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The Parts and Parcel: A Collegiality Model for Teacher Disciplinary Professional Learning Communities

Avraham Merzel [1,*], Stephanie Bismuth [1] and Zvi Arica [2]

[1] The Seymour Fox School of Education, The Hebrew University of Jerusalem, Jerusalem 9190501, Israel; stephbi77@gmail.com
[2] Ministry of Education, Jerusalem 9510402, Israel; zvikaarica@gmail.com
* Correspondence: avraham.merzel@mail.huji.ac.il

Abstract: While teachers' professional learning communities (PLCs) have been extensively studied, discipline-specific PLCs (DPLCs) have received less attention, particularly regarding the subject matter's role and its connection to other community dimensions. To explore this, we conducted two independent studies on DPLCs. Study 1 examined physics teacher DPLCs, using participant observations and literature-based analysis. Study 2 investigated science and technology teacher DPLCs through interviews and passive observation, which was analyzed through content analysis. Both studies yielded remarkably similar findings, leading to a synthesized model encompassing five dimensions: the structural dimension, reflecting the community's tangible and logical organization; the content dimension, emphasizing the discipline-specific focus of the DPLC; the common production dimension, showcasing joint enterprise activities and products of the DPLC; the social-affective dimension, addressing social, emotional, and value-based aspects that establish a sense of community; and the meta-community dimension, exploring the DPLC's relationships with its broader environment. These dimensions operate bidirectionally: inward—the effect of the community on the individual, and outward—the effect of the individual teacher on the community. We discuss how interactions between these dimensions shape DPLCs and influence teacher development. Additionally, we highlight the significance of this unified model for DPLC leaders, researchers, and policymakers in teacher development.

Keywords: professional learning communities (PLCs); disciplinary professional learning communities (DPLCs); teacher professional development; collegiality model

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1. Introduction

Professional learning communities (PLCs), popular since the 1990s, have spread from the field of business to education (Thompson et al., 2004). Defining teacher communities (TCs) as PLCs, however, is challenging due to myriad characterizations (DuFour, 2004; Grossman et al., 2001; Levy et al., 2019; Lomos et al., 2011; Vangrieken et al., 2017). For example, Vangrieken et al.'s (2017) review defined TCs as either PLCs or communities of practice (CoPs), yet pointed out that although they draw upon different theoretical bases, "in practice, it is difficult to separate them" (p. 55). There are still no universal definitions (Huijboom et al., 2020; Prenger et al., 2019; Stoll et al., 2006; Vescio et al., 2008), but, overall, it refers to teachers sharing and interrogating their practice in a collective effort (Stoll et al., 2006).

Teacher PLC definition efforts have led to a multiplicity of components, which makes it difficult to obtain a clear picture of their structure and operating mechanisms, yet the study of teacher PLCs rarely considers this multidimensional nature (Van Meeuwen et al., 2020).

Attempting to define a framework, Van Meeuwen et al. (2020) mentioned two conditions: (1) the framework should be comprehensive enough to illustrate all the characteristics and interactions between various components and (2) the framework should be dynamic in terms of interactions between influencing factors and contexts that evolve over time. Previous framework attempts, however, focused only on certain aspects (e.g., DuFour, 2004), or did not describe relationships between the different parameters (e.g., Chen & Wang, 2015). When a proposed framework consists of many characteristics (e.g., the TenKey model of Jäppinen, 2012; Jäppinen et al., 2016), its complexity encumbers its use as a tool for non-researchers (i.e., teachers and policymakers). Therefore, any proposed framework should also be simple and useful, comprising a small number of clear dimensions.

PLCs have traditionally convened schoolteachers to share generic teaching practices, applicable without being tied to a particular subject matter. Only recently have PLCs started convening teachers of a specific discipline (e.g., physics), recognizing their importance in deepening teachers' understanding of science content (Gunning et al., 2020) and their instrumental role in helping teachers address students' unique challenges in learning science (Viskupic et al., 2019), as well as making teaching "both an expression of and a participation in the discipline" (Parker, 2002, p. 382). However, most studies are of beginning or evolving science teacher PLCs affiliated with teacher preparation or university–school partnership (Friedrichsen & Barnett, 2018; Kloser et al., 2021). These disciplinary PLCs (DPLC; MOFET, 2020) ostensibly align with the CoP framework, characterized by a shared repertoire (Wenger et al., 2002). However, CoPs usually refer to the shared proficiency as teaching, not necessarily to teaching a specific subject. Thus, we use the term DPLC to highlight the importance of subject matter to teachers' learning in these communities.

While participating in such communities, teachers share resources and critically reflect on their own and their peers' teaching to promote the professional growth that might lead to improving students' learning (Borko et al., 2010; Desimone, 2009; Hord, 2009; Levy et al., 2019; Pareja Roblin et al., 2014; Stoll et al., 2006). Although DPLCs consist of teachers with a shared discipline, they are heterogeneous regarding school, seniority, educational background, professional development background, and other characteristics (Levy, 2017; MOFET, 2020; Prenger et al., 2019). Typically comprising 15–30 teachers, DPLCs avail intimacy, self-exposure, and mutual fertilization, as different teaching approaches can be introduced.

Discourse about what professional teachers should know has not diminished over the years (e.g., Carlson et al., 2019), and one would expect that platforms for teachers' professional growth would focus on this knowledge. Therefore, it is surprising that the lens used to examine teacher PLC characteristics through the perspective of a specific discipline, although mentioned as a possibility (Vangrieken et al., 2017, p. 52), is missing. From the paucity of DPLC research, the need arises for a practical and empirically based conceptualization of its dimensions to inform teachers, leaders, policymakers, and future study on this topic. This need led us to the research question:

What dimensions characterize the conduct of DPLCs, what are the inter-dimensional connections, and how can these dimensions be organized into a model that could provide a structured framework for evaluating and assessing DPLCs to inform decision-making processes?

2. Methodology

2.1. Overview

This research project combines two studies, using different methods on different DPLC populations. Study 1 involved participant observations (Jorgensen, 1989; Richmond & Manokore, 2011; Shank, 2006) to establish preliminary categorization of DPLC dimensions based on grounded theory (Charmaz, 2006). These preliminary categorizations were then

refined and operationalized (Top et al., 2018) by extracting characteristics from relevant literature with a saturation method (Saunders et al., 2018). These characteristics were sorted according to the preliminary categorization and underwent peer validation. Although some examined literature did not explicitly deal with disciplinary communities, we analyzed it through the lens of disciplinary teachers' perspective.

