ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/325692405

Design-Centric Research-Practice Partnerships: Three Key Lenses for Building Productive Bridges Between Theory and Practice

Chapter · May 2018

DOI: 10.1007/978-3-319-17727-4_122-1

CITATIONS
29

READS
1,220

4 authors:

Yael Kali
University of Haifa
119 PUBLICATIONS **2,538** CITATIONS
SEE PROFILE

Bat-Sheva Eylon
Weizmann Institute of Science
91 PUBLICATIONS **3,797** CITATIONS
SEE PROFILE

Susan Mckenney
University of Twente
157 PUBLICATIONS **6,877** CITATIONS
SEE PROFILE

Adi Kidron
Weizmann Institute of Science
20 PUBLICATIONS **154** CITATIONS
SEE PROFILE

All content following this page was uploaded by Yael Kali on 20 June 2018.

The user has requested enhancement of the downloaded file.

Design-Centric Research-Practice Partnerships: Three Key Lenses for Building Productive Bridges Between Theory and Practice

Yael Kali, Bat-Sheva Eylon, Susan McKenney, and Adi Kidron

Contents

Y. Kali (✉) · A. Kidron
University of Haifa, Haifa, Israel
e-mail: yael.kali@edtech.haifa.ac.il; adi.kidron@edtech.haifa.ac.il

B.-S. Eylon
The Science Teaching Department, The Weizmann Institute of Science, Rehovot, Israel
e-mail: bat-sheva.eylon@weizmann.ac.il

S. McKenney
ELAN, Department of Teacher Professional Development, University of Twente, Enschede, The Netherlands
e-mail: susan.mckenney@utwente.nl

© Springer International Publishing AG, part of Springer Nature 2018

J. M. Spector et al. (eds.), *Learning, Design, and Technology*,
https://doi.org/10.1007/978-3-319-17727-4_122-1

Abstract

The last decade has witnessed a strong increase in research that moves toward mutually beneficial collaboration between researchers and practitioners. This chapter focuses on such collaborations that aim to design resources for use in schools while also advancing theoretical understanding of the dynamics within such partnership. We refer to such endeavors as design-centric research-practice partnerships (DC-RPPs). To guide the development of productive DC-RPPs, we synthesize insights from three theoretical lenses: (1) scholarship of teaching and practitioner research, (2) change laboratory formative interventions, and (3) multi-level boundary crossing. These lenses, together with a framework that characterizes DC-RPPs based on the practical constructs of (1) processes, (2) roles, and (3) habits-of-mind, are used in a 3 × 3 theory-practice matrix to elicit and articulate nine design principles that can support productive DC-RPPs. We describe two cases that illustrate how the design principles come to life in authentic DC-RPPs (one with 3 middle schools, focusing on interdisciplinary learning, and the other with 22 high schools, focusing on physics) and conclude with a discussion of emerging work that could support DC-RPPs and recommendations for future research.

Keywords

Research-practice partnerships (RPPs) · Design-based research (DBR) · Design principles · Scholarship of teaching · Change laboratories · Boundary crossing

Introduction

Research-Practice Interactions

Educational research is conducted to inform scientific understanding but also for the purpose of understanding and improving educational practice. With this dual goal in mind, investigations have been undertaken to explore how educational professionals access, value, and use research (Broekkamp & van Hout-Wolters, 2007; de Vries & Pieters, 2007; Vanderlinde & van Braak, 2010). Similarly, studies have been conducted to describe modes through which knowledge is generated and shared in the field of education (Bauer & Fischer, 2007; Lavis, Robertson, Woodside, McLeod, & Abelson, 2003; Nutley, Walter, & Davies, 2007). While most educational research today can still be characterized by a hierarchical relationship in which practitioners are the object of study and researchers translate their findings for them, the last decade has witnessed a strong increase in research that moves beyond data extraction agreements (Wagner, 1997) toward mutually beneficial collaboration between researchers and practitioners (van Braak & Vanderlinde, 2012). Policymakers, funders, and scholars are pioneering ways for researchers and practitioners to work together, and research-practice partnerships (RPPs) are particularly promising in this regard (Coburn & Penuel, 2016).

RPPs

RPPs are long-term collaborations between practitioners and researchers that are organized to investigate problems of practice and solutions for improving schools and school districts (Coburn, Penuel, & Geil, 2013). The partnerships are not established solely for short-term projects but rather cultivate long-term relationships that can provide the infrastructure for improvement (Penuel, 2015). Sustainable educational partnerships feature mutual benefit and dependencies (Dede, Rockman, & Knox, 2007), as well as continued use of social resources (contact among people), conceptual resources (ideas and processes), and physical resources (materials, tools). By focusing on real-time local challenges, RPPs can lead to research that is informative, timely, and relevant to local stakeholders (Henrick, Munoz, & Cobb, 2016). The RPP interactions themselves can benefit practitioners by increasing awareness of important advances in relevant scholarship or by creating opportunities to develop and apply new knowledge (Coburn & Penuel, 2016). Benefits to researchers are also present, since serving practice is a fundamental goal and collaboration enables fulfilling this goal especially because (1) studies situated in practice bring with them the ecological validity that renders the derived knowledge more useful and (2) regular interactions with practitioners help keep researchers aware of, and sensitized to, the realities and concerns of those working in classrooms (McKenney & Pareja-Roblin, 2018). In addition, RPPs can lead to innovations in both practice and research, including transformative learning for both design researchers and practitioners (Kali, 2016).

Educational RPPs can involve various types of practitioners (e.g., teachers, administrators, parents), work at small or large scales (e.g., one school, a citywide school district), and tackle myriad kinds of problems (e.g., teacher turnover, learning outcomes, bullying). They may aim to (1) generate research findings that can inform practice or policy, (2) increase schools' capacities to engage in a sustained, disciplined effort at improvement, or (3) design resources for use in schools. Such aims are sought while also advancing theoretical understanding (Coburn et al., 2013). The remainder of this chapter focuses on RPPs that seek to address all these aims, referred to here as design-centric research-practice partnerships (DC-RPPs). In particular, given the focus of this handbook, it focuses on researcher and practitioner learning during DC-RPP engagement, with emphasis on examples involving learning technologies.

About This Chapter

The overarching goal of this chapter is to abstract design knowledge from existing theoretical lenses, relevant to DC-RPPs, and to synthesize this knowledge in a way that can help increase current understanding on research-practice synergy. Thus, by offering considerations to guide DC-RPPs, this paper aims to contribute to the development of productive bridges between theory and practice. Following this introduction, the "Key Lenses" section starts with a literature review on DC-RPPs,

much of which stems from design-based (implementation) research. In so doing, we examine the processes, roles, and habits-of-mind that enable DC-RPPs. The remainder of the "Key Lenses" section synthesizes insights from three lenses that can enrich and guide (1) learning to inform DC-RPPs, (2) learning through DC-RPPs, and (3) learning from DC-RPPs. These refer, respectively, to three theoretical lenses: (1) scholarship of teaching and practitioner research, (2) change laboratory, and (3) boundary crossing.

In the following section – "Design Principles for Productive DC-RPPs" – we use these lenses to elicit design principles that can support the processes, roles, and habits-of-mind of productive DC-RPPs. Then, the "Employing DC-RPP Design Principles" section describes two cases (one with 3 middle schools, focusing on interdisciplinary learning, and the other with 22 high schools, focusing on physics) that illustrate how the design principles come to life in authentic DC-RPPs. The chapter concludes with a discussion of the dynamic nature of DC-RPPs, as portrayed in different trajectories taken by participants in the two cases, and recommends directions for future research.

Key Lenses

Existing Insights About DC-RPPs

Much of what we know about DC-RPPs stems from a family of approaches that connect basic and applied educational research in, on, or through design. These include design experiments (e.g., Collins, 1992), design-based research (e.g., DBRC, 2003), design-based implementation research (e.g., Penuel, Fishman, Cheng, & Sabelli, 2011), and educational design research (e.g., McKenney & Reeves, 2012). It is important to note that these terms are not interchangeable and that design-centric research in the field of education does not always involve the kinds of partnerships described above. Indeed, some experts have gone to lengths to describe key differences (Reinking & Bradley, 2008; Penuel et al., 2011). Here, we focus on insights relating to long-term research-practice partnerships that share the dual aim of deriving new knowledge through the design of solutions to problems in educational practice, as well as their implementation. We relate these insights to three categories of challenges in DC-RPPs described by McKenney (2016) as knowledge of design *processes*, ability to envision and take on new *roles*, and developing the *habits-of-mind* that can serve the enterprise, as follows.

First, while educators and researchers are typically familiar with the concept of design, many lack experience or formal training in the *process* of designing and implementing educational innovation. The overall DC-RPP process entails three core phases: analysis, design, and evaluation. During analysis, discussions are held to shape a better understanding of the educational problem to be addressed, the target context, and the stakeholder needs. Often, this phase also includes an open-ended exploration of where and how similar problems have been tackled elsewhere. Throughout design, potential solutions to the problem are generated, explored, considered, and then mapped and constructed. During this process, the core ideas

underpinning the design – including their theoretical and practical grounding – are articulated. This enables underlying assumptions and the design framework to be shared and critiqued by the various stakeholders. In evaluation, depending on the phase of development, elements of a partial or full design are tested for soundness, feasibility, local viability, broader institutionalization, immediate effectiveness, or long-term impact. Each of these phases is undertaken not in isolation but rather with explicit consideration of concerns relevant to the implementation of the designed solution. Because each of these phases can be shaped differently depending on the aims and context, DC-RPPs are recommended to *Define and tailor key processes*. We refer to this recommendation as the first of three meta design principles (MDPs) that we suggest for guiding productive DC-RPPs (MDP1).

