community of Practice survey measure (Hardesty et al., 2022), daily reflective journals with guided prompts, observational field notes, and focus groups that were video-recorded and transcribed.

2.3.1. Quantitative communities of practice survey measure

At the time of the study, there was no validated survey for measuring a community of practice within education. Therefore, we relied on a researcher-created measure (Hardesty et al., 2022) that was undergoing validation outside our study. This measure is drawn from Wenger et al.'s (2002) guidelines for practitioners on the three domains related to communities of practice: 1) domain (shared domain of interest that is the focus of the group), 2) practice (shared collection of skills, tools, and resources available to professional who practice in the domain), and 3) community (relationships among practitioners that allow them to support and learn from each other). A preliminary analysis of the measure

(N = 135) indicated high internal consistency (Cronbach's alpha = .98; Hardesty et al., 2022).

For this project, we adapted the measure's wording to reflect "Pop-Up PD." Teachers rated the 20 items (see Table 3 for specific questions) on a 5-point Likert-type scale ranging from 1 to 5 (1 = *Strongly Disagree*, 2 = *Disagree*, 3 = *Neutral*, 4 = *Agree*, and 5 = *Strongly Agree*).

Educators completed a paper copy of the communities of practice measure at the end of the focus groups on Day 4. The measure was collected anonymously to encourage the participants to be honest in their responses. Responses were analyzed using descriptive statistics: maximum, minimum, and median scores due to the skewed distribution of the results.

2.3.2. Qualitative analysis of daily reflective journals, focus groups, and observational field notes

Teachers completed four daily online journals containing 3–5 question prompts, such as "Tell us in a few sentences what you did today, what went well, and what you have questions about" and more open-ended questions, such as "Anything else on your mind?" For this analysis, we selected four responses to questions related to the co-design process: "What was it like working with the research team?" (Day 1 and Day 4), "How would you describe the co-design process to another teacher?" (Day 4), and "What did you like most about the workshop? Do you have suggestions to improve the workshop?" (Day 4). Teachers also engaged in a 60-min focus group reflecting on the four-day co-design professional development sessions. Graduate students conducted these focus groups. The sessions were video recorded and transcribed.

The journal responses and focus group transcripts were analyzed using a grounded thematic analysis (Saldaña, 2011). Using communities of practice as a theoretical lens for the first round of coding, we identified deductive codes. We used open coding for the second round of coding (Strauss & Corbin, 1997) to identify inductive codes that were grounded in the data and may have been overlooked with the initial deductive coding. Codes were not mutually exclusive, and each teacher's response or turn of talk was coded as a whole. Two researchers coded and discussed using iterative team-based open coding until they reached intercoder consensus on each code (Cascio et al., 2019). This final set of agreed-upon codes (Table 2) across the two datasets was organized into three themes that best represent the major findings in the study: engagement and values, relationship with the researchers, and knowledge building.

Three trained researchers also took observational field notes during the professional development sessions. All three researchers used the same observation and reflection instrument to record daily observations focusing on 2−3 teachers. For validity purposes, these field notes were used to reconstruct descriptive examples to triangulate the results (Creswell & Miller, 2000) from the teachers' journal entries.

3. Results

RQ1: To what extent did teachers view the co-design RPP as a newly developing community of practice?

Overall, the co-design RPP process received high ratings from the participants (N = 9). As shown in Table 3, the maximum score on the communities of practice measure for educators was 5 and the minimum was 4. The median score across all items across all teachers was 5 and the mean was 4.87. Eight teachers had a median score of 5 across all items. One teacher had a median score of 4 and mean score of 4.4. These scores suggest that teachers viewed the partnership as a developing community of practice in terms of a strong sense of belonging to the community, increased identification as a professional teacher within the community, and improvement of teaching practice.

Similar findings were illuminated in the participant's journals as participants noted that they felt a supportive community emerged. For example, when prompted to describe the co-design process to another teacher, a participant wrote, "Basically, you are working collaboratively with another professional to create a lesson, unit, or project. You are utilizing both of your strengths but also encouraging each other through your weaknesses." A different participant shared, "I would say that it is a design that lets all people flourish and share his or her expertise."

RQ2: How did teachers conceptualize their engagement and knowledge building with researchers in a co-design RPP?

As indicated by the quantitative measure, teachers felt a strong sense of belonging to the RPP and increased expertise as a result of

Table 2
The coding scheme used to code journal responses and focus group transcripts.