Study 2 aimed to uncover how DPLC characteristics contribute to lesson design—an aim distinct from Study 1. To gain deeper insight into teachers' considerations, we conducted interviews with teachers and a DPLC leader, alongside passive observations at DPLC meetings (DeWalt et al., 1998; Spradley, 1980). We categorized DPLC characteristics independently of Study 1 (we report the connection between DPLC characteristics and lesson design elsewhere). Having identified similarities in both categorizations, we refined the definitions of the DPLC dimensions and their relationships to construct one model. Study 1 was conducted by the first and third authors, and Study 2 was conducted by the first and second authors. The final refinement of DPLC dimensions and their relationships occurred through joint discussions involving all three authors.

In the following sections, we describe both study populations and methodologies, elaborate on aggregated findings and model dimensions, and conclude with a visualization of their relations. We highlight the model's significance for teachers, DPLC leaders, and policymakers in terms of teachers' professional development (PD). For both studies, we have the ethical approval of the institutional IRB, and all cited participants gave their informed consent.

2.2. Populations

Study 1 included two high school physics teacher DPLC networks, active since 2012 and 2016, comprising a total of 19 DPLCs, involving approximately 35% of the country's physics teachers in 2022 (cf. Arica & Merzel, 2021; Eylon et al., 2020; Levy, 2017; Levy et al., 2019, 2020, 2021). Study 2 involved a separate network of 23 DPLCs for middle school science and technology (SaT) teachers, established in 2015 and distributed nationwide (cf. Scherz, 2018). These DPLCs resemble those of Prenger et al. (2019). We selected these communities due to our deep familiarity with the participating teachers, which fostered openness and a willingness to collaborate.

The DPLCs within these networks share common features. They consist of around 20 teachers from different schools who meet approximately 12 times annually for 4 h sessions. Each DPLC is led by two academically trained leading teachers, supported by participation in a national DPLC for leading teachers. Their training followed the "teachers as learners" approach (Levy, 2017; Levy et al., 2020) to develop mentoring skills and discipline-specific pedagogical content knowledge (Levy et al., 2021; Scherz, 2018). Leaders facilitate both group and individual work, synchronously and asynchronously (face-to-face, and online during the COVID-19 pandemic, and hybrid henceforth). Each network also organizes an annual gathering for its members.

These DPLCs resemble the member-oriented TC with a preset agenda (Vangrieken et al., 2017), although not government-initiated, but still supported by the Ministry of Education. They are designated for teachers' PD, while also encouraging adherence to national standards. They have guidelines, designed by accompanying academic institutes, and they try to fulfill all the objectives Vangrieken et al. (2017, p. 52) mentioned. Member teachers, however, retain agency, so DPLCs are open to changes, as each community comes to reflect its own members' needs. Common to all studied DPLCs, participation is entirely voluntary.

2.3. Data Collection and Analysis

2.3.1. Study 1

This study incorporates participant observation and characteristics' analysis based on a literature review.

With over 18 years of teaching experience each, and as members and leaders of high school physics teachers' DPLCs, the first and third authors have amassed impressions and observations. Alongside our study of physics education and physics teachers' PD, the approach resembles complete participant observation (Shank, 2006; Spradley, 1980). Participant observers gain an "insider-outsider position combined in one stance", along with an understanding of "the contextual complexities in their study sites" (Shank, 2006, p. 713). They collect group experiences elaborated through conversations with other participants that could be considered informal interviews (Jorgensen, 1989, p. 22). Such method proved its worth for conducting research on community behavior (Richmond & Manokore, 2011; Schloss, 2009).

While commonly used in TC research (Vangrieken et al., 2017), observations might be biased by researchers' personal views (DeWalt et al., 1998; Schwartz & Schwartz, 1955). However, the constructivist grounded theory approach to qualitative analysis (Charmaz, 2006) acknowledges that as long as the nature, structure, and values of the context are clearly specified, this is not problematic (Kapon & Merzel, 2019). The first and third authors documented observed events, assigned them characteristic titles, and then categorized them, outlining a preliminary DPLC dimension categorization.

To enhance generalizability, we then examined TC characteristics in the existing literature, which is akin to Van Meeuwen et al.'s (2020) methodology. Ours, however, was not conducted by searching keywords in databases. Instead, we followed the saturation principle often used in qualitative research, which posits that further data collection beyond a certain point yields diminishing returns (Saunders et al., 2018). Also, we did not quantify the occurrences of these characteristics as they naturally evolve throughout TC development (Grossman et al., 2001; Van Meeuwen et al., 2020), and studies on different TC development stages emphasize different characteristics. Given the dearth of emphasis on subject-specific TCs, our focus was on TC characteristics that relate to any specific subject matter or consider pedagogy as content, to enhance and refine our preliminary categorization.

We reviewed 16 studies that explored TC activities and behaviors and extracted salient characteristics (see Appendix A). Some characteristics recurred with varying levels of detail, while others (e.g., Woodland, 2016) presented interactions between community members, from which characteristics were derived. During our literature review, we made minor adjustments to our preliminary categorization, and we were able to categorize the added characteristics into five dimensions: structure, content, common production, social-affective, and meta-community (see below). When we found that increasing characteristics added no new dimensions, we halted our search, deeming saturation to have been achieved (Saunders et al., 2018).

In total, we compiled 167 characteristics of a (D)PLC. A five-stage peer validation refined our categorization. Firstly, we sorted together about one-third, randomly selected, of the characteristics into the predefined categories based on our observations. Secondly, each researcher independently sorted the entire corpus of characteristics. Thirdly, we compared our independent categorization of approximately one-fifth of the corpus resolving discrepancies and refining definitions until consensus was reached. Fourthly, we independently re-categorized the entire dataset and re-examined our results, achieving an 89.9% agreement rate. Remaining discrepancies primarily pertained to interpretations of characteristics as they appeared in the reviewed literature. Once these interpretations

were clarified, categorization into one of the five dimensions became straightforward. We discussed the discrepancies ultimately reaching a 99% agreement rate.

2.3.2. Study 2

This study incorporates in-depth interviews (Kouritzin et al., 2009) and passive observations (DeWalt et al., 1998; Shkedi, 2003). We interviewed three DPLC member teachers and one leading teacher, twice: at the beginning and end of a school year. Additionally, we conducted passive observation during five community meetings throughout the school year.

Focusing on a single SaT DPLC, this study resembles a case study (similar to Richmond & Manokore, 2011; Sjoer & Meirink, 2016; Velthuis et al., 2015). The second author participated in the SaT DPLC project from the outset, initially as a community member and later as a leading teacher. During this study, she was part of the leadership team guiding the national SaT leading teachers' DPLC. Hence, she was familiar with the leaders of the DPLCs under investigation, making it a convenient sample.