Second, as may be gleaned from the descriptions above, the tasks undertaken in each core process require DC-RPP participants to take on more than the traditional *roles* and often share responsibilities of consultant/facilitator, designer, and researcher. The consultant/facilitator role encompasses sharing expertise to help problem-solving, strategy, and planning (mostly consultant), as well as supporting others in the team to achieve an outcome by providing structure, guidance, or supervision (facilitator). In DC-RPPs, this latter role is especially required during analysis (helping people to expose their problems and knowledge thereof). But it is also present in design (sharing expertise, managing resources), evaluation (helping to understand what is happening/troubleshooting), and implementation, especially if the facilitator serves as "program champion" who helps others become and remain in touch with their reason for being involved (often tied to sense of moral purpose). The designer role includes developing and realizing a plan for the appearance, form, or workings of something that does not yet exist – most likely programs, processes, products, or policies. Naturally, this role is heavily present during the design phase (influencing the design process as well as the designed products), but it is also important in other phases, as foundational knowledge for design continues to develop. The role of the researcher is fulfilled by anyone conducting systematic investigation to develop new knowledge (facts, principles, theories, etc.). This role is most clearly present during the phases of empirical investigation, analysis and evaluation, but researcher expertise also serves design, e.g., by providing research-based insights. Though preferences may exist, each of these roles can be taken on by either researchers or practitioners, and they may shift over time. Clear understanding and agreements about roles are crucial to fulfilling them well. As a result, DC-RPPs are recommended to *Facilitate engagement through dynamic roles*. We refer to this recommendation as MDP2 for productive DC-RPPs.

Third, since DC-RPPs intend to develop the capacity for sustaining change, the inculcation of *habits-of-mind* that serve the process is required, most notably trust, empathy, and flexibility. Creating capacity for change requires the ability to work across contexts which relies on trust, which is served by norms of interaction, and shared commitments (Donovan, Snow, & Daro, 2014). In productive educational partnerships, trust is developed by engagement that is deep, direct, and frequent (Penuel, Bell, Bevan, Buffington, & Falk, 2016). Empathy is needed for exploring and attending to the needs, wishes, and concerns of stakeholders; creating designs

that are usable, practical, and congruent with stakeholder concerns; helping understand and interpret data; and taking into account (un)shared goals or the incentives, motives, and reward structures in different settings. Finally, flexibility is needed for (1) balancing well-framed investigation with open-mindedness, (2) staying focused on design goals while utilizing unplanned opportunities (Kali, 2016), and (3) drawing conclusions and deriving new questions. Flexibility also serves the orchestration required to optimize the use of the human and material resources available in ways that remain aligned with overall project goals. Therefore, DC-RPP participants are advised to *Cultivate productive habits-of-mind* (MDP3).

The three MDPs introduced above are used in this chapter to elicit pragmatic design principles (PDPs) from each of the three theoretical lenses. We therefore begin by introducing these lenses.

The Scholarship of Teaching and Practitioner Research

The scholarship of teaching (Hutchings & Shulman, 1999; Shulman, 2011; Trigwell, Martin, Benjamin, & Prosser, 2000) and practitioner research (Cochran-Smith & Lytle, 2001, 2009) are two movements that represent a rich field of research characterizing the nature of teaching as a profession and ways that scholarship develops within communities of teachers. Although scholarship of teaching usually refers to higher education, whereas practitioner research typically refers to K-12 settings, there are many similarities in the ways these movements view professional teaching. This includes three main principles: (1) commitment to systematically exploring own teaching, as reflected in students' learning, or what Cochran-Smith and Lytle (2001) refer to as "generating local knowledge of practice"; (2) sharing this knowledge within a community of teachers and thus making it "community property" (Shulman, 1998, 2011) that can be critiqued, negotiated, and improved; and (3) a community effort to "go meta" (Shulman, 1998, 2011) and develop conceptual frameworks for understanding practice (Cochran-Smith & Lytle, 2001). Education researchers, instructional designers, content specialists, and learning scientists often take part, as partners, within such communities (see, e.g., conferences organized by the International Society for the Scholarship of Teaching and Learning, ISSOTL, 2017). In DC-RPPs, the systematic explorations and collective learning take place as an integral part of the collaborative design process. The understandings derived from these explorations regarding local conditions for implementation and spread, as well as regarding the stakeholders (learners, teachers, colleagues), are prerequisites for, and can inform, design. We thus refer to the scholarship of teaching and practitioner research as a lens that can enrich our conceptualization of DC-RPPs in situations in which *learning can inform design*.

Change Laboratory Formative Interventions

Change laboratory is a method of intervention and a theoretical framework that has been developed by researchers at the Center for Activity Theory and Developmental

Work Research (Engeström, 2007; Engeström, Virkkunen, Helle, Pihlaja, & Poikela, 1996; Sannino, Engeström, & Lemos, 2016; Virkkunen, 2013). It is based on collaboration between researchers and practitioners who work together to identify and design solutions to disturbances and bottlenecks in the practitioners' prevailing work practices. Inspired by Vygotsky's work, the change laboratory method includes a set of instruments and conceptual tools, which the researcher-facilitator uses to facilitate the group's collective analysis of their work activity system and sometimes for its (re) conceptualization. The intervention is referred to as "formative" due to the developmental nature of the change process in which the group gradually designs tentative solutions and experiments with them. These eventually become generative solutions that can lead to practical systemic transformation within the community, as well as to the development of theory. Change laboratory researchers refer to this whole process (collective design, participatory analyses, and implementation phases) as "expansive learning." For this reason, we view change laboratory formative interventions as lenses that can help conceptualize *learning through design* in DC-RPPs.

Multilevel Boundary Crossing

Teacher-researcher partnerships are sometimes conceptualized in relation to the boundary crossing literature (as in Penuel, Allen, Coburn, & Farrell, 2015). The concept of boundary crossing refers to ways people from two or more different communities of practice learn to productively work with each other. In DC-RPPs, these are the researchers' and the practitioners' communities of practice. The boundaries that participants need to cross are therefore sociocultural differences between the groups. Following a comprehensive review of the literature, Akkerman and Bakker (2011) defined four learning mechanisms (or boundary crossing processes) that take place at boundaries between different communities of practice: identification, coordination, reflection, and transformation. Although these processes may progress in different order (Akkerman & Bruining, 2016), reflection and eventually transformation usually stem from earlier identification and/or coordination processes. The most dramatic process of transformation in boundary crossing denotes a process in which people change their existing practices or develop new practices at the boundary between the different communities of practice. In a DC-RPP, this may occur when a researcher, as a result of the partnership with practitioners, develops new ways to make sense of processes that take place in the learning environment being explored or when a teacher, as a result of the partnership with researchers, begins to reflect in a more systematic manner on how teaching affects student learning. The co-designed learning environment in DC-RPPs fulfills an important bridging function, referred to as "boundary object" in the boundary crossing literature (coined by Star, 1989 and Star & Greisemer, 1989). The boundary crossing can take place at different levels: the institutional, interpersonal, and intrapersonal (Akkerman & Bruining, 2016). Taken together, the boundary crossing literature serves as an important lens for conceptualizing *learning from design partners* in DC-RPPs.

Design Principles for Productive DC-RPPs

Design principles integrate descriptive, explanatory, and predictive understanding to guide the development of interventions (McKenney & Reeves, 2012). They serve as research-based guidelines for instructional design and can be articulated at different grain sizes (Kali, 2006, 2008). In this chapter, we distinguish principles relevant to DC-RPPs in two layers of abstraction. The more abstract layer consists of MDPs, such as the three described above, related to practical aspects of DC-RPPs: processes, roles, and habits-of-mind. The MDPs, which serve as the rows in the theory-practice matrix below (Table 1), are made more concrete with pragmatic design principles (PDPs), articulated for each of the three lenses presented (scholarship of teaching, change laboratories, and boundary crossing) in the columns of the matrix. In this way, this chapter presents PDPs to guide learning (1) as input for, (2) through, or (3) from DC-RPPs, respectively.

MDP1: Define and Tailor Key Processes

PDP1: Scholarship Processes

The scholarship in teaching and practitioner research movements describe the processes through which the profession of teaching advances. These include processes in which teachers are involved in systematically collecting evidence on their own practice and exploring relationships between these practices and their students' learning. It also involves sharing the evidence and negotiating insights with peers. Cochran-Smith & Lytle (2001) describes the way teachers generate such "local knowledge of practice" within professional inquiry communities as follows:

> Through talk and writing, they make their tacit knowledge more visible, call into question assumptions about common practices, and generate data that make possible the consideration of alternatives. Part of the culture of inquiry communities is that rich descriptive talk and writing help make visible and accessible the day-to-day events, norms, and practices of teaching and learning and the ways different teachers, students, administrators, and families understand them. In this way, participants conjointly uncover relationships between concrete cases and more general issues and constructs. (pp. 53–54)

The process in which in situ explorations of an individual teacher become more generalized and applicable for teaching in other contexts (or what Shulman calls "going meta") involves a commitment to making these explorations and their outcomes "community property," so that they can become "subject to peer review and evaluation and accessible for exchange and use by members of one's disciplinary community" (Shulman, 2011, p. 4). This also enables developing principles that cut across contexts, and "building, interrogating, elaborating, and critiquing conceptual frameworks that link action and problem-posing to the immediate context as well as to larger social, cultural, and political issues" (Cochran-Smith & Lytle, 2001).