Theme	Code	Definition	Example
Engagement and Values	Enjoyment	Expressing joy, happiness, or fun while interacting with the group	"The research team was **truly a joy** to work with."
	Diverse Expertise	Valuing the multiple types of knowledge and expertise brought to the group by researchers or teachers	"I love that **all of the people have expertise in various things**."
	Improving Education	Referring to a shared goal of improving teaching practices and learning for students	"Working together to **make learning accessible for all students**."
Relationship with Researchers	Researcher as Partner or Colleague	Referring to researchers treating teachers as a partner, equal partner, or colleague in a positive or professional manner.	"I appreciate **being treated as an equal and as a knowledgeable professional**."
	Researcher as Supporter	Referring to the research team as being helpful, supportive or describing how the researcher supported the teacher's curriculum design or ideas.	"As you begin to write your pop-up, **the team offers help when needed, asks questions to guide you, and supports you in every aspect** of writing the pop-up."
	Researcher as Expert	Referring to the researchers as experts; using terms that suggest researchers were imparting resources; teachers as passive receivers of knowledge.	"I liked all of the **information and resources that were provided**."
Knowledge Building	Co-Constructing Knowledge	Referring to learning together while working together; relying on others' knowledge to accomplish a task or reach a goal	"We had chances to **work with our school-level peers, but also work with and learn from the research team**."
	Identifying Conflicts	Describing a practice, norm, or ways of knowing in the group that was problematic, frustrating, or created conflict or tension	"Even though we did an example and worked through some ideas, **I didn't realize step-by-step everything that needed to be in my pop-up until day 3**."
	Negotiating Meaning and Practices	Proposing a solution or mediating a conflict or tension regarding knowledge and practices in the group	"Next time, **I would recommend giving teachers a checklist/ specific list** of what exactly needs to be in the pop-up"

Table 3
Communities of practice survey items and descriptive statistics.

Item	M	SD	Median	Mode
1. I feel a greater sense of connection to other professionals as a result of my participation in this Pop-Up PD	4.78	0.44	5.00	5.00
2. I have built new professional relationships as a result of my participation in this Pop-Up PD	4.78	0.44	5.00	5.00
3. I feel less isolated as a result of my participation in this Pop-Up PD	4.22	1.30	5.00	5.00
4. This Pop-Up PD added new pertinent skills to my professional toolbox	4.89	0.33	5.00	5.00
5. I will be able to use the skills learned in this Pop-Up PD with my students in the near future	4.78	0.44	5.00	5.00
6. This Pop-Up PD emphasized the sharing of participant knowledge and experiences	5.00	0.00	5.00	5.00
7. I felt safe sharing and learning in this Pop-Up PD	4.89	0.33	5.00	5.00
8. This Pop-Up PD provided an inclusive and accessible environment that allowed my full participation	5.00	0.00	5.00	5.00
9 This Pop-Up PD used knowledge from its participants as part of the Pop-Up network	5.00	0.00	5.00	5.00
10 My knowledge of best practices improved by learning from other participants in this Pop-Up PD	4.89	0.33	5.00	5.00
11. This Pop-Up PD presented information that was relevant to the topic at hand	5.00	0.00	5.00	5.00
12. I gained new knowledge about the session topics as a result of this Pop-Up PD	5.00	0.00	5.00	5.00
13. This Pop-Up PD emphasized the use of best practices	5.00	0.00	5.00	5.00
14. I will be able to use these best practices with my students in the near future	4.89	0.33	5.00	5.00
15. This Pop-Up provided opportunities to expand my expertise	4.89	0.33	5.00	5.00
16. I have increased my expertise as a result of this Pop-Up PD	4.89	0.33	5.00	5.00
17. This Pop-Up is responsive to new and emerging issues	4.89	0.33	5.00	5.00
18. I am more aware of new and emerging issues as a result of this Pop-Up	4.89	0.33	5.00	5.00
19. This Pop-Up PD addressed a topic that I am committed to	4.78	0.44	5.00	5.00
20. The participants of this Pop-Up shared a commitment to the topic of this Pop-Up PD	5.00	0.00	5.00	5.00

Note. In this table, we provide the results of the Communities of Practice measure. This survey was adapted from the ECHO Community of Practice Measure (Hardesty et al., 2022). Participants responded to items given a 5-point Likert-type scale with 1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*.

participation. At the same time, teachers and researchers experienced moments of tensions as they constructed knowledge and negotiated expertise, primarily around different ways of using data science tools, preferences for teaching and learning, and domain-specific data science language and practices. The following findings summarize teachers' 1) active engagement with researchers and other teachers in the community of practice, 2) perceptions of the roles of the researchers, and 3) knowledge building process with researchers and other teachers, including mitigating the conflicts that emerged.