DPLC participants (N = 12, ten women) teach in eight different middle schools, boasting diverse teaching experience and varying PD backgrounds. We conducted the interviews face-to-face, online, or via phone. They were recorded and transcribed. The first interview covered participants' professional backgrounds, teaching credo, lesson-design approaches, and their expectations from a PD program in this context. The year-end interview focused on reflecting on their initial interview responses in light of their participation in the DPLC. We also asked them to define and characterize a DPLC and to evaluate its impact on their professional growth. We selected participants with diverse teaching experience and seniority within the community (Table 1) due to the significance of these factors and the assumption that perceptions regarding the community evolve over time (Avdor et al., 2010; Grossman et al., 2001; Sutton & Shouse, 2019).

Table 1. Interviewee details.

Pseudonym (Gender)	Role in DPLC	Role in School	Formal SaT Education	DPLC Seniority	Teaching Experience (Years)
Zurit (female)	Member	Science teacher and coordinator	M.A. in science education	4th year	11
Odelia (female)	Member	Science teacher; general teacher	Studying for a science education diploma	1st year	2
Amitay (male)	Member	Science teacher and coordinator	None	3rd year	11
Haviva (female)	Leader	Science teacher; has a managerial role in school	M.A. in science education	4th year; 1st year as leader	15

During the passive observations (Shkedi, 2003; Spradley, 1980), the second author observed DPLC meetings without actively participating in them, to characterize the community space, participants' interactions, and meeting conducts. Data were recorded as field notes.

The analysis of the interviews and the meetings observations, built as grounded base theory (Charmaz, 2006; Shkedi, 2003), was independent of Study 1's categorization. It involved several stages: content analysis (Creswell, 2009) initially generated 50 distinctive codes for DPLC characteristics. These codes were then sorted into primary themes,

resulting in three major categories and two more subtle ones. Finally, relationships between categories were determined (Shkedi, 2003). In discussions between the first and second authors, we noticed the similarity between these categories and those developed in Study 1. Instances from Study 1 were then offered to the second author for peer validation, and all three authors refined the categories until full consensus was reached, consolidating both study findings in five dimensions of the DPLC.

3. Findings

3.1. Overview

Analysis of the participant and passive observations, the interviews, and the research literature revealed that all the DPLCs under study were characterized by the constant practical and emotional involvement of the individual teachers in the community. We refer to this involvement as "community collegiality". Such collegiality can be found in all DPLCs, to different extents, as characterized by five dimensions:

(1) The structural dimension, which describes the tangible and logical structure of the DPLC;
(2) The content dimension, which describes the focus on the discipline and its teaching;
(3) The common production dimension, which describes the fruits of DPLC-member cooperation and collaboration;
(4) The social-affective dimension, which describes the social and emotional aspects as well as values that establish a sense of community;
(5) The meta-community dimension, which describes relationships between the DPLC and its environment.

We also found that each of these five dimensions streams effects in two directions: i. the "inward" influence of the community on individual teachers and ii. the "outward" influence of individual teachers on the community. Generalizing these directions, for the meta-community dimension, "inward" refers to the influence of the environment on the DPLC, and "outward" refers to the influence of the DPLC on its environment. All dimensions are linked semi-hierarchically, and are entangled by relationships.

In the following sections, we define and elaborate about the dimensions of the community collegiality. We illustrate these dimensions with examples from the physics teachers' DPLCs, as was collected through the participant observations (Study 1) and from the interviews and passive observations of the SaT DPLC (Study 2). We combined the findings of the literature review of Study 1 with the descriptions of the characteristics that make up each dimension, rather than presenting a separate literature review. By integrating these studies within the findings section, we situate each dimension within the broader research landscape, providing a more direct connection between the literature and our findings.

3.2. The Structural Dimension

This dimension pertains to the physical and logical aspects of the community and its activities, reflecting DPLCs' demeanor and member participation. Physical characteristics include the participating population, meeting frequencies, time allocations, gathering places (including online platforms), and required resources (Bolam et al., 2005; Eylon et al., 2020; Hord, 2009; Jäppinen, 2012; Jäppinen et al., 2016; Woodland, 2016). Logical characteristics pertain to meeting conduct, typically involving various content modules (associating the structural and content dimensions). For example, the SaT DPLC mix comprises an overture activity, science pedagogical content knowledge (PCK) activity, community construction activity, and a final summary with feedback (Scherz, 2018). In contrast, many high school physics teacher DPLCs focus on short modules where teachers share and discuss materials

and ideas, followed by a longer, in-depth physics PCK module, which is usually guided by leading teachers.

"Outward" structural dimension influences the effort and time participants invest in the community, including the endeavor to attend meetings, investment in meaningful participation, forum contributions, and taking the sweat for presenting activities or class experiences. Conversely, the "inward" influence pertains to the effort of the individual teacher to persist in participation, such as extending the workday or rescheduling personal issues.

The importance of the gathering place is emphasized by meetings held in school physics labs, which house the equipment for disciplinary content activities. A teacher (from Study 1) once volunteered to demonstrate electrostatics teaching activity, but forgot the required tools. Finding what he needed in the school lab, although not his own, was prompt.

Participation is a central aspect of this dimension, and it is noticeable when people are absent (Bronfenbrenner, 1977). An example from Study 1 showed that during the 2020 school year, a 20-member physics community convened every two weeks, with a usual attendance of 15. However, only six teachers consecutively participated in the first three meetings. Ultimately, a long-term learning process only began on week six, when enough members had consistent attendance.

This dimension was also exemplified in Study 2. Odelia mentioned persistence as "binding", perceiving that "we come to a particular place and a permanent group [. . .] transforms into a community" (year-start interview). Thusly, regularities of the community influence "inward" on the individual teachers. Complementarily, individual teachers "outwardly" and negatively affect the community when they miss gatherings. Haviva summarized that "regularity is necessary for the community [. . .] it is important ((for the sake of community)) to participate" (year-end interview).

3.3. The Content Dimension

This dimension refers to the presence and weight of the discipline and its teaching within the community, characterized by considerations of students, reflections on instruction, and tools for adjusting teaching to achieve desired results (Adams & Vescio, 2015; Bolam et al., 2005; DuFour, 2004; Eylon et al., 2020; Grossman et al., 2001; Hord, 2009; Jäppinen, 2012; Jäppinen et al., 2016; Levy, 2017; Levy et al., 2020; Little, 2012; Newmann, 1996; Shulman, 1997; Vescio et al., 2008; Woodland, 2016). Also included are the characteristics of viewing teachers as professionals, regarding the discipline and its pedagogy (Adams & Vescio, 2015; Eylon et al., 2020; Hord, 2009; Newmann, 1996; Shulman, 1997; Vescio et al., 2008) capable of developing new teaching materials (Vescio et al., 2008), and interacting with content experts such as university physics researchers (Levy, 2017; Shulman, 1997), which also connects to the meta-community dimension (see below).