Teacher inquiry can serve DC-RPPs by fostering close connections to insights based on daily practice. Any design process involves making a myriad of design

Table 1 Design principles for productive DC-RPPs (theory-practice matrix)

Meta design principles (MDPs)	Pragmatic design principles (PDPs)		
	Scholarship lens	**Change laboratory lens**	**Boundary crossing lens**
MDP1: Define and tailor key processes	**PDP1: Scholarship processes** Systematically investigate, within a professional community of teaching, questions that relate own practice and student learning while committing to sharing findings, negotiating, and refining cross-cutting principles	**PDP2: Change laboratory processes** Reflect on the collective's object of activity to identify historically formed contradictions; develop and experiment with generative and concrete solutions (for contradictions) to reach "theoretically mastered developments"	**PDP3: Boundary crossing processes** Engage in activities that help individuals, groups, and institutions identify and respect the various expertise within the partnership, coordinate distributed work, and reflect at own practice
MDP2: Facilitate engagement through specific and dynamic roles	**PDP4: Scholarship roles** Develop the social, organizational, and digital infrastructures that will enable all DC-RPP participants to assume roles of researchers and peer reviewers who constantly seek to advance practice, as well as the profession of teaching	**PDP5: Change laboratory roles** Consider role division in which practitioners serve as leaders of change, designers, and experimenters, while researchers serve as provokers and supporters of process	**PDP6: Boundary crossing roles** Attend to the role of brokers as linking between groups that differ socioculturally (e.g., researchers and practitioners)
MDP3: Cultivate productive habits-of-mind	**PDP7: Scholarship habits-of-mind** View teaching as profession, in which knowledge that is developed in a wide set of inquiries serves as a "community property" to lead social change. Trust may play a crucial role for such sharing	**PDP8: Change laboratory habits-of-mind** Be prepared to question accepted practices, and analyze problematic situations, which may require a somewhat "revolutionary mindset"	**PDP9: Boundary crossing habits-of-mind** Be open and flexible to take up others' perspectives and to transform on an interpersonal, intrapersonal, and/or institutional level

decisions. One of the benefits of DC-RPPs is that the close relationship between researchers and practitioners enables multiple cycles of in situ testing of tentative design conjectures. Building on "local knowledge of practice" within this process increases the ecological validity of the design decisions.

To fulfill this potential, this PDP advises participants within DC-RPPs to adopt processes that are typical to the practitioner research and scholarship of teaching movements, that is, to (1) develop means for systematically collecting evidence on student learning with the designed learning materials, (2) to create opportunities for DC-RPP participants to collaboratively develop and negotiate local knowledge of practice, as well as to (3) engage in sharing, critiquing, and synthesizing design knowledge with larger communities of scholars in the field, using public infrastructures such as the design principle database (Kali, 2006, 2008; Kali & Linn, 2008).

PDP2: Change Laboratory Processes

The key processes in change laboratory formative interventions refer to the way collectives (e.g., a group of practitioners who seek to evoke a change within their school) initiate and engender change within their community. The change process usually begins by the group's deep reflection on their own practices. Of special interest in this reflection is identifying the object of the group's activity (their vision for what they want to achieve as a group). Such reflection enables participants to identify historically formed contradictions or conflict of motives. After identifying the contradictions, the change laboratory approach guides the group, while they embark on a collective design effort to understand and face these identified gaps. "The collective design effort is itself the core of an expansive learning process, involving reconceptualization and practical transformation of the object of the learner's activity" (Sannino et al., p. 2). The artifact designed by the group serves for practical experimentation of the ideas developed (e.g., trying out a prototype in school). This iterative experimentation and development enables the group to develop a solution to the identified contradiction. In expansive learning, the solution is inspired by, but deviates from, the theoretical notions that the interventionist brings to the table. Ideally, the solutions developed should be generative, meaning that they would promote additional actions that serve the community in reaching the aspired vision.

Exposing and addressing conflicting motives within DC-RPPs is crucial to their productivity. Many DC-RPPs stumble upon impediments in the co-design process, which stem from various contradictions or conflicts of motives that have not been surfaced and discussed within the partnership. A conflict of interest could be, for instance, a desire of school leaders to adopt a certain innovative educational approach but with a lack of capacity or even will of the teaching staff to embrace such a change. Contradictions may also stem from different agendas that researchers and practitioners bring to the partnership.

To prevent such impediments, and to foster awareness of conflicting motives, this PDP (based on the change laboratory literature) recommends DC-RPPs to engage in processes specifically designed to (1) surface the contradictions among participants or those that the innovation might provoke, (2) develop a shared vision that resolves the conflicts, (3) develop a genuinely authentic goal for the co-design process and product, (4) experiment with prototypes and evolving versions of the design, and (5) reach a generative design product that will inspire additional activities that serve the shared vision.

PDP3: Boundary Crossing Processes

In their review of the literature, Akkerman and Bakker (2011) found that mutual *identification* occurs when "intersecting practices are (re)defined in light of one another. In this process, people are concerned with (re)defining the way in which the intersecting practices are different from one another and how they can legitimately coexist" (p. 142). They also found that the process of *coordination* of the different practices takes place when "means and procedures are sought, allowing diverse practices to cooperate efficiently in distributed work, even in the absence of consensus" (p. 143). Their analysis showed that boundary crossing can lead to a *reflection* process, "which is about mutually defining the different perspectives that each intersecting practice can bring, and openness to take up others' perspectives to look at one's own practice." Finally, usually as a result of the former processes, a *transformation* process occurs, leading to "profound changes in practices, potentially even the creation of a new, in-between practice, sometimes called a boundary practice" (p. 146).

The sociocultural differences between researchers and practitioners are often underestimated, as is the need for explicit attention to bridging them. Similar to other partnerships between multi-expertise partnerships, DC-RPPs might become quite challenging (Akkerman et al., 2013). Researchers and practitioners bring with them very different sets of practices, beliefs, and values. These sociocultural differences can result in misunderstandings regarding all aspects of the collaborative work.

To avoid such misunderstandings, and to foster productive communication among various participants of a DC-RPP, this PDP (based on the boundary crossing literature) recommends to develop activities designed to promote identification, coordination, and reflection processes. These activities should be tailored to the specific (changing) needs of the partnership and attend to the various levels in which boundary crossing processes may occur (i.e., intrapersonal, interpersonal, and institutional). Engaging in such activities may lead to transformation processes at all levels. For instance, at the institutional level, as a result of such a collaboration, a school or department in a college or university may adopt or develop new practices and procedures.

MDP2: Facilitate Engagement Through Dynamic Roles

PDP4: Scholarship Roles

A main construct in Shulman's vision regarding the scholarship of teaching includes teachers' active participation in a scholarly community of teaching. He maintained that:

> A scholarship of teaching will entail a public account of some or all of the full act of teaching – vision, design, enactment, outcomes, and analysis – in a manner susceptible to critical review by the teacher's professional peers and amenable to productive employment in future work by members of that same community. (Shulman, 1998, p. 6)

A similar notion regarding the need for a community to encourage professionalism can be found in Cochran-Smith's work:

> From an inquiry stance, teacher leadership and group membership look very different from how they might look when teachers are 'trained' in workshops or staff development projects. Taking an inquiry stance on leadership means that teachers challenge the purposes and underlying assumptions of educational change efforts rather than simply helping to specify or carry out the most effective methods for predetermined ends. (Cochran-Smith & Lytle, 2001, p. 54)

Note that in both accounts, the roles of teachers extend the more traditional notions of teaching and include roles that researchers typically play within their communities, including research and peer review.

Many DC-RPPs are planned (and funded) for several years; after which practitioners are expected to take full ownership of maintaining and continuing to develop the innovation. One of the challenges of DC-RPPs is to develop infrastructures that will enable sustainability of the practices associated with implementation of the designed innovation over time despite various dynamics within a school (e.g., teacher turnover, new policies, etc.). This is especially true for technology-enhanced innovations that might be more susceptible to change.

To sustain the innovation, this PDP (based on the scholarship of teaching literature) suggests developing social, organizational, and digital infrastructures that will enable and encourage all DC-RPP participants (researchers and practitioners from various institutions) to take part in a scholarly community, *assuming roles of researchers and peer reviewers* who constantly seek to advance not only local practice but also broader insights that extend what is currently known about professional teaching.

To do so, DC-RPP leaders should develop, together with participants, the mechanisms that will allow participants to play these various scholarship roles in the inquiry community processes. These mechanisms, ultimately, should be embedded within the regular activities of the practitioners and enable them to gain credit for their efforts.

PDP5: Change Laboratory Roles

One of the prominent aspects of change laboratory formative interventions is that the practitioners are those who take a leadership role in the change process. As part of this role, practitioners are those who identify the tensions in prevailing practices, design tentative solutions, and explore them. The research interventionist's role is to provoke and support this processes, as described in PDP4. In fact, (Engeström, 2011) views the agency of the practitioners in formative interventions as a foundational point of departure, which distinguishes this tradition of research from design-based research. According to his analysis, design-based research is "associated with notions of perfection, completeness, and finality" (p. 600) that are in conflict with such practitioner agency. But there are many different perspectives on design-based research in this regard. Whereas Engestrom argues that design-based researchers

typically take the role of leaders and are those who "make the grand design," while practitioners assume the role of implementers who contribute to its modification, McKenney and Reeves (2012) emphasize the importance of collaborative agenda setting in this genre of inquiry.