3.1. Engagement and values

3.1.1. Enjoyment, socializing, and building relationships

According to teachers' daily journal submissions, when asked "What was it like working with the research team?" teachers responded similarly at the end of Day 1 and at the end of Day 4. The number of responses that were coded for *enjoyment* increased from Day 1 (5 responses) to Day 4 (7 responses), indicating an increase in positive feelings towards the professional development sessions and the research team. For example, at the end of Day 1, one teacher simply responded, "This was excellent," and another teacher replied, "The team is amazing! Thank you for partnering with us." Similarly, at the end of Day 4, one teacher replied, "I love loved it!" and another responded, "a joy and a pleasure." Another teacher stated, "The research team has been so helpful, kind, and fun to work with! I loved the karaoke too!" This last comment was about a session in which the researchers and teachers ate lunch together and sang karaoke songs. The decision to organize a karaoke session emerged from informal discussions between researchers and teachers. One teacher provided a microphone, and another teacher provided a disco ball. Three researchers and one teacher performed while the other teachers and researchers provided support through cheers, laughter, and singing along.

3.1.2. Valuing diverse expertise within the group

Teachers also valued the *diverse expertise* of researchers and teachers in the group. In their Day 4 entries, six teachers mentioned the varied expertise and knowledge in the group as an asset. For

example, one teacher wrote, "I love that all of the people have expertise in various things," referring to teachers and researchers. Another teacher specifically valued the diverse knowledge within the research team and wrote, "I think it was very beneficial to have a diverse research team to work with that stretched our thinking throughout the week." During the co-design sessions, we observed that teachers relied on each other for different areas of expertise. For example, three third-grade teachers developed a unit on data science and social media usage. The reading teacher focused on writing and conceptualizing the scenario and driving question for the unit. The science teacher, who had experience with digital technologies and robotics, created activities using TUVA, the digital data science visualization tool. The math teacher researched websites and resources to support the activities.

3.1.3. Shared goal of improving education

It was clear that teachers were working towards a shared and valued common goal of *improving education* for their students by developing new data science curricula aligned with their student's interests. For example, on Day 4, one teacher wrote that they believed co-design could be defined as "Working together to make learning accessible for all students." In the focus groups, teachers had an opportunity to elaborate on their shared goal of improving education for their students. One teacher stated that if she were to explain what she was doing during the pop-up to another teacher, she would say, "You need to make sure that every child in your classroom feels successful and feels like their education is successful to them, they are succeeding—that they're learning." Other teachers focused on choosing scenarios and topics that were directly of interest to their students. For example, one teacher planned to have students speak with a professional social media manager for her unit on data science and social media usage to help students with their imagined futures. She explained, "I think it is important for us [the teachers] to give them [the students] something they are interested in that could lead to a career." Another teacher, who developed a unit about making a data-based decision about choosing a family dog, elaborated on the importance of about students' interests: "And we had to make sure that our project could … a kid would be interested in it no matter what. I think that

was something pretty big … I mean, everybody likes dogs, right?" The music teacher, who developed a unit about making data-based claims about song popularity, added her thought process on cultivating engagement with an entire class of children. She stated, "I was thinking like that too. Everybody listens to music, even if they don't listen to the same thing. And the dataset I found covers multiple years and has a little bit of every kind of genre on it. And so, I think the kids will be able to find something they like and that they relate to at some point."

These teachers also described their commitment to this project and their responsibility to be the initial implementers of the data science pop-up and train other teachers. In the focus group, one teacher offered a suggestion and her vision for successful scaling up in the entire school, "We have the responsibility of introducing the project to the entire school, K-5. If we could have a consistent template to work from and just make adjustments with each grade, we will be able to implement this and include standards without too much work or stress for the teachers or the students."

3.2. Roles of the researchers

3.2.1. Researcher as partner and colleague

Teachers self-reported that they viewed the *researchers as partners and colleagues*, indicating that they felt the researchers treated them as professionals and felt an established partnership built on mutual respect. One teacher wrote, "It was a great experience being treated as a professional and an equal." Similarly, another teacher wrote, "They all did a great job truly working with us as partners in this project." In the focus group, a different teacher elaborated on their feelings towards the researcher partnership: "I really appreciated that your research team treated us as equals, like knowledgeable professionals. I enjoyed that you guys were very organized and you communicated your ideas and what your expectations were very clearly and specifically and that was very beneficial and respected."

3.2.2. Researcher as supporter

In addition to viewing the researcher as a partner, all teachers at some point had a response in their journals coded for *researcher as supporter*, indicating that teachers valued the researcher's support and help during co-design. For example, one teacher responded, "The team was very helpful. Enjoyed working with each of them." Some teachers identified their comfort and feelings of safety with asking questions during the sessions stating, "I always felt like I could ask questions without judgement from the team." During co-design sessions, researchers embodied the role of helper when they made suggestions and elaborated on design decisions during curriculum development. For example, the third grade group developing a dog adoption unit expressed a desire to incorporate multiplication and division competencies into their activities. The researcher working with them at the time suggested designing an activity in which students manually grouped a numerical variable into categories to help them learn division and categorization. He suggested grouping "dog weight" into "big, average, little." Although they ultimately did not implement his idea, the third-grade team found this suggestion to be helpful at the time.