Subject-matter emphasis primarily occurs through sharing (Adams & Vescio, 2015; Bolam et al., 2005; Eylon et al., 2020; Hord, 2009; Jäppinen, 2012; Jäppinen et al., 2016; Vescio et al., 2008), as DPLC members provide teaching materials and methods for review, modification, and use. This sharing involves the collective exploration of discipline-specific teaching challenges and professional strategies to overcome them, including insights into teaching practices, dilemmas, difficulties, and successes. It excludes the emotional support aspect of the social-affective dimension and the creation of new materials found in the common production dimension. Suitable times and platforms for sharing, especially beyond regular meeting times, are closely tied to the structural dimension.

Sharing is an "outward" expression of the content dimension, while influence flows "inward" when one requests sharing. This dimension also contributes "inward" by enhancing individual teachers' content knowledge (CK) and PCK via explicit requests for

explanations, feedback, and when adopting others' activities. Most observed DPLC meetings (Studies 1 and 2) involved much "outward" sharing, with up to half of the meeting time dedicated to it. Requests in the DPLC WhatsApp groups, like "Does anyone have a nice video about inertia?", are "inward" asking for sharing. In Study 1, such a request collected five different videos from two other DPLC members (who shared "outwards").

Subject-matter knowledge is also enriched. In one meeting, a teacher demonstrated a lesson about refrigerator magnets and the Halbach Array (Halbach, 1980), which many participants were unfamiliar with, so they learned both the science and a teaching approach. Most observed meeting times (Studies 1 and 2) included joint learning of the community's discipline and ways to implement it in class, even when the primary module goal was promoting community cohesion. This joint learning was facilitated through modeling and "teachers as learners" practices (Levy, 2017; Levy et al., 2020). This centrality was also present in the Study 2 interviews. Odelia summarized, "we become students", and highlighted that, through such activities, she "understands what works well and what doesn't, and how I can teach it" (year-start interview).

The diversity of content keeps DPLC meetings relevant for participants. As exemplified, "[the leading teachers] always bring new stuff" and "the diversity, the different methods ((for teaching)), the new knowledge makes it [the community] really strong" (Odelia, year-start interview). Content sharing stands out as a DPLC's key feature. Amitay said that "the whole idea of community is sharing" and called it "cross-fertilization" (year-end interview), demonstrating how teachers share content outward and embrace content inward.

While we lack quantitative data, our impression from Study 1 suggests that requests for sharing become frequent as the workload on teachers increases, especially when final exams approach. Many teachers prefer materials (including exams) that have already been quality-assured by their peers. Additionally, although sharing tendencies have been associated with the maturity of the community (Bolam et al., 2005, p. 137), we suspect that, in DPLCs, teachers who perceive themselves as knowledgeable in both subject matter and teaching are more inclined to share—inwardly, by experimenting with others' activities in their own classes, and outwardly, by providing feedback on these experiments while offering materials and activities for others to use.

3.4. The Common Production Dimension

Collated under this dimension are characteristics that describe how teachers work together to create new elements. These characteristics include developing teamwork norms, teaching materials, assessment tools, and insights through reflective dialogue. It also includes pooling of data from various classes for analysis, and the characteristics for collaboration and cooperation (Adams & Vescio, 2015; Bolam et al., 2005; DuFour, 2004, 2007; Eylon et al., 2020; Grossman et al., 2001; Hord, 2009; Jäppinen, 2012; Jäppinen et al., 2016; Levy, 2017; Levy et al., 2021; Little, 2012; Shulman, 1997; Vescio et al., 2008; Woodland, 2016). Jäppinen and colleagues (Jäppinen, 2012; Jäppinen et al., 2016) highlight "collaborativeness" as a key aspect of PLCs. This dimension essentially enables teachers "to achieve together what they cannot accomplish alone" (DuFour & Eaker, 2009, p. xii).

In DPLCs, common production involves both cooperation and collaboration. Here, cooperation denotes coordinated work on separate projects contributing to a shared goal, where each contribution is identifiable in the final product. Collaboration, on the other hand, results in a final product without distinct individual contributions. Distinguishing between these two modus operandi of DPLCs is essential for creating a common language for the leaders of DPLCs to set their goals.

In one instance in Study 1, a DPLC organized an event for high school physics students, where some teachers collaborated to create a treasure hunt, while others cooperated to arrange refreshments, lectures, registration, and other logistical aspects.

The content dimension and the common production dimension are distinguished through the actions of "sharing" versus "cooperation and collaboration". For example, teachers' reflective talk, in which they share their experiences from their classes, without aiming to create collective outcomes, pertain to the content dimension. When such discussions aimed to generate new collective understandings and, a fortiori, tangible products, it dwells in the common production dimension. Mostly, common production is deliberated explicitly (for example, by the DPLC leaders). Nevertheless, any common production inherently has many content components.

Common production's "outward" influence emerges when participants plan and develop novel teaching, learning, or assessment tools, thereby expressing their professionalism. It also has an "inward" influence as individuals learn new modalities of lesson-design and activity planning or adopt the use of the new products. Inward influence is also demonstrated by self-reduction during teamwork, which allows other members to express their expertise, and is based on one's trust in peers' abilities. Hence, it is displayed in a behavior of readiness (or even a demand) for the division of labor.

An illustration of "inward" influence is found in a physics DPLC (Study 1) that created escape room activities in groups. Initially, one teacher took on the entire task, but, after intervention from leading teachers, he eventually stepped back, allowing other group members to collaborate.

In the SaT DPLC (Study 2), the content dimension received the most time allocation, with limited focus on explicit common production. However, interviews underscored its importance. Zurit emphasized that a DPLC "is a community that collaboratively builds new things together" (year-end interview), while Haviva, reminiscing about a portfolio of DPLC group projects about invasive species, noted the benefits of the new common product for learning. Influence directions of the common production are seen as teachers gain from the DPLC (inward) and contribute to the DPLC (outward).

Another type of DPLC cooperation is required between the accompanying academic institute and the field. However, this falls outside intra-community member relations and will be discussed in the meta-community dimension section below.