But regardless of one's perspective on design-based research, we believe that the change laboratory formative interventions lens can inspire a range of alternative roles and divisions of labor in DC-RPPs. These may be used to enrich current conceptualizations of design research (e.g., McKenney, 2016), and especially design-based implementation research (Penuel et al., 2011), which already highlight practitioner agency and ownership as key elements and encourage a more distributed role taking between researchers and practitioners. Such enrichment is required because fostering participants' agency and ownership of change processes that combine external innovation with local visions of practitioners is a challenging endeavor. Yet it is also a vital component in sustainability (Bergen & Van Veen, 2004; Cviko, McKenney, & Voogt, 2015; Ketelhut & Schifter, 2011).

The change laboratory formative interventions can become a useful lens in delineating the roles of participants and researchers-interventionists in DC-RPPs. Specifically, this PDP urges DC-RPP participants to consider a division of roles in which practitioners will lead the process of defining the problem and designing and experimenting with solutions, while researchers will serve as provokers and supporters of the process. Such a division of labor can broaden the range possibilities for distributing roles among participants and suggests an alternative to the more common role division, in which researchers lead and design and practitioners implement and contribute to modification.

PDP6: Boundary Crossing Roles

The multilevel boundary crossing literature examines the dynamic nature of roles within partnerships that include different communities of practice. Of special interest is the role of brokers. Akkerman and Bakker's literature review and Akkerman and Bruning's further conceptualization (2011) revealed "the potentially significant role of individual people in (re)establishing continuity, especially in situations in which there is not yet a formalized structure for collaboration between different practices" (Akkerman & Bruining, 2016, p. 11). In those cases, there are often one or a few people doing the crossing, who have the authority and status to join people together for mutual benefit.

In many DC-RPPs, individual researchers (typically graduate students) and individual practitioners (typically enthusiastic teachers, deeply engaged in the partnership) serve as brokers in partnerships, which may include other established researchers, as well as additional teachers and school leaders. By experiencing some of the practices of the other profession, these individuals may develop common language and understanding, which enable them to advance the co-design process and knowledge building within the DC-RPP. Akkerman and Bruning (2016) note that due to the crucial role that brokers play in partnerships that involve sociocultural differences, special attention should be paid to this role. First, "when these brokers appear to have most responsibility for establishing continuity across

different practices, they are likely to have a challenging political position and can probably gain from organizational recognition and support" (p. 41). Second,

> For sustainability reasons... partnerships might gain from circulating broker positions over time among various actors rather than relying too strongly on a few actors doing the crossing. This or alternative approaches is needed to make sure that others can also be involved and consequently learn from mutual activity. (p. 41)

One of the biggest challenges of DC-RPPs is to develop the capacity for sustaining change. Careful attention to the role of brokers can help address this challenge. Therefore, this PDP recommends DC-RPPs to identify individuals who may inherently become brokers within the partnership as a first step and to encourage these brokers to share or even pass this role to others as the partnership develops.

MDP3: Cultivate Productive Habits-of-Mind

PDP7: Scholarship Habits-of-Mind

In the preface of their book, Cochran-Smith and Lytle (2009) describe inquiry as a stance as follows:

> ... a worldview and habit of mind – a way of knowing and being in the world of educational practice that carries across educational contexts and various points in one's professional career and that links individuals to larger groups and social movements intended to challenge the inequities perpetuated by the educational status quo. (p. xiii)

This habit-of-mind requires not only cultivation of scholarship skills but also trust-building processes that allow teachers to surface, discuss, and critique their day-to-day events, norms, and practices, among peer practitioners as well as researchers. This PDP stresses the importance for DC-RPPs to design and develop work environments in which such trust is cultivated.

PDP8: Change Laboratory Habits-of-Mind

The expansive learning involved in change laboratory formative interventions "requires breaking away from the given frame of action and taking the initiative to transform it. The new concepts and practices generated in an expansive learning process carry future-oriented visions loaded with initiative and commitment by the learners" (p. 5).

In DC-RPPs, such a "revolutionary" habit-of-mind is especially needed when the design endeavor largely deviates from prevailing school practices. Evoking such a habit-of-mind among practitioners requires a delicate exploration of the needs, desires, and expectations of participants. Thus, this PDP advises DC-RPP leaders to carefully question accepted practices and analyze problematic situations, as a basis for cultivating the "revolutionary" stance required for leading profound changes within an educational system. The processes and roles described in PDP2 and PDP5 enable such exploration.

PDP9: Boundary Crossing Habits-of-Mind

Based on their review of the literature, Akkerman and Bakker (2011) claim that "all learning involves boundaries. . . The boundary of the domain or community is constitutive of what counts as expertise or as central participation. When we consider learning in terms of identity development, a key question is the distinction between what is part of me versus what is not (yet) part of me" (Akkerman & Bakker, 2011, p. 132).

The boundary crossing literature views learning as the development of identity, in which "others" with different experiences, knowledge, beliefs, and values play a crucial role. But in order to be able to learn from interactions with others, one is required to cultivate an "otherness" habit-of-mind, that is, to be open to identify and value the perspectives that others bring to a partnership and to be flexible to take up other's perspectives, in a way that may change own (professional) identity.

To enable productive collaborative work between researchers and practitioners, such openness is required. Therefore, this PDP advises DC-RPP participants to cultivate an atmosphere that will foster such a flexible state of mind. Here too, the processes and roles described in PDP3 and PDP6 can foster such an environment.

Employing DC-RPP Design Principles

To illustrate the value of the set of PDPs in the theory-practice matrix described above, this section presents two DC-RPP cases and illustrates how the various PDPs were employed in them. The first case describes a 2-year program that aimed to foster interdisciplinarity in three middle schools, and the second case describes an 18-month program aimed at improving and innovating physics teaching and learning by leading teachers from 22 high schools. The rationale for choosing the two cases is multifaceted. First, we view them as representing productive DC-RPPs, as they both embed strong and deep ties between theory and practice, seek innovation in both theory and practice, and seek extended applicability (in Sannino et al.'s terminology – they are generative). Second, as described below, the value of the outcomes stemming from both programs has been formally acknowledged by circles wider than the DC-RPP by both researchers and practitioners. Third, the processes within both DC-RPPs were documented and studied. Fourth, authors of the current chapter were involved in the partnerships, enabling to base the characterization in both cases on information beyond the published record. Fifth, they represent two different profiles of the use of the set of PDPs in the theory-practice matrix. Specifically, while both cases employed all the nine PDPs, the profile of case 1 emphasizes the *formative intervention in change laboratory* lens (PDPs #2, 5, and 8), while the profile of case 2 emphasizes the *scholarship of teaching and practitioner research* lens (PDPs #1, 4, and 7).

Our characterization of the two cases is a retrospective enterprise, based on the PDPs described above. It should be noted that in real time, both cases were perceived as teacher professional development programs that view design as an important method for teacher learning but not as DC-RPPs. This conceptualization was

developed retrospectively as well. We introduce each case, first, generally, and then in relation to the PDPs. Since our analysis of the cases showed that there was a strong relationship between processes, roles, and habits-of-mind for each of the lenses (we further discuss this finding in the "Discussion" section), we present the employment of PDPs in sets related to the theoretical lenses they represent (columns in the theory-practice matrix).

Case 1: Fostering Interdisciplinarity in Middle Schools

General Description of the Program

This case describes a DC-RPP that was formed with the vision of fostering interdisciplinarity within schools. Three schools, which were interested in developing a partnership around this vision, participated. The goal of the partnership was to adopt and adapt a technology-enhanced instructional model, originally designed to promote interdisciplinary learning in higher education (Kidron & Kali, 2015), for the use of middle school students (Kidron & Kali, 2018). The model, entitled Boundary Breaking for Interdisciplinary Learning (BBIL), refers to three perspectives – curricular, pedagogical, and organizational. Each of these perspectives builds on theoretical grounding and is represented as a design principle: *breaking boundaries between disciplines*, *breaking boundaries between learners,* and *breaking boundaries between organizational hierarchies*, respectively. An implementation of the model in higher education, via a course named "learning in a networked society (LINKS)," has been shown to promote interdisciplinary understanding of undergraduate students (Kidron & Kali, 2015). The LINKS course, which involved six disciplinary knowledge domains – learning sciences, science-communication, health sciences, cognition, communication, and information sciences – served as a reference for the DC-RPP in adaptation of the BBIL model (Table 2 describes selected features for each of the BBIL model's design principles and illustrates how they were implemented in the LINKS course).