3.2.3. Researcher as expert

At the same time, teachers referred to the *researchers as experts* and used language that indicated their understanding that the researcher imparts knowledge and expertise onto the teachers. For example, in the focus group, one teacher said, "I enjoyed how we were given or presented a new concept and then we were given time to implement that new concept into our unit." Here, this teacher used passive language such as "were given time" and "were

presented," indicating an authority or control that researchers had over teachers' time and knowledge. Similarly, another teacher framed aspects of the co-design as receiving pieces of knowledge from the researcher: "I think the way you broke it up and let us work on those pieces. That was very helpful because if you just shoot information at us it's overwhelming, and I don't know what to do. So, that was very useful." Immediately after this comment, another teacher added, "I agree, and also worked through it as an example. When we did it on the first day, that kind of, helped click with what we needed to design." This teacher used language such as "what we needed to design," suggesting that teachers perceived that the researchers had design requirements for the curriculum and found it helpful when researchers explicated those requirements.

3.3. Knowledge building

3.3.1. Co-constructing knowledge

When asked to describe the co-design process in their journals on Day 4, 7 teachers referenced some form of *co-constructing knowledge* with each other or with researchers. For example, one teacher wrote, "We had chances to work with our school-level peers, but also work with and learn from the research team … I can't emphasize enough how much I've learned over the past 4 days." Another teacher simply described co-design as "Working together - learning with and from each other." Similarly, another teacher explained co-design as a way for all stakeholders to grow and share knowledge: "I would say that it is a design that lets all people flourish and share his or her expertise."

In addition to teachers' self-reports, we observed the group's interactions captured in the observational field notes. In one design session on Day 1, the third-grade team reviewed their learning standards and decided to focus on science standards around traits and social studies standards around rural/suburban/urban areas. They agreed on a scenario around dog adoption and began conceptualizing their unit. They wanted to ask their students to choose a dog best suited for their families and use a dataset with information about different dog breeds to justify their decisions. The teachers found a TUVA dataset containing information about each dog breed: average weight, maximum life expectancy, and whether it was good with children. One teacher in the group stressed the importance of relating the scenario to students' lived experiences while still connecting to the educational standards. She argued with the others, "You want what dog is best for your family? If you have a yard, you can use a bigger dog. We have to tie it to their environment." The three teachers discussed how students' varied home lives would affect how they perceived the scenario and ultimately agreed that they needed to alter their dataset to address this need. As they discussed their next steps, a researcher approached the team and asked if she could join them. The teachers explained that they wanted students to explore whether certain breeds would be better as indoor or outdoor pets.

The researcher encouraged this idea and offered to recreate the dataset spreadsheet for them with an additional variable column titled "Good for Indoors?" to match the syntax of another column titled "Good for Children?" The teachers and the researcher browsed the internet to find information about which dogs spend more time indoors or outdoors. The researcher documented the data, typing a "Yes" or a "No" for each breed. When the column was completed, the researcher shared the spreadsheet file with the teachers through a shared drive. Then, one teacher created a link for sharing the dataset on TUVA and shared it with the other two teachers. They all decided to use this dataset for their pop-up curriculum.

In the above example, the teachers began designing their pop-

up unit by collectively selecting third-grade standards, conceptualizing their scenario, and identifying a dataset from TUVA. Then, one teacher shared knowledge about the importance of relating to students' interests and their lived experiences and "tying it to their environment." After some discussion and negotiation, they agreed to alter the dataset. To achieve this task, they relied on the researcher's knowledge to add their idea as a coherent variable to their existing dataset. The researcher and teachers conducted internet research and co-constructed a dataset that met their needs.

In another example, during a design session on Day 3, a fifth-grade music teacher and researcher worked together to design student data exploration activities. The teacher had identified a driving question for her unit: *What musical elements need to be considered when writing and producing a popular song?* The scenario she planned to present to students asked them to role-play as music producers:

> You are a music producer looking to craft your next hit with a popular musician from Easley. After looking at data on the top Spotify songs from the past 10 years, you are going to pitch an idea for the next hit song to the musician! In order to make a good pitch and convince the musician to work with you, you must use the data to decide what makes a song successful and popular!

She explained to the researcher the definitions of the different musical elements, such as pitch, tone, and tempo. The research followed up with questions such as "Does beats per minute count as tempo?" to construct an understanding of the unit's content. After her explanation, the teacher shared that she was unsure how to structure activities around the dataset of songs. The researcher suggested they create graphs together using TUVA, the digital graphing tool, and see what data-based claims they could make related to the driving question. Together, they discovered that students could compare musical elements such as tempo and genre using bar graphs and grouping options in TUVA. They realized that creating the graphs and working backward would be an effective strategy for designing activities.