3.5. The Social-Affective Dimension

This dimension encompasses emotional, social, value, and interpersonal interactions that shape the community's atmosphere (Jäppinen, 2012). It primarily revolves around feelings of partnership, attitudes towards the community, peers, profession, and shared goals, including matters of identity and belonging to a collective greater than its individual parts. These emotions blur the boundaries between the individual and the group by cultivating a sense of shared professional destiny. This shared destiny promotes honesty, tolerance, and trust among DPLC members, creating a safe environment for teachers to reveal their less successful aspects as teachers and receive friendly support. The literature identifies characteristics such as passion for the profession (Levy, 2017; Shulman, 1997), mutual trust, respect, openness (Bolam et al., 2005; Hord, 2009; Levy, 2017; Newmann, 1996), shared responsibility and commitment (Bolam et al., 2005; DuFour, 2004; Grossman et al., 2001; Levy, 2017), and group identity (Grossman et al., 2001; Levy, 2017; Levy et al., 2021; Shulman, 1997), as well as shared meaning and vision (Adams & Vescio, 2015; Bolam et al., 2005; Hord, 2009; Levy, 2017; Vescio et al., 2008). Therefore, we nested the value aspect under the social-affective dimension, as shared vision and goals catalyze partnership.

The "outward" aspect of this dimension is expressed through feelings of responsibility for colleagues, their goals, and their students' success. This is demonstrated by community members' motivation to be more active, driven by the understanding that individuals should contribute to the PD of their peers (Lehavi et al., 2019; Segal et al., 2024). It is also reflected in efforts to make others feel that their assistance is valuable to fellow DPLC members.

The "inward" aspect involves a sense of belonging, self-confidence, and feeling how meaningful one is for the DPLC. Inward effects are observed when teachers identify with the community's characteristics, adopt its behavioral patterns and norms, and accept group decisions despite personal preferences.

Study 1 provided evidence for the social-affective dimension through the family-like atmosphere among fellow teachers. During meetings, personal life events were regularly discussed. A strong sense of community identity was manifested by a logo printed on T-shirts and used to mark their common productions. "Outward" responsibility was evident as teachers devoted vacation time to improve their work for presentation at the national teachers' assembly. One teacher mentioned, "I worked so that our community would look good at the conference." Another outward example was teachers' enthusiasm for improving meeting ambiance by bringing refreshments. An inward example was when one teacher openly admitted his lack of understanding regarding three-phase current supply. Extroverting such incomprehension can be challenging in a professional society, but he admitted to us that he felt comfortable doing so due to his deep trust in the community's support. Meetings often concluded with teachers expressing how they arrived exhausted from their workday but left refreshed and optimistic, demonstrating the "inward" impact.

During the COVID-19 pandemic, when a DPLC could not meet in person, we witnessed repeated concerns about the loss of face-to-face support, sparking discussions about the community sessions' format. This example highlights the tight relationship between the structural and social-affective dimensions, exacerbated by the content dimension as the restrictions of video meetings left some teachers worried about their abilities to teach advanced experimental inquiries.

In Study 2, interviews emphasized the social-affective dimension. Participants described that "the DPLC is that there is someone like you that understands you, in the same place as you are" so connection can be "genuine and non-judgmental" (Zurit, year-start interview). Characteristic of the social-affective dimension is the emotional sharing of difficulties, challenges, and successes that generates peer support (distinct from content sharing). For instance, Odelia mentioned her initial discomfort in sharing teaching problems and failures but found comfort in realizing that others, including experienced teachers, faced similar issues. Participating in a DPLC, according to Haviva, "increases the sense of belonging to a profession, since when SaT teachers meet together, on a regular basis, with their peers, with the goal of promoting SaT learning, it causes a deep commitment for teaching SaT." (year-end interview). Zurit echoed that the DPLC is a capable professional autarky, since it "is us"; it is "not an outsider" that lectures the teachers, because "we don't need anyone from outside; we have enough resources, let's use ourselves" (year-start interview). Odelia also mentioned "the community's strengths" being its "human capital" and "the relations that are formed" (year-end interview). Amitay mentioned his self-esteem, as evoked by the DPLC, "I am very meaningful to the community" (year-start interview); also feeling that "there is room" to express himself, with both inward and outward influence reflected in his words.

3.6. The Meta-Community Dimension

This dimension is less prominent in the literature. It entails looking at the DPLC from outside, as one unit, which is a part of larger systems, and viewing its development trajectory, maturation (Bolam et al., 2005; Grossman et al., 2001; Levy, 2017), and its pursuit of goals aligned with its mission and its proprietors. The meta-community dimension includes aspects of management, sustainability, leadership, decision-making processes, goal setting, the role of academic support, and the evaluation of DPLC achievements (Bolam et al., 2005; Grossman et al., 2001; Hord, 2009; Jäppinen, 2012; Jäppinen et al., 2016; Levy, 2017; Levy et al., 2020, 2021; Woodland, 2016). Being nodes of networked communities, knowledge is also diffused to and from DPLCs (Levy, 2017; Levy et al., 2020; Scherz, 2018). As teacher and student learning processes are entangled (Grossman et al., 2001; Levy, 2017), this dimension includes the development of the aforementioned dimensions for fostering teachers' PD. Similarly, leading teachers also experience PD, both as teachers and as leading teachers.

The meta-community dimension's "inward" influence is of the environment on the community, while "outward" influence is of the DPLC on its environment. Academic support (unlike researchers participating in the PLC, cf. Pareja Roblin et al., 2014), for instance, influences the structural and content dimensions through allocating time, space, and subject-matter agendas as an "inward" impact. Conversely, when a DPLC holds a student conference, the outward influence affects other educators and their students, not only community members.

Study 1 provides evidence for this dimension. Prior to each new school year, the coordinators of the DPLC sets, including academic support and Ministry of Education supervisors, convene to discuss organizational matters, establish goals, and assign personnel to lead the DPLCs in the set. This represents an "inward" influence on a DPLC.

DPLC set conferences also exemplify the meta-community dimension. These conferences, organized and supported by the accompanying academic institute, feature community members as presenters, showcasing activities and teaching materials developed within their communities (content and common production dimensions). One year, a DPLC showcased escape rooms it developed, while another featured "magic in physics" demonstrations. Knowledge exchange during these conferences fosters an "outward" influence, with DPLCs learning from each other. Notably, during the COVID-19 pandemic, one DPLC devised a new rubric for assessing students' lab work (cf. Etkina et al., 2006). This rubric was introduced at their annual conference and adopted by the Ministry of Education as an assessment tool.

Study 2, focusing on a single DPLC, had limited evidence for the meta-community dimension. However, Haviva mentioned knowledge diffusion in the DPLC's set, both "inward" and "outward". She described the meta-community dimension as hierarchical connections between layers:

> *"We get ((content)) from the leading teachers' community and we are connected to the [supporting academic] Institute. . . and I passed it on, and they [the teachers] will pass it on to their classes. . . the communities are built in a way that there is more; consequently, a weave is formed".* (year-start interview)

4. Discussion

4.1. Inter-Dimensional Relationships and the Emerging Collegiality Model

The five dimensions of DPLC "collegiality" (structure, content, common production, social-affective, and meta-community), include all its functional aspects. They are consistent with the literature, having been refined through categorization of the reported TC characteristics. The common production, content, and social-affective dimensions are

intertwined, inspiring each other, as grounded in the structural and the meta-community foundations. The conceptual connection between these dimensions is expressed in four main nodes that govern the behavior and the spirit in a DPLC: (1) participation, (2) sharing, (3) coordinated work, and (4) partnership.