The partnership included researchers, members of an educational non-governmental organization (NGO), ministry of education supervisors, and school principals and teachers from the three schools. Overall, a total of about 40 participants were involved. The mechanisms that supported the collaborative work in the partnership included the following: (1) kickoff meetings in each of the schools, with a small forum of representatives to discuss the goals and suggest an "operation model" (Table 3); (2) co-design workshops (30 h in each school, in each year of the study), facilitated by one of the researchers, which enabled teachers to get familiar with the BBIL model and design their preliminary technology-enhanced learning environments and enabled researchers to learn about the characteristics, needs, affordances, and constraints in the schools; (3) reflection in practice meetings that were held within each team (often with one of the researchers) during enactment in each of the schools; (4) whole DC-RPP retreats that were conducted once a year, in which all participants met in order to share insights and lesson learned in each of the schools, as well as provide peer feedback, and reexamine the insights in light of the

Table 2 The BBIL model's principles, features, and implementation in the LINKS course. (Adapted from Kidron & Kali, 2015)

BBIL design principle	Selected features and example implementation in the LINKS course
Breaking boundaries between disciplines Curricular perspective building on theoretical notions of interdisciplinarity and knowledge integration	**Cross-cutting interdisciplinary theme** A theme that serves as a backbone through which knowledge from the different disciplines is integrated. The cross-cutting theme chosen for the LINKS course was "learning in a networked society"
	Integrative cross-domain artifact Following a series of lessons in more than one disciplinary domain, students create an original artifact that integrates their ideas in these domains. The LINKS course integrative artifact was a short essay
	Integrative lenses A set of predefined generic questions for each disciplinary domain designed to foster interdisciplinary connection making. In LINKS, the integrative lenses included questions such as how *learning is* conceptualized in the various disciplinary domains
Breaking boundaries between learners Pedagogical perspective building on theoretical notions of learning communities	**Streamlining learning between community members** Sequenced activities in which artefacts developed and shared in the community are later on used by other community members. In the LINKS course, community artifacts developed using the integrative lenses were used by individuals for creating their integrative artifact
	Learning community norm prompts Prompts designed to promote productive community learning norms (e.g., respect other ways of thinking). In the LINKS course, norms were directly discussed (online) in the community and published in the course website
Breaking boundaries between organizational hierarchies Organizational perspective building on the notion of cognitive apprenticeship	**Personal mentoring between levels of hierarchy** Technology-enhanced communication channels that enable personal mentoring of novices by advanced community members. The LINKS undergraduate students were mentored by graduates in a parallel course
	Modeling artifacts between levels of hierarchy Artifacts developed by advanced community members to make visible their ways of thinking are shared with novices. In the LINKS course, artifacts developed by the graduate student community were shared following the study of each domain with the undergraduate students

Table 3 Learning environments developed by the three practitioner teams

	School 1	School 2	School 3
Cross-cutting theme	Connections	Revolutions	Futurism
Disciplinary domains and topics	Biology (animal communication) Chemistry (chemical bonds) Social studies (social structures) Art (relations and feelings)	Biology (the discovery of microorganisms) History (the French revolution) Geography (continent discovery) Art (the invention of the camera)	Biology (genetic engineering) Physics (alternative energy) Geography (pollution)
Operation model	Two eighth-grade classes taught for a total of 32 h spanning 16 weeks	Four eighth-grade classes taught for a total of 36 h spanning 4 weeks	Two eighth-grade classes taught for a total of 40 h spanning 6 weeks
Identity of the interdisciplinary moderator	Disciplinary experts (development team)	The homeroom teachers (some were also disciplinary experts)	Disciplinary experts + homeroom teachers

theory; and (5) a DC-RPP website, in which the processes and products of the collaborative work were constantly documented by all participants.

During the first year of the partnership, each of the practitioner teams adapted the BBIL instructional model (Table 2) for their specific school contexts. Specifically, they collaboratively designed, enacted, and evaluated their own technology-enhanced interdisciplinary learning environments. Toward the end of the year, all learning environments comprised of technology-enhanced activities designed for students to study disciplinary contents as well as explore interdisciplinary connections between them (as demonstrated in the menu of the "Connections" learning environment, designed by School 1, in Fig. 1). Based on the design principles of the BBIL model, they all included an integrative assignment (the integrative cross-domain artifact in Table 2), which they chose to design as a culminating activity. The learning environments differed in their themes, content domains, operation models, and distribution of roles between disciplinary and interdisciplinary teaching, as demonstrated in Table 3. In the second year, additional teachers joined each practitioner team for a second iteration, in which the learning environments were either revised or completely redesigned based mainly on practitioner reflections but also on student reflections regarding the enactment in the first iteration (student reflections were collected using a survey designed by the teachers, as well as via some interviews conducted by the researcher).

Strong Affiliation with the Change Laboratory Lens

Employing change laboratory roles (PDP5). Since the goal of the DC-RPP in this case was to adopt the notion of interdisciplinarity, and since the schools were interested in adopting the BBIL model and exploring new ways to implement it in

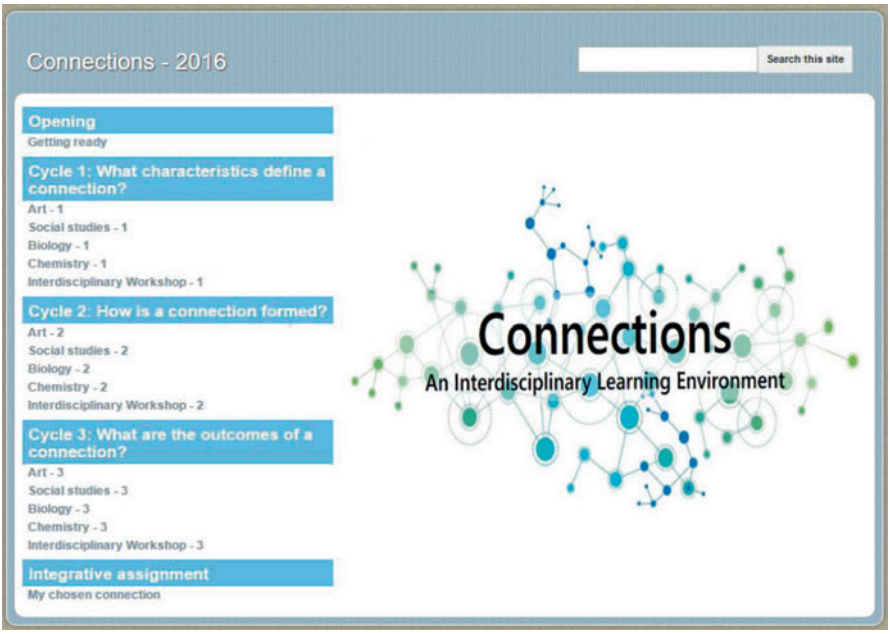

Fig. 1 Homepage of the learning environment designed by School 1 practitioner team

each of the schools, the roles of the researcher and practitioners naturally took a change laboratory character. That is, the practitioners were those who served as leaders of change in their schools, as well as designers of the technology-enhanced learning environments and experimenters of the tentative solutions that they designed. The researchers, who initially suggested the BBIL model as an inspiration for practitioners to invent their own solutions, were naturally positioned as provokers and supporters. These roles enabled the processes described in the next section.

Employing change laboratory processes (PDP2). As suggested in PDP2, one of the initial stages was analysis of each of the practitioner teams' prevailing school practices and identification of contradictions with the interdisciplinarity vision (as portrayed in the BBIL model) that the schools sought to adopt. Since the original model was designed for the context of higher education, many dilemmas emerged regarding various aspects of implementation. Kidron and Kali (under review) document 22 dilemmas that were raised, some of which represent "productive deviations" (Sannino et al., 2016) from the original designed solutions.

For example, a major design consideration was raised in the DC-RPP around ways to put together the various disciplinary perspectives as part of one coherent learning sequence. In the context of the higher education course, it was quite simple to teach each of the perspectives as a whole, in sessions of about 2 weeks each. Students were provided with a set of "integrative lens" questions (see Table 2) after each of these sessions, which they discussed in an online forum to promote their

knowledge integration between perspectives. However, organizational constraints made it quite difficult for the three schools to implement such a learning sequence. An alternative solution that came up involved splitting all the contents according to several "integrative lenses" questions (see Table 2), rather than according to the disciplinary domains. This enabled each of the domain-expert teachers to continue to meet every week with all students (as was the case prior to the intervention). The dilemma that was raised was whether such a solution might prevent students from developing deep understanding in each disciplinary domain and engage them too early in making connections between domains.

As suggested by PDP2, the three practitioner teams *experimented with such solutions* and shared the practical knowledge gained in each of the three practitioner teams over a period of 2 years. This enabled the teams not only to improve the technology-enhanced learning environments they designed but also to improve the design principles of the BBIL model with additional design considerations and a range of new solutions that extend its applicability to broader contexts. The resultant "enhanced principled instructional model" (Kidron & Kali, 2018) can be viewed as a type of *generative solution* (as PDP2 advises) developed in the DC-RPPS, which can inspire additional activities that serve the vision of promoting interdisciplinarity in schools. To enable the design knowledge developed in the DC-RPP to reach a wider audience, members of the DC-RPP (the NGO representatives and the facilitating researcher) are currently writing a book intended for teachers, principals, and educational policymakers.

Employing change laboratory habit-of-mind (PDP8). The roles and processes described above required practitioners to adopt a habit-of-mind of questioning accepted processes (regarding the interdisciplinarity vision) analyzing problematic situations with regard to this vision and designing and experimenting with the solutions they designed (as advised in PDP8). In two of the schools, based on the knowledge and experience they gained in the program, teachers continued to develop additional interdisciplinary projects even after the intervention has ended. One of the teachers who moved to a different school initiated a totally new interdisciplinary program in his new school, demonstrating his cultivation of this "revolutionary" habit-of-mind. That said, it is important to note that this habit-of-mind, and the leadership roles and processes associated with it, was very demanding of the teachers. Perhaps for this reason, the reflection on explanatory models aspect of PDP8 was only moderately employed, as described in the section below describing the way in which the scholarship of teaching PDPs was employed.