3.3.2. Identifying conflicts

Along with episodes of co-constructing knowledge, teachers also identified moments of frustration and tension during co-design. Although the third-grade team could find a dataset about dog breeds fairly quickly, this was not the case for the fourth and fifth-grade teachers on Day 1. Several teachers felt frustrated with the lack of definition of a "dataset" and dataset examples. The fourth-grade team attempted to access a social media usage dataset on TUVA but could not access it without purchasing a premium subscription. A researcher helped them search for and find a similar dataset, but the team had to refine their questions and activities to use the dataset.

Similarly, the fifth-grade music teacher wanted to focus on popular songs from this decade but could not locate a dataset on Day 1. A researcher attempted to help her search for a dataset and suggested a few websites to investigate. They tried to download data files together, but the teacher expressed frustration and confusion around downloading and viewing the dataset. The teacher became increasingly frustrated and exclaimed, "Can I have another helper?" indicating that she wanted the current researcher to leave and another researcher to assist.

3.3.3. Negotiating meaning and practices

On Day 2, the PI on the project began the co-design session by acknowledging the existing conflicts. She stood in front of the room and addressed the teachers. She explained that the researcher with the most extensive knowledge of datasets would visit each group and offer assistance. She assured teachers that they would find a dataset today that could be useful for their units.

After the researcher worked with each team of teachers to identify a dataset and brainstorm activities together, the teachers' frustrations subsided. The music teacher had decided to use a subset of the "Spotify All Time Top 2000s Mega Dataset. During the session, she stated, "I feel better about this today than I did yesterday," and was laughing and smiling more than the previous day. A different researcher, who had extensive knowledge of the design of special education curriculum, sat with the music teacher for close to 1 h, co-designing the unit. The teacher's initial driving question was: "What is the genre or what type of song is likely to be more successful?" The researcher suggested that a broader question could help reach students from different backgrounds and abilities. He suggested, "If you were judging popularity, what would you use to decide/measure popularity?" He asked the teacher if she wanted to include an investigation of lyrics and songs about social issues. He also asked, "Can you work in some math in there?" The music teacher was not interested in incorporating math competencies but was interested in the exploration of lyrics. The researcher supported her decisions and reiterated that she had flexibility and agency in which standards she would like to incorporate and the types of activities she wanted to design around her scenario and dataset. As they worked together, they alternated who was typing on her curriculum template.

In the focus group discussions, three teachers restated their frustrations around locating datasets and offered suggestions for the next year when they again participated in the summer co-design sessions with an additional cohort of teachers. For example, one teacher stated,

> "Since there are only like 10 or 14 datasets you can choose from in TUVA, if you guys could provide maybe a few extra datasets. Maybe, you can't meet everybody's needs. Like, you didn't know what we were going to do. But I think it would have helped … if I would have been able to see example data."

In this quote, the teacher referred to the frustrations around not having knowledge on locating datasets and wanted resources from the researchers to help facilitate that knowledge. Another teacher agreed with this comment and added, "I feel that … one of the pieces that we [should] do is we go and try to find data and try to upload it … Just so we have the experience of finding data. Real data, not Wikipedia." This teacher suggested that the researchers offer guided opportunities for teachers to locate legitimate sources for datasets and input the data into the TUVA tool themselves. She continued, "Because I don't even know where to start, to be honest with you, to find good research data." Another teacher agreed and added, "Yes! Well, it's just that I had absolutely no idea. I had no prior knowledge of finding a dataset … Not having a background in data science, I had no idea what I was looking for." Thus, the teachers noted that there was limited guidance on finding legitimate datasets online and suggested ways of modifying the interactions between teachers and researchers to facilitate that particular knowledge construction and practice.

Teachers were also frustrated regarding what the researchers cared about and expected to be included in the pop-up. Teachers expressed that some of the researchers' needs were not explicated. Thus, teachers were confused regarding their roles as co-designers of the curriculum, particularly in the area of data science. For example, in her final journal entry, one teacher wrote,

"Next time, I would recommend giving teachers a checklist/ specific list of what exactly needs to be in the pop-up. Even though we did an example and worked through some ideas, I didn't realize step-by-step everything that needed to be in my pop-up until day 3. By telling us explicitly what needs to be included and how you need to present the data to students, I think it will make the initial and beginning stages of writing the pop-up more clear."

This teacher wanted a list of researcher expectations for their research purposes. She referred specifically to "how you need to present the data to students," indicating that she wanted to rely on the researchers for knowledge around framing the dataset and the data analysis for students. In the focus group, another teacher shared a similar sentiment, "I didn't realize some of the aspects of what we did on that day had to be in our projects. Like, how we presented the data, or how you asked the question … I still like the way we did it, but I think that if it was more explicit, then that would have made it a little more clear before you write it." Again, this teacher emphasized the data science knowledge and practices of what "had to be in their projects," meaning what was of interest to the researchers. In another focus group, one teacher differentiated between the practices she was familiar with and those she was unfamiliar with. She noted that she analyzes "data a lot as teachers, but it's cleaned and all that stuff is done for us by the district office … we can analyze it all day for you. But, we can't, well, finding it is probably the newest field for us."