We visualize the components of DPLC collegiality and the relationships between them in a yin-yang-yong shape model (see Figure 1 below). Thusly represented, each borderline between two areas represents constructive interference between them. The individual is the red circle in the center, because feeling "central" in the community avails inward and outward contribution. Within each of the three woven dimensions, the other two appear as internal yin-yangs, held up by the structural dimension (the gray dots in the center of the internal yin-yangs), which combine to represent the feelings and behaviors of sharing, coordination, and partnership.

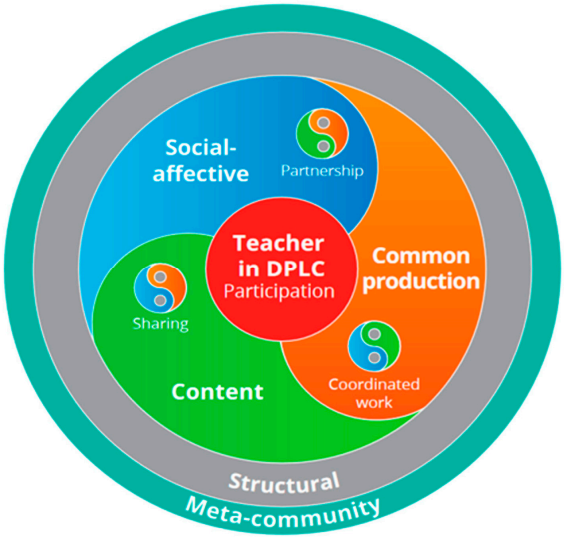


Figure 1. The Community Collegiality Model.

Participation is tangent to all dimensions. DPLC members willingly invest in participation, viewing it as a valuable professional resource (Bismuth, 2021), with beneficial meetings that provide materials (content) for "teaching tomorrow morning" (Levy, 2017). They recognize fellow DPLC members as experts in their field (teaching physics or teaching SaT) and as natural partners for content-focused discussions for yielding new insights about their discipline and ways to teach it, as well as fostering cooperation and collaboration for creating teaching materials and methods. As their passion for the profession connects DPLC members (Kapon & Colton, 2020), with a commitment to their colleagues (social-affective dimension), friendships are created that further motivate participation. Ministry of Education procedures (meta-community) incentivize participation by rewarding it with paid PD hours based on teachers' meeting attendance (structural dimension).

Sharing is when teachers connect the content they possess (materials, CK, and PCK) with colleagues. Empathy and emotional needs for reassurance and support drive sharing "outward". Simultaneously, approval of teacher's materials and confirmation of actions promote self-efficacy ("inward"), a pattern found in the literature (Lakshmanan et al., 2011; Thompson et al., 2019); hence, the content and the social-affective dimensions combine. Sharing "inward", while adopting the contents of other teachers, also involves the social-affective dimension because the donors are friends who deal with the same challenges; hence, the adopting teacher can trust this content. Since sharing is often a starting point for the common production dimension and an indicator of the social-affective dimension,

scaffolded by the structural dimension, these combine to form the yin-yang within the content dimension.

The *coordinated work* (i.e., collaboration and cooperation) of the common production dimension could, likewise, not exist without the bedrock of structural dimension. To produce insights from the common learning and design new teaching materials, which are anchored in the content dimension, it is bounded in the structural dimension of the population because concerted teamwork needs time and space, yet also the knowledge that fellow professionals possess about teaching the subject matter. The common production generates strong social interactions (e.g., veteran–novice interactions; Eshchar-Netz & Vedder-Weiss, 2021) and strengthens partnerships among same-discipline professionals, so the content, social-affective, and the structural dimensions together form the yin-yang of coordinated work.

Partnership, a powerful emotion, is both the engine and the product of teachers' DPLC participation. Trust, effort, and long-term commitment are required for working together toward a common production. These contribute to group identity (Belzowski et al., 2013; Vangrieken et al., 2017), which leads to stronger partnership. DPLCs with weak partnership yield little sharing (content) and fruits (common production), so the social-affective dimension includes aspects of both content and common production dimensions (Figure 1).

The dimensions we found are congruent with Wenger et al.'s (2002) three CoP characteristics, and specifically to TCs (Brouwer et al., 2012), with "mutual engagement", corresponding to the social-affective dimension, "joint enterprise", corresponding to the common production dimension, and "shared repertoire", corresponding to the content dimension. Unlike Wenger et al.'s shared repertoire, the content dimension is not about teaching in general, but relates to specific school disciplines. Our findings also resonate with the elements identified in primary school non-science teacher communities working to improve science instruction (Richmond & Manokore, 2011). However, we further distinguish between intra-community and meta-community dimensions, offering a more interconnected model.

Designing our new model, we followed Van Meeuwen et al. (2020) to provide an exhaustive description of characteristics, their interactions, and dynamic change (see below); however, we tried to keep the model simple—useful as a thinking tool for DPLC stakeholders (Vangrieken et al., 2017). Simplicity underscores the importance of visual representation. Naturally, when designing models, tension exists between the fine resolution needed to obtain a full description and the simplicity of the figure. For example, Jäppinen and her colleagues (Jäppinen, 2012; Jäppinen et al., 2016) described an intricate model featuring 10 categories and numerous sub-categories. While their model provides an in-depth description, we acknowledge that its complexity might hinder its use for member teachers ("What is expected from me as a DPLC member?"), leading teachers ("What are the DPLC goals and where do I want to lead my fellow teachers?"), and policymakers (criteria for assessing the functioning of a DPLC).

Chen and Wang (2015) offered a model of PLC development with only four steps, but it does not describe all dimensions and interactions. Van Meeuwen et al. (2020) offered a model with 11 characteristics, organized under three categories, but they describe the driving factors of the community as external, whereas the collegiality model has these factors embedded in its dimensions. Furthermore, they describe non-disciplinary communities, so it is not surprising that specific disciplines and their teaching receive minor attention, while in DPLCs and in the collegiality model, the subject matter is of major importance.

Additionally, they mention the prevalent ambiguity in the literature regarding the distinction between the conditions for a DPLC's existence and the characteristics that shape

its nature and operation (Van Meeuwen et al., 2020, p. 413). It is clear from the collegiality model and in accordance with Vangrieken et al. (2017) that the structural and the meta-community dimensions are necessary conditions for a DPLC to exist. However, the levels of common production, content, and social-affective dimensions vary depending on the DPLC type and its developmental stage.