Affiliation with Other Lenses

Employing boundary crossing PDPs. The various mechanisms that supported the DC-RPP (e.g., the kickoff meetings, annual retreats, collaborative maintenance of the partnership's website) enabled all participants to engage in boundary crossing processes (PDP3). These processes were especially prominent in the co-design workshop and reflection-in-action meetings. In these intensive meetings, as documented in interviews with teachers and in a journal kept by the researcher (Kidron & Kali, 2018), the teachers and the facilitating researcher had many

opportunities to get acquainted with and develop a more knowledgeable appreciation of the expertise of each other. Such identification processes, as well as coordination of practices within the team, enabled the teachers and the researcher to meaningfully reflect on their own practices and sometimes to transform their own practices. Such transformation occurred at all levels described by Akkerman and Bruining (2016). Specifically, through the interpersonal joint work, the three teams developed new ways to foster interdisciplinary teaching and learning in each of the schools. At the institutional level, this required transforming organizational structures for enactment of these programs (for instance, pooling all teaching hours to enable an intensive period devoted for the project). At the intrapersonal level, some teachers, who were especially open to take up the role of designers and embrace it as part of their professional identity (PDP9), began to serve as facilitators of their peers in the second year of the partnership. Their role in this year, which can be considered "brokering" (PDP6), represents a significant intrapersonal transformation. An additional boundary crossing process was on the side of the facilitating researcher (author 4 of this chapter). The work with the schools was originally external to his PhD, in which he intended to study interdisciplinarity only within higher education. His decision to incorporate an analysis of the DC-RPP work as a major part of his dissertation reflects a significant intrapersonal transformation process.

Employing scholarship of teaching PDPs. As mentioned above, the balance between teachers' role as leaders of change and designers (PDP5) and their role as researchers who explore their students' learning in a community of scholars (PDP4) in this case was somewhat biased toward the former. Vast energy was required from teachers for engendering the change in their schools. As a result, only little time was devoted in the DC-RPP for systematically investigating students' learning (PDP5) with the technology-enhanced learning environments the teachers designed and developed. The reflection in practice meetings, which was the mechanism of the DC-RPP in which such investigation could have taken place, was used mainly for addressing ongoing needs. For instance, the teams used these meetings for synchronizing activities within the team, discussing emerging implementation issues, refining the learning materials or activities for the students based on insights from the enactment, or solving unexpected problems (e.g., infrastructure fails or unplanned school activities which interrupted the planned timeline). Teachers also used these meetings to reflect on their experiences in the classes and to share emergent student insights, which was crucial for the team to support the students' interdisciplinary understanding (Kidron & Kali, 2018). However, we view these latter activities as a partial employment of scholarship of teaching and practitioner research processes (PDP 1), roles (PDP4), and habits-of-mind (PDP7).

That said, the next stage planned for the DC-RPP – in those schools in which interdisciplinarity has become part of the schools' activity – is intended to focus on deepening the process of investigating students' development of interdisciplinary learning. We discuss the implications of this DC-RPP case together with case 2, following its description below.

Case 2: Innovating Physics Teaching and Learning Workshop

General Description of the Workshop

The workshop was part of a 3-year professional development program for 22 Jewish and Arab leading Israeli high school physics teachers from all over the country who met for a full day each week throughout the year. The program aimed at developing teacher leadership for promoting physics education in Israel. Indeed, following the program, most of the graduates became involved in leadership roles such as facilitators of regional professional learning communities of physics teaching and curriculum developers in additional DC-RPPs.

The DC-RPP workshop (330 h) included activities that were carried out as part of the program's weekly meetings, while the participants continued to collaborate between meetings. The partnership included a team of 8 physics education researchers and expert practitioners from the staff of a science teaching department in a research university and all the 22 leading teachers. Within the wider goal of teacher leadership in physics education, the specific aim of the workshop was to develop teachers' capabilities to carry out systematic research-based design of learning-centered activities. Learning about physics education research findings and ways to use them in practice were part of this aim.

Participants of the DC-RPP worked in teams of 5–6 to design learning modules of between 6 and 10 h each. A science education researcher or expert practitioner served as mentor in each of the teams. Participants chose the module topics from a list of topics related to the existing syllabus (e.g., "the first and second laws of Newton"). All topics were characterized in the literature on physics education research (PER) as challenging for both teaching and learning and thus requiring genuine changes in the way they are taught. The modules developed by the teams included activities and resources (e.g., simple lab equipment), as well as suggestions of teaching sequences.

During the workshop, teachers systematically and continuously collected data on their practice and on their students' learning (an evidence-based approach). The DC-RPP teams shared with the plenum their experiences, insights, and challenges, raised questions regarding the relationship between practice and learning and about alternative ways to bring about change, and received feedback. This process led to the development of cross-cutting ideas. The DC-RPP workshop consisted of several stages (Table 4), each of which ended with a mini-conference attended by additional colleagues from the physics and physics education community (e.g., leading teachers, physics education researchers, interested physicists).

Upon completing the workshop, some of the teams published a paper in the Israeli Journal of Physics Teachers, summarizing the module's content, the pedagogy, the findings from the various investigations, and the reflections on the whole design process. The learning materials of each team were also published through a teachers' website and are being used in a variety of forms until today. Findings were also presented in international meetings of researchers and teachers and published in peer-reviewed journals. The article by Eylon and Bagno (2006) became a practical input for teachers as it was included in a resource book published by the physics teacher education coalition (PTEC) (Meltzer & Shaffer, 2011).

Teachers' responses to questionnaires given immediately after the workshop and 6 years later suggest that the program has had lasting beneficial impacts on the participants' attitudes toward teaching and on their classroom practice. In particular, most of the teachers singled out the design of the module as an activity that was most meaningful, useful, or important to them. Additionally, teachers adapted and adopted the approach exemplified in the workshop in their work as facilitators of regional teacher communities. The researchers benefited as well. The lessons learned from this intensive collaboration have been applied in a variety of research and development projects for professional development of physics teachers.

Strong Affiliation with the Scholarship Lens

Employing scholarship processes (PDP1). A major mechanism that promoted a genuine change in the participants' views and practices throughout the workshop was the goal-driven, evidence-based iterative design process that the DC-RPP participants carried out. This process was supported by resources within the workshop. Participants systematically investigated questions related to their own practice (physics teaching) and student learning. Additionally, a successive refinement of goals took place throughout the workshop. For example, as described in Table 4, in stage I of the design process, the teachers developed a diagnostic questionnaire to examine student understanding of central ideas related to the initial goals of the module, administered it to their students, analyzed the answers, and reflected collaboratively with their peers in the team and also with the other teams. Based on the findings, members of the DC-RPP realized, for example, that some assumptions about students' incoming knowledge were unfounded, and therefore the team revised the goals for the modules they designed in stage II. In some of the teams, these findings were quite shocking, as participants initially viewed the topic of the module ("the relationship between Newton's first and second laws") as too obvious and assumed that they had the required experience to teach it. Through the investigation, participants realized challenges that are often not attended to. The collaborative discussions within the professional community of teaching led to cross-cutting insights. For instance, many teachers grappled with basic questions concerning the design of "good" test questions for probing student thinking on a particular topic and tried to unpack what understanding means in that topic. In their reflections on the process, the teachers claimed that as the DC-RPP advanced, they attempted to reveal students' thinking about physical phenomena rather than focusing on their technical skill to use equations. The teachers reported that the physics education research literature on students' understanding was very useful in this process. In stage III, after teachers taught the first version of the module to their students, some teams were disappointed to find gaps between what they taught and what their students have learned (as analyzed in the DC-RPP using the diagnostic tool developed). In most of teams, this resulted in negotiating criteria for narrowing the scope of the module and reconsidering the goals. This challenging selection process required "going meta" while negotiating criteria for deciding what to include in the design of the module. For example, one cross-cutting criterion that came up was making the learning relevant to students.

Table 4 Stages in the DC-RPP, features, and implementation. (Adapted from Eylon & Bagno, 2006)

Stages in the DC-RPP	Selected features and examples of implementation in the workshop
Stage I: Defining teaching and learning goals (about 120 h) 1. Initial definition of goals 2. Review of the literature 3. Diagnosis 4. Revision of goals *Mini-conference I* Aim: Collaborative negotiation of the required innovation based on PER literature and practitioner (researchers and teachers) experience	**Experience as learners** Teachers carry out activities related to specific modules. This experience challenges teachers' physics and physics teaching knowledge (matched to proximal zone of development)
	Iterative revision of goals Within each design team, teachers carry out content analysis and characterize relationships among concepts and principles relevant to the planned module in a concept map
	Diagnosis Teachers design a diagnostic questionnaire to probe students' understanding. They administer, analyze, and summarize the findings and then discuss with the RPP and other implications for the design of the module (e.g., deciding to narrow its scope)
Stage II: Designing the module (about 120 h) 5. Initial design *Mini-conference II* 6. Development of module Aim: Initial design and development of activities based on collaborative learning of PER-based innovative teaching strategies and feedback from experts	**Collaborative learning of innovative teaching strategies** Each design team reviews a PER-based instructional strategy (e.g., the predict-observe-explain strategy), presents to the plenum, and leads discussion about challenges and advantages
	Consultation with experts Toward the mini-conference, participants approach expert teachers. Physics educators and physicists for feedback and assistance in explaining complex ideas
	The "story of the module" Toward the mini-conference, teachers develop "story of the module" posters including goals and rationale for strategies, alternative sequencing, and entry conditions. They also describe the process leading to the initial design
Stage III: Performing small-scale research study (about 90 h) 7. Design and implementation 8. Consolidation and reporting *Mini-conference III* Aim: Identifying gaps between what is taught and what students learn, as well as reflecting on (practical and theoretical) lessons learned in the DC-RPP	**Assessing student learning** Within each design team, teachers formulate research questions and tools, implement the modules in their classes, and administer and analyze the assessment (e.g., using questionnaires and interviews). They start individually, and then they share, reflect, and collaboratively interpret findings and implications for design