4. Discussion

The findings suggest that elementary educators and researchers cultivated the beginnings of an RPP community of practice focused on co-designing interdisciplinary data science curricula. The thematic analysis of daily journals, focus groups, and observational notes suggest that teachers 1) mutually engaged in the community of practice by having shared goals, values, and experiences; 2) viewed the researchers' roles in the community as multifaceted, and 3) co-constructed knowledge with other teachers and researchers while negotiating meanings and practices when conflicts emerged. This study supports claims by Palincsar et al. (1998) that contrary to the original conceptualization that communities of practice naturally emerge (Lave & Wenger, 1991), communities of practice can be intentionally seeded and cultivated (Wenger, 1998) between teachers and researchers in educational contexts.

In our community of practice, teachers enjoyed their membership and often took pleasure in the practices of the community. Regarding social behaviors, teachers and researchers took coffee breaks, discussed personal stories, and participated in the lunchtime karaoke session on the final day. Several teachers commented that they "loved karaoke" and enjoyed themselves, which suggested that this activity helped build trust and friendship among members. Moreover, teachers were explicit about the group's shared vision of improving education by designing multidisciplinary data science experiences for their students and scaling this project up to expose all students in their school to data science. This finding aligns with conceptualizations of sustainable communities of practice having joint enterprises (Wenger, 1999) and a shared purpose (Buysse et al., 2003).

Teachers viewed the researchers concurrently as partners, support staff, and experts during the co-design process. According to self-reports, most teachers described the community of practice as a partnership and felt that researchers treated them as respected and valued professionals. Teachers reported that researchers were helpful and supportive when writing their pop-up curricula. In our

observations, we noticed moments in which researchers would help teachers reform datasets or brainstorm activities. At the same time, teachers also referred to the researchers as experts, seemingly contradictory to the other roles. Teachers demonstrated their areas of expertise in knowing the interests of their students, choosing and writing a scenario, and designing developmentally appropriate activities aligned with their chosen scenario and driving question. This reliance on diverse expertise (Palincsar et al., 1998) and interdependence facilitated a community in which members embraced multiple ways of knowing and doing and depended on each other to meet shared goals. Our findings also suggest that a successful partnership can mean teachers view the researchers interchangeably as experts, partners, and helpers, indicating that teachers and researchers fluctuate in terms of agency and expertise depending on the task.

During the co-design process itself, teachers and researchers co-constructed knowledge together by elaborating each other's ideas and negotiating meanings. Teachers and researchers typically shared co-created artifacts such as data visualizations, written scenarios, or drafts of lesson plans. Members used these artifacts as objects to guide one another through their ways of thinking, negotiate meaning together, and use their co-created insights to meet their shared goals (Pyrko et al., 2017). In these harmonic episodes, teachers and researchers relied on each other's knowledge to co-construct a useful product. In fact, one teacher referred to these co-design experiences as "a design that lets all people flourish," suggesting that our seeded community of practice offers an equitable space for professionals involved to grow and develop. However, to continually grow and flourish, members should feel agentic in changing the culture and norms of the community to better meet their needs.

When moments of frustration and conflict emerged, teachers expressed them, researchers acknowledged them, and teachers felt agentic enough to initiate change. Specifically, teachers felt frustrated that researchers did not clearly specify the data science aspects that were important for the research project and thus, should be incorporated into the pop-up design. For future meetings with them and additional teachers, they asked that researchers be more explicit about their desires for the project, especially when pertaining to data science knowledge and practices, an area that was new for the teachers. This finding supports claims that members in a thriving community of practice are motivated to co-construct and negotiate knowledge and feel a sense of ownership over the co-constructed products that are built upon a foundation of shared values and goals (Wenger 1997). However, this finding also highlights a typical tension in co-design RPPs. Researchers structure professional development to facilitate teachers' education about innovative pedagogies or domains, but at the same time researchers want to actively create something together with teachers using that new knowledge (Kelter et al., 2021). Emerging tensions are inevitable when engaging in design and relying on distributed expertise, even when members think they have clearly defined the roles and values within the group. However, as this study suggests, when such tensions emerge, identifying and negotiating knowledge and practices can alleviate them and help build strong partnerships.