4.2. Influence Directions

An important feature of the collegiality model dimensions' "inward" and "outward" influence is expressed in all DPLC organization levels—DPLC sets (national), single DPLCs (regional), and, most substantially, the teacher's level (participant). "Inward" refers to the impact the DPLC has on an individual teacher and "outward" refers to the influence a teacher has on the DPLC and its fellows. TCs are often established to implement school reforms or national standards (e.g., Blankenship & Ruona, 2007; DuFour & Eaker, 2009; Friedrichsen & Barnett, 2018; Hord, 2009; Murphy & Lick, 2005; Richmond & Manokore, 2011; Vangrieken et al., 2017), but the DPLCs discussed here have much wider goals, and although they have aspects of formal TCs, they also resemble member-oriented teacher communities (Vangrieken et al., 2017).

The collegiality model describes DPLCs that aim for teachers' PD in order to develop PCK components (Carlson et al., 2019), with "inward" and "outward" processes. For example, a teacher's personal theoretical knowledge—"personal PCK" (as described in their Refined Consensus Model)—becomes public knowledge—"collective PCK"—through sharing (outwards) with fellow teachers. Through the common production of teaching methods, collective PCK turns into personal PCK and, when experimented in class, then becomes the teacher's knowledge that is enacted in a specific situation with specific students—the "enacted PCK" (Carlson et al., 2019); thus, DPLCs have "inward" effects on teachers who embraced the shared teaching methods. To visually represent the influence directions in the collegiality model, we decided to place the teacher adjacent to the dimensions, rather than making the model cumbersome with arrows.

4.3. DPLC Dynamic Development

In Figure 1, all dimensions are given equal representation, meaning they receive similar attention and importance in the model's visual design. However, the model can also describe different DPLCs and the dynamic development of a DPLC. This variability can be expressed by changing the dimensions' relative areas, as exemplified in Figure 2. DPLCs of different types (Arica & Merzel, 2021) and durations (Grossman et al., 2001; Vangrieken et al., 2017) will accentuate their dimensions accordingly. For example, the common production dimension is not as prominent in all communities at all times. Especially during the COVID-19 lockdowns, DPLCs focused less on common production, needing more social-affective support and teaching activities (the content dimension) that were introduced "top-down" (e.g., by the supporting academic team; the meta-community dimension) to meet the challenges of isolated life and online work.

Accepting the notion of teachers as learners of their own teaching (Feiman-Nemser, 2012) conveys that the common production dimension should receive more attention as a component of TCs since it is generally accepted that better learning is product related (e.g., Ackermann, 2001; Papert, 1993; Stager, 2005). In some DPLCs, however, even though the main focus is on the content, it is not necessarily transformed into production. The common production dimension is often less emphasized, despite frequent creation of common insights, possibly because participants are less aware of it when no explicit meta-cognitive processes present these insights as common production (as we have seen in Study 2). When DPLCs are more mature and as the community identity becomes stronger,

common production becomes more significant and is even required, so cooperation and collaboration trajected for common production is the most advanced DPLC occurrence (Chen & Wang, 2015).

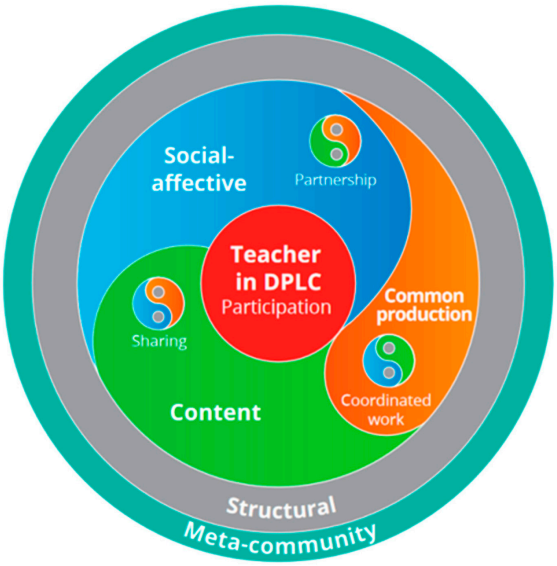


Figure 2. A DPLC with less focus on the common production dimension.

4.4. Dynamic Teacher Development in a DPLC

DPLC participants might grow both in the collegiality dimensions that represent their goals, and in their degree of involvement. For example, joining a DPLC might be motivated by some economic considerations or administrative demands, where the timing of the sessions happens to align with the teacher's schedule (structural-only participation), or by needs for new content or for support, but without a desire to create anything new. As teachers develop, they become more involved in sharing, partnerships, and ultimately, coordinated work. Nevertheless, some evidence suggests that to support such professional development the structure of the DPLC should remain stable (Shim & Thompson, 2022). Such a trajectory of development is represented by a path from the periphery of the model toward the center (Figure 3). Involvement is represented by the growing size of the circle that represents the individual.

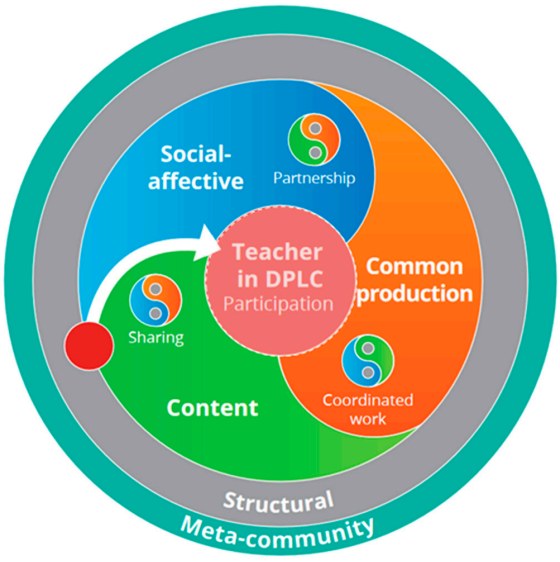


Figure 3. Teacher development trajectory in a DPLC.

5. Conclusions

5.1. Theoretical Implications

The conceptualization of the collegiality dimensions could be useful for extracting measurable parameters of DPLC functioning. Huijboom et al. (2020) offered ways to assess teacher PLCs, and now teacher DPLCs can be similarly appraised. Measuring the structural dimension, for example, can consider teachers' meeting attendance and extra-meeting participation time. The content dimension could be measured by the quantity and quality of materials that teachers request and offer, also considering feedback on such contents. The common production could be evaluated by examining time and workforce invested in joint projects and participants' feelings of ownership about them. Finally, the social-affective dimension could be estimated through self-reports on feelings and perceived motivations and, to some extent, through observations, by the sacrifices that teachers make that favor the DPLC.