Facilitate engagement through specific and dynamic roles (PDP4). The feedback from colleagues within and between the design teams, as well as with additional colleagues that teachers met in stages I, II, and III, was a significant input to the DC-RPP. This process enabled all the participants to assume roles of researchers and peer reviewers. In the preparation process of the mini-conferences, members of the workshop discussed the structure and formats of the meeting. These discussions, supported by the experienced mentors, started a process of engagement in, and developing the mechanisms for sharing, critiquing and synthesizing design knowledge (as recommended in PDP4). Toward these mini-conferences, the groups worked intensively on consolidating the various inputs (e.g., realizations from their experience as learners in the workshop, findings of the investigations, their own practical knowledge) and explicating them toward making their ideas visible and public. In interviews, teachers described the challenge of preparation toward these meetings (Eylon & Bagno, 2006). They also explained that their own analysis of their practice and the requirement to explicate and explain their considerations brought about a "quantum jump" in their expertise as teachers. This included contents of their module, understanding of the aspects they should attend to in designing instruction, and the relationship between their teaching and their students' learning. The accompanying research on the workshop examined various documents prepared by the DC-RPP, such as transcripts of the meetings and the conferences, the initial version of the module, and interviews with the teachers. The analyses and triangulation of data documenting the activities designed and developed in the DC-RPP, and the roles that participants took to develop them, indicated a considerable increase in the coherence of these activities (e.g., between stated goals and findings regarding student learning, as well as between stated goals and the actual content of the module)(Eylon and Bagno, 2006).

Cultivate productive habits-of-mind (PDP7). It should be noted that the participating teachers were experienced and successful teachers with sound knowledge of physics. They were required to teach a packed curriculum and therefore were somewhat reluctant, at early stages of the partnership, to take up changes in practice that require considerable time and effort, even when they acknowledged the need for change. The building of trust was an essential component in teachers' willingness to openly discuss their ideas. Initially, teachers attributed teaching and learning difficulties to their own inadequacies. The processes and roles described above (PDP1 and PDP4), in which teachers realized that their ideas and findings are respected and that other members of the DC-RPP are grappling with similar issues, were essential in their willingness to share and open up.

Some of the central activity strands in the workshop were designed to form important habits-of-mind for "learner-centered" practice. An example is the "evidence based approach" in which teachers take an inquiry stance (Cochran-Smith & Lytle, 2009) and continuously follow their practice and student learning to make decisions on the basis of data they collect. These aspects played an important role in later activities of the researchers such as the binational UK-Israel collaboration on the development of an evidence-based continuing professional program for science teachers (Harrison, Hofstein, Eylon, & Simon, 2008).

Affiliation with Other Lenses

Employing change laboratory and boundary crossing PDPs. As mentioned above, the workshop started as a professional development program in which the change laboratory and boundary crossing roles (PDP5 and PDP6) were not symmetric. The physics education researchers led the process. Retrospectively, it seems that they underestimated the sociocultural difference between themselves (as researchers) and the practitioners and were not sensitive enough to this gap. Through the deep involvement with the DC-RPP activities, the practitioners developed ownership on the design process and material development. There was a change in the division of roles within the partnership and teachers, who gradually began to serve as leaders of change, designers, and experimenters, while the researchers began to take more supportive roles (PDP5). In a similar manner, there was more sensitivity to the role of brokers (PDP6). For example, the teachers suggested adding expert curriculum developers to the teams. These experts enabled better linkage between the researchers and the teachers in the design process. Interestingly, the changes in the role division were strongly associated with employment of PDP8 and PDP9 (change laboratory and boundary crossing habits-of-mind). While at early stages practitioners were reluctant to consider alternative modes of teaching, as time went on, they began to value the perspectives that researchers brought to the partnership and were more willing to try out new directions. In projects that were taken up by some members of the partnership in later years, the employment of these PDPs was enhanced and became an important a priori consideration in designing additional DC-RPPs.

Discussion

The analysis of the two cases, as mentioned above, shows that the main processes, roles, and habits-of-mind in each of the cases are strongly related to a specific theoretical lens in the theory-practice matrix (one of the columns in Table 1). This affiliation can be explained by the fact that these practical aspects of a DC-RPP are related to, and may affect, each other. In case 1, for instance, the processes of engendering change within the schools, and exploring the contradictions that need to be addressed, required teachers to embrace that "revolutionary" habit-of-mind and assume the role of leaders of change and designers of new learning environments that would allow the change to take place. In case 2, the processes of investigating questions that relate own practice (physics teaching) and student learning were naturally related to teachers' assuming roles of researchers and peer reviewers in the community. As all participants (researchers and teachers) developed trust as a habit-of-mind within the community, processes of sharing, critiquing, and synthesizing design knowledge became natural.

That said, other PDPs from the theory-practice matrix, though not as saliently employed, were also part of the cases' profiles, indicating that PDPs in the various lenses may strengthen each other. In case 1, for instance, the boundary crossing

processes, roles, and habits-of-mind were crucial for participants to collaboratively engender a meaningful change within the schools. That is, in order for practitioners to embark on the complex task of designing their technology-enhanced learning environments intended to promote interdisciplinarity, they were required to develop an appreciation of design as a practice that can support teaching and that they would want to adopt. On the other hand, the researchers' appreciation and understanding of the complexity of the teaching ecology within the schools enabled them to better support the design process of the teachers. PDPs that strengthen each other between lenses were also found in case 2. There was a strong relationship between changes over time in the habits-of-mind pragmatic principles PDP8 and PDP9. From being reluctant to consider alternative views and changes in practice, teachers became interested to consider alternatives and experiment with new strategies. A similar relationship between the lenses was observed in employing pragmatic principles PDP5 and PDP6 by the researchers. Overtime, they became more sensitive to the sociocultural gaps between the researchers and practitioners in the partnership. This resulted in reconsideration of the division of roles and led to active seeking of brokers. The finding that PDPs from various theoretical lenses can strengthen each other supports earlier research on design principles. Kali, Levin-Peled, and Dori (2009), for instance, based on their research on design principles for promoting collaboration in higher education, recommend identifying clusters of design guidelines that strengthen each other. The set of PDPs in the research-practice matrix can be viewed as such a cluster for guiding productive DC-RPPs.

Interestingly, PDPs that were only partially employed, such as the scholarship PDPs (#1, 4, and 7) in case 1, and change laboratory formative interventions PDPs (#5 and 8) in case 2 became much more salient in further stages in both cases. In case 1, this was illustrated by the intention to go deeper into investigating students' interdisciplinary understanding in further steps of the program. In case 2, this was illustrated in the design of more opportunities for practitioners to serve as leaders of change in later stages of the project. These developments illustrate the dynamic use of PDPs over time in both cases. In fact, we view the dynamics in case 1 as moving from focusing on change laboratory PDPs to a dual focus that also emphasizes scholarship of teaching PDPs. In case 2, the dynamics represent the other direction, that is, moving from a focus on scholarship of teaching PDPs to the dual focus in which change laboratory formative intervention PDPs are also emphasized. We believe that these trajectories portray the complex nature of conducting design-based research in general (e.g., Akkerman et al., 2013) and in DC-RPPs in particular. This complexity was addressed in different trajectories in the two cases.

Conclusion

Communicating the complex nature of design research endeavors, especially when they are conducted in DC-RPPs, is a challenging task, due to the multiple aspects involved in (a) design, (b) research, and (c) partnerships. The theory-practice matrix of PDPs introduced in this chapter addresses this challenge. By enabling exploration

of specific connections between theory and practice in DC-RPPs, it has provided a productive way for characterizing, comparing, and contrasting between two DC-RPP cases. Although the cases varied in many aspects (e.g., use of technology, disciplinary contents involved, the scope of design, the focus on student learning), the set of PDPs enabled exploration of the unique connections between theory and practice they represent. We believe that the abstraction and articulation of the PDPs in the theory-practice matrix will enable not only to accumulate and synthesize lessons learned from the emerging research trajectory of DC-RPPs but also to guide such future endeavors and thus build important bridges between research and practice in education. Finally, we view the current theory-practice matrix of PDPs as a growing endeavor and call additional DC-RPP researchers to expand it with additional relevant lenses.

References

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81*(2), 132–169.

Akkerman, S. F., Bronkhorst, L. H., & Zitter, I. (2013). The complexity of educational design research. *Quality and Quantity, 47*(1), 421–439.

Akkerman, S. F., & Bruining, T. (2016). Multi-level boundary crossing in a professional development school partnership. *Journal of the Learning Sciences, 25*(2), 240–284.

Bauer, K., & Fischer, F. (2007). The educational research-practice interface revisited: A scripting perspective. *Educational Research and Evaluation, 13*(3), 221–236.