Taken altogether, this study provides evidence of an active and sustainable community of practice defined by Wenger (1998) as "engaging in join activities, creating artifacts, adapting to changing circumstances, renewing interest, commitment, and relationships" (p. 3). Thus, our main claim in this paper is that a sustainable co-design RPP community of practice can be seeded and cultivated when teachers and researchers mutually engage by having shared goals and values, allow for the researchers to embody multiple roles, and engage in knowledge co-construction and negotiation to

improve ways of knowing, doing, and being within the group. Our study adds to the literature by providing a detailed account of how researchers and teachers co-construct knowledge together, including identifying tensions and negotiating meaning, in a newly developing RPP. This knowledge co-construction supported a shared goal of improving teaching and learning and a collective excitement for learning how to create innovative, interactive data science education experiences for students.

Despite these findings, our study is interpreted in light of the following limitations. First, as with any RPP, they take time to establish. This study occurred during the first year of our multi-year RPP. Our project was funded in September of 2020 which coincided with the start to an unprecedented school year given the COVID-19 pandemic. In light of the pandemic, we focused on a building a respectful partnership (Lane et al., 2021). We collaborated with the school's administrators to develop the activity calendar and set meeting times. The team opted to meet seven times. Although this is lower than typical RPP research, the findings from this study indicate the initial formation of a community of practice. We encourage researchers to explore the amount of time to establish a community of practice within an RPP related to co-designing curriculum. Second, while this study includes teachers' viewpoints, it does not address the researchers' point of view. Although researchers were involved in the co-design process and are authors of this paper, their voices and data are not reflected here. Future studies could address this limitation by asking researchers to complete similar measures as the teachers.

In our view, the researchers and teachers were both part of the community of practice as both groups found value in their interactions with each other. In light of the positive findings on the Community of Practice measure, the results must be interpreted with caution. First, this is an unpublished researcher-created tool modified from Hardesty et al. (2022) to measure participants' views of the CT-STEM Pop-up PD. Additionally, validation studies are in progress but not yet published in peer-referred journals. Second, our study was developed and conducted within one school setting during one school year. As such, there are limitations related to the generalizability of the findings, the sample size, and the short period of time. Future work should continue to include additional cohorts over a more extended period of time.

5. Conclusion

Using the lens of communities of practice, the findings in this mixed-methods study explored data from the beginnings of a co-design RPP. The key findings were that teachers mutually engaged in the community of practice by having shared goals, values, and experiences, viewed the researchers' roles in the community as multifaceted, co-constructed knowledge with other teachers and researchers, while negotiating meanings and practice when conflicts emerged. As researchers utilize RPPs more often, the co-design process and community of practice lens provide a framework for collaboration towards achieving a shared goal of improving education for students. The findings in this study help researchers to better understand how knowledge is co-constructed and negotiated in co-design RPPs. Based on what we have learned, we suggest that seeding and cultivating communities of practice of researchers and teachers in ways that we have described can create sustainable, effective co-design partnerships. Our future studies will document how this community of practice develops and changes over time.

Data availability

The authors do not have permission to share data.

References

Buysse, V., Sparkman, K. L., & Wesley, P. W. (2003). Communities of practice: Connecting what we know with what we do. *Exceptional Children, 69*(3), 263–277. https://doi.org/10.1177/001440290306900301

Cascio, M. A., Lee, E., Vaudrin, N., & Freedman, D. A. (2019). A team-based approach to open coding: Considerations for creating intercoder consensus. *Field Methods, 31*(2), 116–130. https://doi.org/10.1177/1525822X19838237

Chalmers, L., & Keown, P. (2006). Communities of practice and professional development. *International Journal of Lifelong Education, 25*(2), 139–156. https://doi.org/10.1080/02601370500510793

Coburn, C. E., & Penuel, W. R. (2016). Research–practice partnerships in education. *Educational Researcher, 45*(1), 48–54.

Connolly, F. (2019). Measuring the value of a research-practice partnership. *NNERPP Extra, 1*(1), 6–9.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. SAGE Publications.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory Into Practice, 39*(3), 124–130. https://doi.org/10.1207/s15430421tip3903_2

Ervin-Kassab, L., & Drouin, S. (2021). Expert learning in (micro)communities of practice: A case study examining teacher professional development. *Professional Development in Education, 47*(4), 699–709. https://doi.org/10.1080/19415257.2021.1876145

Farrell, C. C., Harrison, C., & Coburn, C. E. (2019). What the hell is this, and who the hell are you?" Role and identity negotiation in research-practice partnerships. *AERA Open, 5*(2), Article 2332858419849595. https://doi.org/10.1177/2332858419849595

Farrell, C. C., Penuel, W. R., Allen, A., Anderson, E. R., Bohannon, A. X., Coburn, C. E., & Brown, S. L. (2022). Learning at the boundaries of research and practice: A framework for understanding research–practice partnerships. *Educational Researcher, 51*(3), 197–208. https://doi.org/10.3102/0013189X211069073

Goldman, S. R., Gomoll, A., Hmelo-Silver, C. E., Hall, A. H., Ko, M.-L. M., Fortune, A. J., Kyza, E. A., Agesilaou, A., Gomez, K., Gomez, L., Pressman, E., Rodela, K., & Tabak, I. (2019). Technology-mediated teacher-researcher collaborations: Professional learning through Co-design. *Computer Supported Collaborative Learning Conference Proceedings, 751–758*.