Building on attempts to develop non-disciplinary models (e.g., Jäppinen et al., 2016; MOFET, 2022; Woodland, 2016), we believe that ours could enable good estimation (perhaps quantitative) of relevant DPLC processes and occurrences. These orthogonal dimensions could span a five-axis space on which activities are projected, to assist with priority setting and intervention decisions. For example, leaders could contingently focus more on attendance, strengthening subject matter aspects, promoting more coordinated work, or building openness and solidarity, considering directional influence ratios, because PD requires that participants offer new ideas (outward) and adopt those of others' (inward) for their own teaching (Adams & Vescio, 2015). Additionally, the model can be used to compare different DPLC types and their contributions to leading and participating teachers. Since myriad stakeholders' involvement, with possibly conflicting agendas, might hinder DPLC success (Vangrieken et al., 2017), this model offers a common language for future discourse.

5.2. Practical Implications

The following described contributions are not speculative. After sharing this model, we noticed how it helped leading teachers with goal setting, how it catalyzed the Ministry of Education to create PD programs for leading teachers and teachers' advisors, and how it facilitated teachers' PD program choice.

The notion that teaching is not a gig, but rather a profession, and that teaching is a lifelong-learning profession, should steer teachers toward PD (Vangrieken et al., 2017). One of the channels for this professional growth is the DPLC. For teachers to benefit the most from their DPLC, they must choose a DPLC type that best suits their needs (Arica & Merzel, 2021; Furtak & Heredia, 2014) and be fully engaged partners; hence, they must understand what is expected from them when they are a part of such a community. This model presents that to them, through the dimensions of collegiality: the structural dimension presents the worth of participating regularly and putting time and effort in the DPLC; the content dimension might help teachers to acknowledge the centrality of their own and their peers' professional growth in the subject matter and its teaching and to deem valuable the contents raised in the DPLC, both "inward" and "outward", because acknowledging the DPLC as a resource for content knowledge and for lesson design (Bismuth, 2021), and asking for help, will encourage teachers to share "outward", as well as increase their understanding of the subject matter; understanding of common production can encourage teachers to be involved in the prevailing mode of coordinated work (cf. Furtak & Heredia, 2014), to spark initiatives that will be very difficult or even impossible for one teacher to execute alone, but that the community could fulfill through cooperation and collaboration (DuFour & Eaker, 2009); accepting the social-affective dimension could relieve subject-specific teachers of the professional solitude that they might experience in school (Vangrieken et al., 2017)

and strengthen self-efficacy (Lakshmanan et al., 2011; Mintzes et al., 2013); and the meta-community dimension should enable teachers to see that they are part of a bigger whole, and that their work has a larger context, sometimes at a national scale, thereby giving their actions a wider meaning. This also magnifies their common production because their created activities might help many teachers. Moreover, the meta-community dimension connects teachers, leading teachers, and policymakers, since, in many DPLC networks, there is a community of leading teachers (Levy et al., 2019, 2020; MOFET, 2020) in which policymakers also take part.

In fact, the collegiality model demonstrates to teachers that they are active partners in their own professional growth as well as in that of their peers, and vice versa. The model captures the "parts and parcel", and reveals the complexity and commitment involved in being a DPLC member. The better teachers understand this complexity, the more effectively they will function within the DPLC and the more meaningful their partnership will become. Consequently, they will take greater pride in their chosen profession and likely invest more effort into their teaching.

Leaders of teachers' communities should have pertinent professional skills (Vangrieken et al., 2017). Leading a DPLC requires the leaders to address cognitive aspects of the subject matter and its teaching as well as affective considerations and the social status of the teachers (Beattie, 2002; Howe & Stubbs, 2003; Sutton & Shouse, 2019). They are also required to examine their DPLC with a meta-community look that is meta-cognitive in its nature. In pursuit of developing their DPLC, leaders are expected to diagnose its strengths and weaknesses. However, many leading teachers do so based on intuition, lacking a theoretical organizing framework. Therefore, there is a need to develop the discipline of teacher educators, since, nowadays, many of the existing PD programs for community leading teachers do not present teacher education as a discipline of its own and do not give the future leading teachers such a perspective. The collegiality model could represent a significant steppingstone in this discipline and could serve as a vehicle for imparting the conceptualization, both for diagnosing communities, but, more importantly, to identify the criteria to which they aspire.

6. Limitations

This study has several limitations. First, although it combines findings from two studies of two different DPLCs, which allows for a broad exploration of DPLCs across different contexts, the DPLCs studied have a lot in common, which may limit generalizability to other disciplines or educational settings. Second, the reliance on participant and passive observations introduces the possibility of researcher bias, particularly in Study 1, where the first and third authors were involved in the observed DPLCs. Although peer validation and literature triangulation were employed to mitigate this, some subjectivity may persist. Third, the integration of the literature review findings within the findings section offers a more contextualized discussion but deviates from conventional structuring, which may affect how readers engage with the study's theoretical foundation. Finally, while the study identifies key dimensions of DPLCs and their interactions, it does not assess longitudinal changes or the potential causal impact of DPLC participation on teacher practice and student learning outcomes. Future research should explore how DPLCs evolve over time and investigate their broader effects on professional development and instructional quality.

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Abbreviations

The following abbreviations are used in this manuscript:

PLC	Professional Learning Community
DPLC	Disciplinary Professional Learning Community
TC	Teachers Community
PD	Professional Development
CK	Content Knowledge
PCK	Pedagogical Content Knowledge

Appendix A

#	Source	Structural	Content	Common Production	Social-Affective	Meta-Community
1.	(Adams & Vescio, 2015)		•	•	•	
2.	(Bolam et al., 2005)	•	•	•	•	•
3.	(DuFour, 2004)		•	•	•	
4.	(Eylon et al., 2020)	•	•	•		
5.	(Grossman et al., 2001)		•	•	•	•
6.	(Hord, 2009)	•	•	•	•	•
7.	(Jäppinen et al., 2016)	•	•	•		•
8.	(Jäppinen, 2012)	•	•	•		•
9.	(Levy et al., 2020)		•			•
10.	(Levy et al., 2021)			•	•	•
11.	(Levy, 2017)		•	•	•	•
12.	(Little, 2012)		•	•		
13.	(Newmann, 1996)		•		•	
14.	(Shulman, 1997)		•	•	•	
15.	(Vescio et al., 2008)		•	•	•	
16.	(Woodland, 2016)	•	•	•		•

The dots represent the presence of the coulumns in the papers.

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