Bergen, T., & Van Veen, K. (2004). Het leren van leraren in een context van onderwijsvernieuwingen: Waarom is het zo moeilijk? [Teacher learning in the context of educational innovations: Why is it so difficult?]. *VELON: Tijdschrift voor Lerarenopleiders, 25*(4), 29–39.

Broekkamp, H., & Van Hout-Wolters, B. (2007). The gap between educational research and practice: A literature review, symposium and questionnaire. *Educational Research and Evaluation, 13*, 203–220.

Coburn, C. E., & Penuel, W. R. (2016). Research–practice partnerships in education outcomes, dynamics, and open questions. *Educational Researcher, 45*(1), 48–54. https://doi.org/10.3102/0013189X16631750

Coburn, C. E., Penuel, W. R., & Geil, K. (2013). *Research-practice partnerships at the district level: A new strategy for leveraging research for educational improvement*. New York, NY: William T. Grant Foundation.

Cochran-smith, M., & Lytle, S. L. (2001). Beyond certainty: Taking an inquiry stance on practice. In A. Lieberman & L. Miller (Eds.), *Teachers caught in the action professional development that matters* (pp. 45–58). New York, NY: Teachers College Press.

Cochran-Smith, M., & Lytle, S. L. (2009). *Inquiry as stance: Practitioner research for the next generation*. New York, NY: Teachers College Press.

Collins, A. (1992). Toward a design science of education. In E. Lagemann & L. Shulman (Eds.), *Issues in education research: Problems and possibilities* (pp. 15–22). San Francisco, CA: Jossey-Bass.

Cviko, A., McKenney, S., & Voogt, J. (2015). Teachers as co-designers of technology-rich learning activities for emergent literacy. *Technology, Pedagogy and Education, 24*(4), 443–459.

DBRC. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8.

de Vries, B., & Pieters, J. (2007). Bridging the gap between research and practice: Exploring the role of knowledge communities in educational design. *European Educational Research Journal, 6*(4), 382–392.

Dede, C., Rockman, S., & Knox, A. (2007). Lessons learned from studying how innovations can achieve scale. *Threshold, 5*(1), 4–10.

Donovan, S., Snow, C., & Daro, P. (2014). The SERP approach to problem-solving research, development, and implementation. In B. J. Fishman, W. R. Penuel, A. R. Allen, & B. H. Cheng (Eds.), *Design-based implementation research: Theories, methods, and exemplars. National society for the study of education yearbook* (pp. 400–425). New York, NY: Teachers College Record.

Engeström, Y. (2007). Putting Vygotsky to work: The change laboratory as an application of double stimulation. In *The Cambridge companion to Vygotsky* (pp. 363–382). Cambridge, MA/New York, NY: Cambridge University Press.

Engeström, Y. (2011). From design experiments to formative interventions. *Theory & Psychology, 21*(5), 598–628.

Engeström, Y., Virkkunen, J., Helle, M., Pihlaja, J., & Poikela, R. (1996). The change laboratory as a tool for transforming work. *Lifelong Learning in Europe, 1*(2), 10–17.

Eylon, B., & Bagno, E. (2006). Research-design model for professional development of teachers: Designing lessons with physics education research. *Physical Review Special Topics – Physics Education Research, 2*, 020106-1–020106-14. https://doi.org/10.1103/PhysRevSTPER.2.020106

Harrison, C., Hofstein, A., Eylon, B., & Simon, S. (2008). Evidence-based professional development of teachers in two countries. *International Journal of Research in Science Education, 30*(5), 577–591.

Henrick, E., Munoz, M. A., & Cobb, P. (2016). A better research-practice partnership. *Phi Delta Kappan, 98*(3), 23–27.

Hutchings, P., & Shulman, L. S. (1999). The scholarship of teaching: New elaborations, new developments. *Change, 31*(5), 10–15.

ISSOTL. (2017). International society of the scholarship of teaching and learning. Retrieved from http://www.issotl.com

Kali, Y. (2006). Collaborative knowledge building using the design principles database. *International Journal of Computer Support for Collaborative Learning, 1*(2), 187–201.

Kali, Y. (2008). The design principles database as means for promoting design-based research. In A. E. Kelly, R. A. Lesh, & J. Y. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching* (pp. 423–438). Mahwah, NJ: Lawrence Erlbaum Associates.

Kali, Y. (2016). Transformative learning in design research: The story behind the scenes. In C. K. Looi, J. L. Polman, U. Cress, & P. Reimann (Eds.), *Transforming learning, empowering learners. The international conference of the learning sciences (ICLS) 2016* (Vol. 1, pp. 4–5). Singapore: International Society of the Learning Sciences.

Kali, Y., Levin-Peled, R., & Dori, Y. J. (2009). The role of design-principles in designing courses that promote collaborative learning in higher-education. *Computers in Human Behavior, 3*(1), 55–65.

Kali, Y., & Linn, M. C. (2008). Technology-enhanced support strategies for inquiry learning. *Handbook of research on educational communications and technology*, 145–161.

Ketelhut, D. J., & Schifter, C. C. (2011). Teachers and game-based learning: Improving understanding of how to increase efficacy of adoption. *Computers & Education, 56*, 539–546.

Kidron, A., & Kali, Y. (2015). Boundary breaking for interdisciplinary learning. *Research in Learning Technology, 23*, 1–17.

Kidron, A., & Kali, Y. (2018). Extending the applicability of design-based research through research-practice partnerships. *Educational Design Research, 1*(2).

Lavis, J. N., Robertson, D., Woodside, J. M., McLeod, C. B., & Abelson, J. (2003). How can research organizations more effectively transfer research knowledge to decision makers? *Milbank Quarterly, 81*(2), 221–248.

McKenney, S. (2016). Researcher-practitioner collaboration in educational design research: Processes, roles, values & expectations. In M. A. Evans, M. J. Packer, & R. K. Sawyer (Eds.), *Reflections on the learning sciences* (pp. 155–188). New York, NY: Cambridge University Press.

McKenney, S., & Pareja-Roblin, N. (2018). Connecting research and practice: Teacher inquiry and design-based research. In J. Voogt, G. Knezek, R. Christensen, & K. Lai (Eds.), *International handbook of information technology in primary and secondary education* (2nd ed.). London, England: Springer.

McKenney, S., & Reeves, T. C. (2012). *Conducting educational design research*. London, England: Routledge.

Meltzer, D. E., & Shaffer, P. S. (2011). *Teacher education in physics: Research, curriculum and practice*. College Park, MD: American Physics Society.

Nutley, S., Walter, I., & Davies, H. (2007). *Using evidence. How research can inform public services*. Bristol, UK: The Policy Press.

Penuel, W. R. (2015). Infrastructuring as a practice for promoting transformation and equity in design-based implementation research. Keynote address at the ISDDE annual conference. September 22–25, Boulder.

Penuel, W. R., Allen, A.-R., Coburn, C. E., & Farrell, C. (2015). Conceptualizing research–practice partnerships as joint work at boundaries. *Journal of Education for Students Placed at Risk, 20*(1–2), 182–197.

Penuel, W. R., Bell, P., Bevan, B., Buffington, P., & Falk, J. (2016). Enhancing use of learning sciences research in planning for and supporting educational change: Leveraging and building social networks. *Journal of Educational Change, 17*(2), 251–278.

Penuel, W. R., Fishman, B., Cheng, B., & Sabelli, N. (2011). Organizing research and development and the intersection of learning, implementation and design. *Educational Researcher, 40*(7), 331–337.

Reinking, D., & Bradley, B. (2008). *Formative and design experiments: Approaches to language and literacy research*. New York, NY: Teachers College Press.

Sannino, A., Engeström, Y., & Lemos, M. (2016). Formative interventions for expansive learning and transformative agency. *Journal of the Learning Sciences, 8406*, 10508406.2016.1204547.

Shulman, L. S. (1998). Course anatomy: The dissection and analysis of knowledge through teaching. In P. Hutchings (Ed.), *The course portfolio: How faculty can improve their teaching to advance practice and improve student learning*. Washington, DC: American Association of Higher Education.

Shulman, L. S. (2011). Feature essays: The scholarship of teaching and learning: A personal account and reflection. *International Journal of the Scholarship of Teaching and Learning, 5*(1) (Article 30).

Star, S. L. (1989). The structure of ill-structured solutions: Boundary objects and heterogeneous distributed problem solving. In M. Huhns & L. Gasser (Eds.), *Readings in distributed artificial intelligence*. Menlo Park, CA: Morgan Kaufman.

Star, S. L., & Greisemer, J. R. (1989). Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907-39. *Social Studies of Science, 19*(3), 387–420.

Trigwell, K., Martin, E., Benjamin, J., & Prosser, M. (2000). Scholarship of teaching: A model. *Higher Education Research and Development, 19*(2), 155–168.

van Braak, J., & Vanderlinde, R. (2012). Het profiel van onderwijsonderzoekers en hun opvattingen over samenwerking met de onderwijspraktijk. *Pedagogische Studiën, 89*(6), 364–376.

Vanderlinde, R., & van Braak, J. (2010). The gap between educational research and practice: Views of teachers, school leaders, intermediaries and researchers. *British Educational Research Journal, 36*(2), 299–316.

Virkkunen, J. (2013). *The change laboratory: A tool for collaborative development of work and education*. Heidelberg, Germany: Springer Science & Business Media.

Wagner, J. (1997). The unavoidable intervention of educational research: A framework for reconsidering researcher-practitioner cooperation. *Educational Researcher, 26*(7), 13–22.

View publication stats