Hardesty, C. L., Dahl, E., Moody, E. J., & Hardesty, C. L. (2022). *The ECHO community of practice measure [manuscript in preparation]*.

Harrison, C., Davidson, K., & Farrell, C. (2017). Building productive relationships: District leaders' advice to researchers. *International Journal of Education Policy and Leadership, 12*(4). https://doi.org/10.22230/ijepl.2017v12n4a770. Article 4.

Kyza, E. A., & Nicolaidou, I. (2017). Co-designing reform-based online inquiry learning environments as a situated approach to teachers' professional development. *CoDesign, 13*(4), 261–286. https://doi.org/10.1080/15710882.2016.1209528

Lane, K. L., Cabell, S. Q., & Drew, S. V. (2021). A productive scholar's guide to respectful, responsible inquiry during the COVID-19 pandemic: Moving forward. *Journal of Learning Disabilities, 54*(5), 388–399. https://doi.org/10.1177/00222194211023186

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Matuk, C., Gerard, L., Lim-Breitbart, J., & Linn, M. (2016). Gathering requirements for teacher tools: Strategies for empowering teachers through Co-design. *Journal of Science Teacher Education, 27*(1), 79–110. https://doi.org/10.1007/s10972-016-9459-2

McLoughlin, C., Patel, K. D., O'Callaghan, T., & Reeves, S. (2018). The use of virtual communities of practice to improve interprofessional collaboration and education: Findings from an integrated review. *Journal of Interprofessional Care, 32*(2), 136–142. https://doi.org/10.1080/13561820.2017.1377692

Palincsar, A. S., Magnusson, S. J., Marano, N., Ford, D., & Brown, N. (1998). Designing a community of practice: Principles and practices of the GIsML community. *Teaching and Teacher Education, 14*(1), 5–19.

Patton, K., & Parker, M. (2017). Teacher education communities of practice: More than a culture of collaboration. *Teaching and Teacher Education, 67*, 351–360. https://doi.org/10.1016/j.tate.2017.06.013

Penuel, W. R., & Gallagher, D. J. (2017). In *Creating research practice partnerships in education*. Harvard Education Press.

Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). Designing formative assessment software with teachers: An analysis of the Co-design process. *Research and Practice in Technology Enhanced Learning, 2*(1), 51–74. https://doi.org/10.1142/S1793206807000300

Pyrko, I., Dörfler, V., & Eden, C. (2017). Thinking together: What makes Communities of Practice work? *Human Relations, 70*(4), 389–409. https://doi.org/10.1177/0018726716661040

Saldaña, J. (2011). *Fundamentals of qualitative research*. Oxford University Press.

Scornavacco, K., Kelly, M. R., & Boardman, A. (2021). Leading with curricular Co-design: An exploration of teacher leadership through the Co-design process. *Journal of Research on Leadership Education*. , Article 194277512110175. https://doi.org/10.1177/19427751211017595

Strauss, A., & Corbin, J. M. (1997). *Grounded theory in practice*. Sage.

Tranquillo, J., & Matthew, V. (2015). *So you Want to Offer a pop-up class?* Epicenter. *National Center for Engineering Pathways to Innovation. Supported by the National Science Foundation Grant Number 1125457*. http://epicenter.stanford.edu/resource/so-you-want-to-offer-a-pop-up-class.html.

Voogt, J., Laferrière, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional Science, 43*(2), 259–282. https://doi.org/10.1007/s11251-014-9340-7

Wenger, E. (1998). Communities of practice: Learning as a social system. *The Systems Thinker, 9*(5), 1–5.

Wenger, E. (1999). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

Wenger, E., McDermott, R. A., & Snyder, W. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Harvard Business Press.

Westbroek, H., de Vries, B., Walraven, A., Handelzalts, A., & McKenney, S. (2019). Teachers as Co-designers: Scientific and colloquial evidence on teacher professional development and curriculum innovation. In J. Pieters, J. Voogt, & N. Pareja Roblin (Eds.), *Collaborative curriculum design for sustainable innovation and teacher learning* (pp. 35–54). Springer International Publishing. https://doi.org/10.1007/978-3-030-20062-6_3.

Wolff, A., Wermelinger, M., & Petre, M. (2019). Exploring design principles for data literacy activities to support children's inquiries from complex data. *International Journal of Human-Computer Studies, 129*, 41–54. https://doi.org/10.1016/j.ijhcs.2019.03.006